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AD 16345

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Technical Report No. 4

SHIPBOARD OBSERVATION OF ELECTRONICS PERSONNEL: SHIPBOARD ACTIVITIES OF ELECTRONICS TECHNICIANS.

March 1953

Project Designation NR 153-093

Contract Nonr-228(02)

Principal Investigator

William W. Grings

Project Director

Glenn L. Bryan

Chief Observers

Donald W. Svenson
Harold R. LaPorte

Relief Observers

Joseph W. Rigney
Stanley Summers
John R. Hills

Data Analysts

William Axelrod
Nicholas A. Bond
Raymond M. Berger

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DEPARTMENT OF PSYCHOLOGY

UNIVERSITY OF SOUTHERN CALIFORNIA

RESTRICTED

PREFACE

This report is one of a series based on shipboard observation of electronics personnel aboard ships of the destroyer class. The titles of these reports are given here along with a brief indication of the content of each. Security restrictions do not permit the general circulation of all of these reports but the accompanying list will help the reader place the present report in context.

1. Shipboard Observation of Electronics Personnel: A Description of the Research.

   A general presentation of the problem, its background, and the observational techniques which were employed.

2. Shipboard Observation of Electronics Personnel: Detailed Descriptions of Observational Techniques.

   A report for the professional worker who desires precise detail regarding the forms and instructions used and the decisions underlying their selection. The summarized data are provided in a classified supplement.

3. Shipboard Observation of Electronics Personnel: Implications for the Training of Electronics Personnel.

   Various problems of training are formulated and related to the observational data. (RESTRICTED)

4. Shipboard Observation of Electronics Personnel: Shipboard Activities of Electronics Technicians.

   Detailed accounts of the activities of electronics technicians are presented. Topics such as the materials, duties, problems, and future plans of the technicians are discussed. (RESTRICTED)

5. Shipboard Observation of Electronics Personnel: Brief Descriptions of Related Electronics Jobs.

   The jobs of the Sonarman, Radarman, and Radioman are briefly described. The areas of overlap between these jobs and the job of the ET are discussed. (RESTRICTED)

6. Shipboard Observation of Electronics Personnel: Implications for Certain Operational and Administrative Problems.

   Problems of Shipboard administration, policy, and the operational requirements of the electronics situation are related to the observational data. (RESTRICTED)

7. Shipboard Observation of Electronics Personnel: General Conclusions and Recommendations for Further Research.

The objectives of the research are reexamined and general conclusions are drawn. Promising research hypotheses and methods are presented. (RESTRICTED)

ACKNOWLEDGMENTS

The research reported in this series reflects the contribution of a large number of persons within the Military Establishment. Grateful appreciation for this assistance is extended to the Cruiser Destroyer Force, Pacific; the Training Command, Pacific, and the Underway Training Element of that command; the Training Division and the Research Division, Bureau of Naval Personnel; the Personnel and Training Branch of the Psychological Services Division of the Office of Naval Research; and the Electronics Coordinator's Section of the Office of the Chief of Naval Operations.

ABSTRACT

This report contains a brief, yet detailed and objective, account of the electronics technician at work aboard ships of the destroyer class. After a short general description of the technician's job, consideration is given to the general maintenance situation — the types of repairs performed and the activities associated with electronics repair. Material, as well as behavioral, factors influencing repair are discussed. Detailed consideration is given later to conditions which limit electronics maintenance, such as contributors to unsuccessful maintenance, equipment limitations on repair, and factors keeping personnel from doing a better job. Finally, an evaluation is made of the critical requirements of the electronics technician in terms of general abilities, and job knowledge and skills.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES
(continued)

LIST OF TABLES
(continued)

SHIPBOARD OBSERVATION OF ELECTRONICS PERSONNEL: SHIPBOARD ACTIVITIES OF ELECTRONICS TECHNICIANS

I. INTRODUCTION

This report presents a detailed picture of the electronics technician as he was observed aboard Naval ships of the destroyer class during fleet training exercises. The description is a composite derived from some eighty-two men serving aboard twenty different ships. These are the men on whom the responsibility rests for maintaining in good working order a major portion of shipboard electronic equipment.

An appreciation of the general position of the electronics technician aboard a ship of the destroyer class can be achieved by a consideration of the equipment with which he works and the function of that equipment to the ship. Communication must be maintained between the ship and land, aircraft, and other ships. This requires receiving and transmitting systems which are highly diversified and specialized of purpose. Long and short wave equipments are needed for distant reception, very high and ultra high frequency devices for closer work. Signals may be carried by frequency or amplitude modulation in forms ranging from CW to phone conversation and teletype.

Radars are numerous and diversified. They serve navigational and tactical functions with special forms for searching the sea, searching the air, and controlling fire power. This means that the presence of many different models of radar instruments, each with completely different design and performance characteristics, is common. To this radio and radar complex may be added specialized equipments for underwater detection, direction finding,

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Although most of them were members of the ship's engineering department, at the time they were observed, the electronic technician teams worked very much as a department of their own with responsibilities some of which were clear cut and concrete, others ambiguous and likely to vary from ship to ship. The technician's dealings were chiefly with the personnel who operate the equipment and with whom they share the responsibility for keeping at a maximum the contribution of electronics to the welfare of the ship.

Specific equipments with which the technicians work most often were surface and air search radars; several radar repeaters; and AM and FM communications transmitters and receivers. Others included fire control radar, sonar, loran, IFF, radio direction finder, infra red, and countermeasure equipments. Test instruments most commonly used were multimeters and vacuum tube voltmeters, wattmeters, tube testers, cathode ray oscillographs, audio oscillators, signal generators, frequency meters, range calibrators, and condenser checkers.

The average electronics technician spends about 20 per cent of his duty time on preventive maintenance and 50 per cent on corrective maintenance. The remainder of his working hours are divided between "book work" such as record keeping (14 per cent), and non-electronic shipboard duties (16 per cent). Each of these classes of duty varies considerably with conditions of watch and operational readiness.

Much of the success of preventive maintenance depends upon the technician's ability to perform operating adjustments on the equipment: to turn it on and off, tune it, calibrate it, and most importantly to be sufficiently familiar with it's output characteristics to detect when equipment performance is below it's peak value. A few matters of preventive maintenance are more routine, requiring only a diligent pursuit of some kind of maintenance schedule.

On communications and radar equipment, corrective maintenance extends to the diagnosis and repair of any malfunction, whether it be major or minor. Appropriate tests are made to locate faulty components, shorts, or misalignments; and proper remedial action is taken. Such repairs relate largely to electronic circuits and their function, although a very significant portion concern mechanical failures and extend to antenna systems, transmission lines, motors, and motor generators.

Responsibility for corrective maintenance upon sonar and fire control equipment is not uniformly invested in the electronics technicians. Ship to ship differences in this regard are wide and are determined largely by availability of skilled maintenance men among the ranks of sonarmen and fire controlmen and the administrative organization of the particular ship. In the average case, the ET services only certain classes of fire control radar and sonar failures, most frequently those which the sonarman charged with electronics maintenance or the fire control technician is unable to repair.

The technician's "book work" consists mostly of ordering and accounting for spare parts, and maintaining failure report forms and equipment repair records. In addition, reference manuals need to be kept up to date, as do equipment histories and field change records. Non-electronic duties vary widely with the ET's rate. Working parties, shore patrol, and gangway watch are most common.

The manner in which general duties were observed to distribute themselves according to the rate of the man is shown in the outline shown on the next page. On the left is listed the duty and the equipments involved, and on the right the rate of the man performing the task, abbreviated as C, 1, 2, 3. These data were obtained from check lists filled out independently by three classes of persons (ETs themselves, electronics material officers, and observers from the research team).

Where a particular rate is noted as performing a given task, it indicates two things: first, that 50 per cent or more of the ships visited reported the rate as performing that duty; and second, that an agreement existed among all three classes of persons reporting. It is important to note that this outline indicates what the men actually do and not what they should be able or qualified to do.

Table 1

Summary Outline of Work Performed by Rates

Activity	Rates to Which Applicable			
Operate and adjust:				
Radio receivers and transmitters	C	1	2	3
Search radar	C	1	2	3
Fire control radar	C	1	2	
Teletype		1	2	3
Sonar	C	1		
Loran	C	1	2	3
IFF	C	1	2	3
Calibrate and shift frequency of:				
Radio receivers and transmitters	C	1	2	3
Search radar	C	1	2	3
Teletype		1	2	3
Fire control radar		1	2	3
Loran and IFF		1	2	3
Measure sensitivity:				
Radio and radar receivers	C	1	2	3
Does preventive maintenance on:				
Radio receivers and transmitters	C	1	2	3
Search radar	C	1	2	3
Teletype			2	3
Fire control radar		1		3
Loran and IFF				3

Table 1
(continued)

Makes minor repairs on:				
Radio receivers and transmitters		1	2	3
Search radar		1	2	3
Teletype			2	3
Fire control radar		1		3
Loran and IFF		1	2	3
Diagnoses major casualties and makes major repairs on:				
Radio receivers and transmitters	C	1	2	3
Search radar	C	1	2	3
Fire control radar	C	1		
Teletype	C		2	
Sonar	C	1		
Loran	C	1	2	3
IFF		1		3
Supervise and train personnel in preventive maintenance on:				
Radio receivers and transmitters	C	1	2	3
Search radar	C	1	2	3
Fire control radar	C	1		
Teletype	C	1	2	
Sonar		1		
Loran and IFF	C	1	2	
Supervise and train personnel in corrective maintenance on:				
Radio receivers and transmitters	C	1	2	
Search radar	C	1	2	
Fire control radar	C	1		
Teletype	C	1		
Sonar	C	1		
Loran and IFF	C	1		
Uses test equipment designated below:				
Multimeter	C	1	2	3
Oscilloscope	C	1	2	3
Tube tester	C	1	2	3
Audio oscillator	C	1	2	3
Signal generator	C	1	2	3
Wattmeter	C	1	2	3
Frequency meter	C	1	2	3
Condenser checker	C	1	2	3
Echo box	C	1	2	3
Range calibrator	C	1	2	3
Wave meter	C	1	2	

Table 1
(continued)

Executes administrative papers designated below:				
Records on electronics equipment	0	1	2	3
Replacement parts orders	0	1	2	3
Stores or parts inventory	0	1	2	3
Job and work orders	0	1	2	
Draws and refers to:				
Block diagrams	0	1	2	3
Wiring diagrams	0	1	2	3

From this outline it may be seen that the principal responsibilities of electronics technicians are with radio and radar equipment. There is a tendency for the higher rates to do less minor repair work and more supervision and training. Aside from this essential difference, the technicians share common activities. With reference to sonar and fire control radar the higher ET rates appear to contribute most to diagnosis of major casualties and supervision and training in corrective maintenance. The lower rates are more likely to make the more routine repairs. A comparable situation exists for teletype, loran, and IFF.

III. THE GENERAL MAINTENANCE SITUATION

By collecting detailed accounts of corrective maintenance situations in the form of written diaries and repair record forms it is possible to examine many aspects of the electronic repair process in terms of relative frequency. Among the questions which are considered below are: On what equipments did the observed electronic failures occur? What is the relative frequency of various causes of failure? What are the chief symptoms from which to diagnose the difficulty? In what repair activities (diagnostic and corrective) do technicians engage?

A. Types of Repairs Performed

Table 2 presents a summary of the equipments repaired in a sample of forty repairs recorded on a repair record form designed by the research group. Each technician completed such a form on the first repair he performed after the observers boarded the ship. From this table it is readily seen that the majority of repair instances occurred on communications equipment and that search radar repairs were nearly as frequent. None was reported on sonar and only a few on fire control radar.

Table 2

Equipments on Which the Failures Occurred
(Sample of 40 repairs completed while observers aboard)

Equipment	Frequency	Per Cent
Radio transmitters TDZ (5), TBS (2), TBL (3), AN/ARC (3)	13	32.5
Search radar SG (3), SC (2), SU (1), SA (1), SL (1), SR (1)	9	22.5
Radio receivers RBS (1), RAO (2), RBB (1), RBC (1), AN/ARC (1)	6	15.0
Search radar repeaters VJ (3), VF (1), VD (1)	5	12.5
Fire control radar MK 25 (4)	4	10.0
Test equipment ME 11/U	1	2.5
Countermeasures (RCM) AN/APR-1	1	2.5
Speaker amplifier	1	2.5

An analysis of causes of equipment failure has been made from these same data and from a sample of 20 directly observed and recorded diary situations. The relative frequency of various classes of equipment failure is indicated in Table 3 (page 9). The most significant cause is electronic tube failure which accounted for over one third of the difficulties. It is interesting to note that failures of other components such as resistors and condensers are much less frequent than failures due to "wear and tear" such as dirty contacts, loose or shorted leads, and broken controls.

Table 3

Analysis of Causes of Equipment Failure
(Sample of 40 repairs completed while observers aboard)

Class of Failure	Frequency of Occurrence	Per Cent
Defective tubes (gassy, low emission, open filament)	15	37.5
Faulty contacts (dirty and erratic relay, switch, and potentiometer contacts, loose lead, and loose tube socket)	6	15.0
Circuit shorts (components shorted to chassis, shorted lead, shorted jack)	5	12.5
Resistor failure (open, short, changed value with heat and age)	5	12.5
Broken controls (potentiometer shaft, inductor roller, loose roller on PPI yoke)	3	7.5
Condenser failure (leaky, shorted)	2	5.0
Open leads or cables	2	5.0
Transformer failure (overflow of internal insulation due to heat)	1	2.5
Crystal breakdown	1	2.5
	40	100.0

These general results are upheld in Table 4 where the smaller sample of cases from direct observation is illustrated with reference to relative frequency and per cent of total down time which is contributed by each class of malfunction, the median down time, and the median time required to isolate the trouble. Since all of these time figures are influenced by the number of instances in which each is based, it is difficult to make comparisons, except for such limited conclusions as that six instances involving defective tubes required less t[illegible]tal time to correct than did two transformer or coil failures or three ins[illegible]tances of faulty contacts. As will be seen later, these relative times are [illegible]ore significantly viewed in terms of the trouble shooting behavior involv[illegible]d—particularly with reference to the number of erroneous hypotheses a[illegible] to the cause of the difficulty which are held by the technicians.

Table 4

Down Time Re[illegible]ulting from Different Types of Equipment Malfunction
(20 trouble-oriented diaries)

Class of Ma[illegible]unction	Frequency	Median down time	Per Cent of total down time	Median time to isolate trouble
Defective tub[illegible]				
Capacitor or r[illegible]o	6	1 hr. 17min.	20.0	58min.
Faulty contac[illegible]esistor failure	3	1 hr. 40min.	7.9	45min.
Improper wir[illegible]s and leads	3	3 hrs.20min.	27.4	2 hrs.20min.
Transformer [illegible]ng	2	57min.	1.9	37min.
Mechanical [illegible] or coil failure	2	21 hrs.15min.	39.5	19 hrs.
Internal [illegible] difficulties	2	47min.	1.4	26min.
(align[illegible]djustments	2	58min.	1.9	45min.
[illegible]ment)	20		100.0	

T[illegible]he principal information from which the ET must make his hypotheses as [illegible]o cause of the difficulty are summarized for the repair records in Table 5.

Table 5

Principal Equipment Symptoms Accompanying the Malfunctions
(Repair Records)

Classes of Symptom	Frequency	Per Cent
Reduced or variable output	10	25.0
Improper reading on front panel meter (No H.V.; no Xmtr current; no Xtal current, no PA current, meter reading unstable)	8	20.0

Table 5
(continued)

Defective sweep signal (no sweep, abnormal rotation, no rotation, jumpy or jerky)	8	20.0
Low sensitivity (receivers)	4	10.0
Defective video other than sweep (intermittent pulsing, erratic signal, no signal)	3	7.5
Loss of ability to adjust or alter signal (no focus control, intermittent volume control, equipment won't turn off)	3	7.5
No video, scopes blank	2	5.0
Equipment completely dead	2	5.0
	40	100.0

It is significant to note in this connection how closely the information available is related to the particular class of equipment involved. Examples of this are output levels of transmitters and sensitivities of communication receivers. In most instances only partial loss of function is involved.

B. Classes of Repair Activities

In analyzing this information for indications of the actual work performed by the technicians, the repair activities have been grouped into two general classes: one concerned with diagnostic activities, the other with corrective action taken after the cause of failure has been located. This information is presented in Table 6 (page 12). Here it will be noted that over 50% of the diagnostic activity concerned basic electrical measurements and the testing of tubes either by replacement or by using a tube tester.

Corrective action, as indicated in the same table, can readily be divided into the replacement of defective parts and the making of circuit or mechanical adjustments of various sorts. Of these, the replacement of parts is most frequent, with the replacement of tubes possessing three times the frequency of replacement of any other class of parts. In this connection, however, it is necessary to remember that a tendency exists to replace tubes in situations where such replacement may not be essential, as, for example, testing tubes by replacement and then failing to return the originals even though they turn out to be satisfactory.

Table 6

Repair Activities Reported on Sample of Forty Repairs
(Repair Record)

A. Diagnostic Activities	Frequency
Measured resistance	14
Tested tube by replacement	12
Tested tube by tube tester	11
Measured voltage across circuit components	10
Made circuit continuity tests	9
Checked or measured grid or plate current	8
Checked condenser	8
Tested components (transformer, choke, etc.) by continuity test	3
Took wave pattern on oscillograph	3
Check tubes visually for gassy symptoms	3
Measured power output	3
Tested switch contacts	2
Felt tubes to see if warm	2
Traced signals	2
Measured sensitivity	2
Measured Xtal resistance	2
Tapped tube for effect on signal	2
Tested relay operation	1
Checked for loose connections	1
Checked generator brushes	1
Measured output of motor generator	1
Check voltmeter readings against standard	1

Table 6
(continued)

B. Corrective Action	
1. Parts replaced	
Tubes	16
Resistors	5
Capacitors	4
Potentiometers	2
Crystal	2
Transformer	1
Wave guide	1
Roller on inductor	1
Filter choke	1
Tube socket	1
2. Adjustments and Other Repair Operations	
Cleaned relay or switch contacts	2
Tightened loose roller on PPI yoke	1
Made replacement shaft for potentiometer	1
Dismantled and cleaned volume control pot	1
Secured leads	1
Cleaned variable condenser with crocus cloth	1

C. The Trouble Shooting Process

The task of locating and correcting trouble in malfunctioning equipment is one of the most important jobs of the electronics technician. No matter how effective a preventive maintenance program may be, major equipment casualties will occur. Because of its central position in the job of electronics technicians, the general nature of the trouble shooting process is worth careful study and should be subject to continued improvement. In fact, an adequate understanding of the maximally effective course of events leading to repair can help in reducing future casualties by contributing understanding to a better program of preventive maintenance.

There are many ways in which the trouble shooting process can be studied. In one way, it can be identified with the general class of behavior most commonly labelled "problem solving" and an attempt made to understand its contributing variables in terms of basic principles discovered in laboratory studies of problem solving. A second method consists of carefully watching trouble shooters at work in the field. It is this second way, which reflects the specific tasks performed by ETs as they were observed to perform them on the job, that is considered here.

The essence of the trouble shooting process is to isolate the stage or circuit which is malfunctioning and then to analyze that stage for defective components. When asked to describe what he does in trouble shooting a radar, one ET responded as follows:

> "If someone comes to report that the SG is out, the first thing I do is see if there is a presentation on the scope. If there is not, I check all of the controls to see if they are properly set, particularly battle switches and the like. If that doesn't help, I get out the instruction books and work down through the different stages. First, you check your tubes and your fuses. Then, if you are working through the receiver, you get a signal generator and work back through the different stages until the signal is lost or drops off. Or, if you aren't getting normal sweeps or trigger pulses you might take waveforms at various spots in your video or mod-generator sections."

The general classes of activity for isolating the difficulty were found to include the following:

1. General inspection for obvious difficulty evident to the senses (i.e., smell of overheated component, sight of

gassy tube or charred resistor).

2. Preliminary hypotheses based on front panel indications and past experiences with the same equipment.
3. Parts substitution.
4. Measurement of basic electrical quantities within the circuit (voltage, resistance, and current).
5. Signal substitution.
6. Dynamic signal tracing--with vacuum tube voltmeter or cathode ray oscillograph.

It would be difficult to give any general step by step procedure, for the sequence followed differs greatly from person to person and from situation to situation. In general, the less experienced men are more at a loss regarding where to look first. They are more prone to "poke around" in the set or make rather widespread tube changes. More experienced men are more systematic and are able to rely heavily on past experience with the particular equipment involved. Not infrequently they are able to proceed immediately to the troublesome unit or component. This is made possible by two lines of reasoning. One is essentially "the last time this happened the cause was the XY component; therefore, I will first check that component." The other line of reasoning proceeds to a hypothesized cause based on an understanding of how the gear functions and on ability to deduce possible causes from symptoms.

It is of interest to note the relation which exists between the number of false starts or wrong hypotheses and the time required to make the required repair. These have been tabulated for twenty trouble-oriented diaries in Table 7. Of these twenty repairs thirteen required an average of less than one hour to complete and had less than one incorrect hypotheses per repair. Of the other longer repairs all possessed two or more false hypotheses about the cause of the trouble.

Table 7

Situations with Unusually Long Repair Times
(Sample of 20 diaries)

Nature of Trouble	Time to Isolate Trouble	Number of Incorrect Hypotheses	Total Down Time
Transformer burned out, shorted HV condenser	36 hr.	2	39 hr.
Broken lead on crystal holder	24 hr.	5	26 hr.
Defective magnetron	13 hr.	9	16 hr.
Shorted capacitor	4 hr.35min.	4	6 hr.15min.
Shorted choke coil	2 hr.34min.	2	3 hr.30min.
Dirty switch contacts	2 hr.20min.	3	3 hr.20min.
Loose prongs, CR tube	1 hr. 5min.	5	2 hr.
Average of all other repairs in sample (N = 13)	35min.	0.6	53min.

The types of conditions leading to the diagnosis of trouble vary greatly as can be seen from this sample of situations from these twenty diaries.

1. Noticed that jiggling set disturbed scope pattern. Guessed that some connection was loose. Discovered loose prongs on CR tube.
2. Replaced tube which if bad might have caused the difficulty. Set returned to normal.
3. Accidentally noticed a HV condenser arc when high voltage applied.
4. Located a faulty condenser by making systematic voltage and resistance checks.
5. Recalled that a similar difficulty had occurred before. Tried the

remedial action which was effective then. It worked.

6. Detected a wire jumper inserted into set to short out overload relay. It was blowing fuses.

7. Unable to locate faulty component, decided to try adjusting alignment.

8. Noticed a charred resistor.

9. Discovered plate voltage of one tube to be low.

10. Located a voltage drop across a group of components which was half of normal operating voltage. Traced to a shorted choke coil.

D. <u>Examples of Effective and Ineffective Trouble Shooting</u>.

By comparing the abbreviated case histories of repairs, some of the basic differences between effective and ineffective repairs can be seen. Two such contrasting summaries are presented below.

<u>Diary 1</u>. Complaint: No sweep on radar repeater.

1.	Tests tubes in sweep circuit.	Normal
2.	Makes visual check of tubes, resistors, etc., .	Normal
3.	Checks waveform at input to driver unit	No input
4.	Tests tubes in delay unit which feeds driver. .	Normal
5.	Takes waveforms at test points within delay unit.	Locates points between which signal is lost
6.	Rechecks tube in isolated circuit in delay unit.	Normal
7.	Measures voltages at pins of this tube.	Plate voltage low
8.	Checks capacitor in plate circuit	Shorted
9.	Replace capacitor	Set normal

<u>Diary 2</u>. Complaint: Search radar has weak returns, limited range.

1.	Replace most of transmitter tubes.	No change
2.	Replace power supply tubes	Normal
3.	Take voltage tests off tube pins in receiver .	Normal
4.	Replace T/R tube	No change
5.	Measure crystal current and AFC current. . . .	Both low

6. Replace crystal. . . . . No change
7. Replace local oscillator tube and adjust . . . . No change
8. Check voltages in LO section . . . . Normal
9. Replace magnetron. . . . . No change
10. Take ring time, make alternate adjustments of LO and T/R box till maximum signal reached. . . . . Condition improved

One distinctive feature of the shipboard trouble shooting situation is that work is typically accomplished by a team of persons, most frequently by a responsible technician and one or two helpers. This fact and some further highlights of the actual behavior involved in repair can be seen in the following detailed (or step by step) account of an ET chief repairing a fire control radar with the help of two fire control technicians.

Complaint: Tube burns out every eight hours of continuous operation.

Equipment concerned: Fire control radar.

Personnel participating in repair: FC/2 FC/SN ET/C

Stepwise activities of ET/C:

1. Tells FC/2 to go get paid.
2. Studies instruction book.
3. Reads various material; looks at circuit diagram.
4. Looks at presentation on MOD-3; turns operating knobs.
5. Studies instruction book; studies schematic.

6. Instructs FC/2 to pull out V109 and check tube on tube tester.
7. Checks set, turns knobs, watches presentation.
8. Puts tubes back in set.
9. Closes set part way, turns it on, watches presentation.
10. Manipulates knobs, watches presentation.

11. Opens set up, starts exploring back of scope.
12. Makes adjustments on scope.
13. Directs FCs to pick up a target.
14. Jiggles set.
15. Turns lights on; opens set; explores back of scope; watches presentation.

16. Turns out lights; adjusts presentation.
17. Turns light on.
18. Opens set; explores back of scope.
19. Wiggles back of scope.
20. Pulls set clear open.

21. Removes socket from back of set.
22. Tightens parts of socket with screwdriver, securing leads.
23. Puts socket back in rear of scope.
24. Closes up set part way.
25. Turns on set.

26. Directs FC/SN to turn off lights.
27. Pokes at socket at back of scope.
28. Makes screwdriver adjustments inside the set.
29. Closes up set. Says the trouble is probably in the scope. He figures the prongs are loose. He says he'll go see if he can find another tube. When asked about checking out tubes, and told that they had been checked out not over 50 hours ago, says not to bother with them.
30. Leaves.

31. Returns with new cathode ray tube.
32. Turns off the power.
33. Opens set.
34. Removes back of tube.
35. Takes tube FC/2 has removed; hands it to FC/SN.

36. Gets a new tube.
37. Slips the new tube in, secures it, and fastens the leads.
38. Takes tube which FC/2 has pulled out.
39. Looks the tube over.
40. Sets new tube on floor.

41. Tests tightness of prongs on old tube.
42. Decides prongs on new tube are loose.
43. Directs FC/SN to get another new tube.
44. Takes second new tube out of box, inspects it, puts it into place, and holds it while FC/2 secures it.
45. Puts the socket in place.

46. Looks scope over.
47. Turns on power.
48. Observes presentation on scope.
49. Makes adjustments of presentation.
50. Instructs FC/2 to tighten down clamp that holds scope in position.

51. Closes set.
52. Makes adjustments of presentation.
53. Directs FC/SN to put plate back over front of scope.
54. Makes more front panel adjustments.
55. Opens set.

56. Jiggles back of tube.
57. Closes set.
58. Observes set.
59. Grabs set and shakes it hard.
60. Watches scope.

61. Looks over stand that set sits on.
62. Discusses ways of securing set so it won't shake when ship is at high speeds.
63. Directs FC/2 to keep set in stand-by and watch scope to see if anything happens when the vibration becomes bad. Says that the cause of the tubes going bad is probably the vibrating.
64. Picks up old tubes and leaves.

Stepwise activities of FC/2:

1. Upon being told by the ET/C to go get paid FC/2 leaves.
2. Returns and plays with knobs.
3. Under instruction of ET/C opens unit, pulls out V109, begins checking tube on tester.
4. Looks on while ET/C turns on set and watches presentation.
5. Makes adjustments of presentation.

6. Tells FC/SN to go up in director and try to get on a target.
7. Adjusts presentation.
8. Makes further knob adjustments.
9. Watches presentation and tells ET/C what is happening.
10. Observes scope while ET/C pokes at socket at back of scope.

11. Reports to ET/C results of chief's screwdriver adjustments.
12. Asks ET/C if he wants him to check all tubes in the set.
13. Aids ET/C in opening set.
14. Aids ET/C in removing back of tube.
15. Aids ET/C in holding plate while FC/SN loosens it.

16. Removes tube and hands it to ET/C.
17. Aids ET/C in putting in new tube, securing and fastening leads.
18. Under chief's instruction, loosens tube again, pulls it out and hands to chief.
19. Aids ET/C in slipping another tube into place.
20. Secures it.

21. Under ET/C instruction, tightens down clamp that holds scope in position.
22. Aids ET/C and FC/SN in putting plate back over front of scope and tightening it down.
23. Looks at presentation and reports effects from jiggling.
24. Observes scope.

Stepwise activities of FC/SN:

1. Helps FC/2 to test tubes on tube tester.
2. Watches ET/C observing presentation.
3. Adjusts presentation.
4. Directed by FC/2 to go up in director and try to get on a ship.
5. Turns out the lights.

6. Turns on lights.
7. Looks up information in his note book concerning the last time tubes were checked.
8. Takes plate off front of scope.
9. Under instruction of ET/C, goes for another new tube.
10. Returns with new tube.
11. Under instruction of ET/C, puts plate back over front of scope.

Further insight into the factors producing good or effective maintenance behavior may be gained by examining information which was secured during critical incident interviews with electronics technicians. Each man was asked to relate an incident in which he or someone he was working with was able to complete a repair which was completely new for him. Situations were sought where ETs had to solve some maintenance problem he had never encountered before and where his training and experience did not apply directly. When these incidents are tabulated and classified they show clearly the importance of following systematic procedures and the dependence upon schematic diagrams and instruction books. Equally important is a dependance upon basic electronics knowledge, particularly knowledge of components and circuitry. Characteristics such as ingenuity and ability to improvise were less important, see Table 8 shown on page 22.

Table 8

Relative Frequencies of Classes of Incidents in Which ETs Solve Novel Maintenance Problems

Class of Solution	Frequencies
Solved by using basic electrical and electronic knowledge	10
Solved by studying schematic	8
Systematically followed steps laid down in instruction books	7
Used experience with, or knowledge of, similar gear	6
Systematically traced circuit	3
Played a hunch	2
Improvised parts	2
Used a process of elimination	2
Depended on help from civilian engineer	2

In another question, men were asked for instances of unusually successful maintenance behavior. These have also been classified and are presented below. In addition to the general classes and frequencies, the actual incidents are listed in abbreviated form.

Table 9

A Classification of Incidents of Unusually Successful Maintenance Behaviors (Each incident is represented by a brief statement)

Category and Incidents	No. of Incidents
Achieved Repair by Unusual Substitution When no Spare was Available	10
Substituted repeater for damaged console of radar.	
Substituted amplifier power supply for burned out dynamotor.	
Combined six transformers to replace burned out one for which there were no replacements.	
Put in a jury rig for a bad rectifier unit that had no replacement.	
Rigged up a temporary blower motor to replace burned out one.	
Replaced shorted out wires in a circuit by using graphite pencil.	
Substituted TDZ generator for an unfixable AN/ARC generator.	
Substituted a tube with different characteristic to eliminate recurring trouble.	
Combined five transformers to replace one burned out one when no spare was available.	
Rigged up a fuse holder to replace a bad one that had no replacement.	

Table 9
(continued)

Designed Circuit Change to Correct Faulty Operation	7
Designed new wiring setup to by-pass burned out slip rings.	
Calculated change in voltage divider network to correct trouble.	
Figured out circuit change to repair gear an engineer could not fix.	
Devised a rectifier circuit to replace a faulty motor generator.	
Designed a bias supply to eliminate faulty thyratron operation.	
Devised a squelch circuit to replace faulty one.	
Increased length of antenna in order to get out on higher frequencies.	
Did Precise, Patient, or Careful Work in Making a Difficult or Tedious Repair	7
Located intermittently shorted capacitor which others failed to locate.	
Repaired unusually bad transmitter by precise, accurate work.	
Make difficult motor generator repair by patient work.	
Completed tedious job without quitting.	
Worked steadily for long hours in order to repair radar.	
Located soap on motor-generator commutators by careful and thorough trouble shooting.	
Attempted numerous procedures in order to remove faulty blower motor from inaccessible spot.	
Used Exceptional Speed in Making a Repair	6
Worked rapidly in order to get fire control gear repaired.	
Used extreme speed in repairing gear.	
Used exceptional speed in repairing a fire control gear.	
Worked steadily and carefully in order to locate source of trouble.	
Combined numerous trouble shooting procedures in order to locate burned out resistor.	
Used schematic skillfully in order to locate bad capacitor.	
Rewired or Rewound Circuits, Motors, or Transformers	6
Did outstanding job in rewiring circuit.	
Rewired high voltage unit.	
Rewound burned out transformer.	
Rewound motor field.	
Rewired power supply.	
Rewound transformer when no replacement was available.	
Manufactured Unavailable Part	4
Manufactured barrel clips for damaged radar.	
Made up chemical compound to eliminate corrosion in wave guide.	
Manufactured clamp to hold antenna together.	
Made brushes for motor generator when none were available.	

Table 9
(continued)

Made Unusual Mechanical Repair of Needed Part	4
Performed difficult job requiring high mechanical skill, of repairing broken helipot.	
Repaired badly damaged telescopic capacitor when no spares were available.	
Made unusual repair on damaged switch.	
Repaired bad tuning mechanism in emergency by cutting out section giving trouble.	
By-Passed Circuit or Component to Keep Set on the Air	3
Shorted out faulty switch to make set operate without delay.	
By-passed burned out section of high voltage power supply when no spares were available.	
By-passed coils when no replacement was available.	
Isolated Trouble by Unusual Means	3
Used light bulb to isolate trouble spot that would not show up on a meter.	
Developed device to measure high voltage when no meter was available.	
Shorted out interlocks with power on and doors open.	
Used Cooperative or Coordinated Effort in Making a Repair	3
Repaired gear in minimum time by working in shifts for many hours.	
Repaired set in minimum time by cooperation.	
Repaired three fire control radars in a short time by coordinating work.	
Made Difficult Repair Under Difficult Conditions	3
Remained undisturbed in trouble shooting despite outside pressure.	
Made difficult antenna repair under extremely cold and difficult conditions.	
Repaired antenna under fire.	

These behaviors may be compared with some that reflect faulty or poor maintenance behavior as they were observed in the diaries. The following instances in Table 10 were extracted from the same twenty diaries which were discussed earlier. For purposes of convenience they have been divided into two general classes, one of which reflects lack of care in handling or working with electronic equipment, the other reflects generally ineffective maintenance procedure.

Table 10

Observed Instances of Ineffective Maintenance Behavior
(Diary data)

Situations Involving Lack of Care in Handling or Working with Electronic Equipment

1. Improperly removed tube cap, breaking lead from cap.
2. Tossed tube to another man.
3. Bent wave guide when prying loose transformer with screwdriver.
4. Leaned against tube, breaking it at base.
5. Handled metal tube with set on, got shock.
6. Used flashlight to tap tube.
7. Tool not handy, so removed fuses from an operating set with hands.
8. Used screwdriver to tap tubes.
9. Shorted out overload relays with jumpers so that they would not work.
10. Attempted switching leads with screwdriver when set was operating.
11. Bent contacts for lighthouse tube by not taking sufficient care in putting it in.
12. Shoved drawer violently in set causing loose terminal board to short everything to ground.

Situations Reflecting Ineffective Procedures

1. Did not correct a basic trouble. Was content to replace component as it periodically went bad.
2. Replaced most of the tubes in a radar transmitter in an attempt to correct the trouble.
3. Did not know where spare parts were.
4. Had trouble finding tools and parts because of a disorderly work shop.
5. Had difficulty finding a capacitor. Did not use instruction book to help.
6. Wasted thirty-six minutes by putting in a new presentation scope without first checking it.
7. Decided wattmeter was at fault when actually the set was not properly tuned.
8. Delayed repair by extensive arguing over symptoms.
9. Neglected to reconnect three leads.
10. Forgot to replace tube previously removed.
11. Repair confused by four different people working on it without coordinating their activities.
12. Replaced components before others were tightened down, requiring that components be removed again in order to tighten down others.
13. Spent an hour and one-half trying to locate trouble in driver unit causing repeater bearings to be 180 degrees out of phase before remembering that they had not lined up the synchros the last time they

Table 10
(continued)

they worked on the repeater.
14. Had no record of last time checked tubes in set.
15. Repair interrupted while someone borrowed tools.

E. Preventive Maintenance

One often hears the statement that the best index of a successful maintenance program is not how quickly equipment is repaired when it breaks down but how little it breaks down. The emphasis is placed on the prevention of electronic failure, and the electronics technician is viewed as a man with a watchful eye on the equipment, continually alert to the first evidences of reduced function. In this way equipment is constantly being treated for minor maladjustments which, if allowed to persist, would result in major casualty.

When questioned about such preventive maintenance activities, the electronics technicians reported that they spent, on the average, about 13 per cent of all of their time aboard ship doing preventive maintenance. This is approximately 20 per cent of their total work time. In addition the ETs, particularly those with greater seniority, express a felt responsibility to train and supervise operating personnel in the care and upkeep of the gear. Because there was some anticipated ambiguity between operating and maintenance personnel on the responsibility for routine preventive maintenance, several attempts were made to observe this division of responsibility.

Equipment instruction manuals frequently differentiate between operator maintenance and preventive maintenance. The most typical maintenance requirement of radio and radar operators is cleaning, although in some instances their maintenance responsibility extends to the correction of tube or fuse failure. Preventive maintenance, on the other hand, consists of periodic routine mechanical and electrical checks and test procedures designed to keep the equipment continuously on the air. Such procedures are typically completed by the electronics technician, but are in some instances required of operating personnel.

The manner in which the attitude regarding responsibility for certain classes of activities differs from ship to ship can be seen in Table 11 where the percentages of men who indicate being required to do each activity is indicated.

Table 11

Percentages of Indicated Groups Who Checked Various Equipment Maintenance Activities as Being Either Required, Forbidden, or Neither

	Dust Exterior				Dust Interior			
	ET	SO	RD	RM	ET	SO	RD	RM
Required	29	78	82	75	45	70	66	62
Forbidden	—	1	—	—	—	3	2	6
Neither	54	10	9	4	41	16	15	9
No Response	17	11	9	21	14	11	17	23

	Replace Fuses				Replace Tubes				Replace Soldered Components			
	ET	SO	RD	RM	ET	SO	RD	RM	ET	SO	RD	RM
Required	71	52	19	10	74	44	5	12	78	37	1	2
Forbidden	—	9	17	15	—	9	37	24	—	15	42	32
Neither	13	29	38	46	11	33	32	38	10	25	30	36
No Response	16	10	26	29	15	14	26	26	12	23	27	30

Sizes of Groups: ET = 82; SO = 116; RD = 202; RM = 112.
(Source: Job Questionnaire, item No. 29)

The most significant facts observable here are that ETs are less frequently required to do cleaning than are the operators, although in no cases are they forbidden to do so. Very few radarmen or radiomen are required to replace fuses or tubes, and a fairly large portion are forbidden to do so. Practically no RDs or RMs are required to replace components requiring soldering, and many are forbidden to do so. The table presents a clear picture of increasing ET responsibility for activities as they range from routine cleaning operations to working "inside the gear." The situation for sonarmen lies between that of the technicians and the operators.

The differences of opinion among officers regarding the amount of duty time electronics technicians should spend on preventive maintenance are shown in Table 12. It is of particular interest to note the much higher estimate of time stated by communications, engineering, and executive officers as compared to the electronics officers, and to note that the ETs give the lowest estimate of all.

Table 12

Opinions Concerning Per Cent Duty Time Electronic Technicians Should Spend on Preventive Maintenance Expressed in Terms of the Median of the Percentages Assigned by Each Respondent Group

N	Respondent Group	Median Per Cent of Duty Time That Should be Spent on Preventive Maintenance by ETs
70	ET	15
11	EMO	22
12	CIC	22
11	ASW	21
10	COMM.	45
12	OPER.	22
7	GUN.	26
12	ENG.	49
10	EXEC.	50

(Source: General Questionnaire, item No. 14)

The importance of the preventive maintenance activities to the welfare of the general electronics picture can readily be seen in the responses of electronics material officers when they were asked in an interview situation what they thought was the key to effective electronics maintenance aboard a destroyer, Table 13. The most frequently mentioned factors involved preventive maintenance behavior.

Table 13

Abstracted Answers of Electronics Material Officers to Question Concerning the Key to Effective Electronic Maintenance Aboard a Destroyer
(10 officers, each giving approximately 2 responses)

Key Factors	Frequency
Combining ED and ET efforts in preventive maintenance into a cooperative effort	4
Proper indoctrination of personnel in preventive maintenance procedure	3
More familiarity with gear (radio and radar men)	3
Establishing incentive in personnel	2
Adequate supervision	1
Constant checking to see that preventive maintenance is done	1
Good preventive maintenance	1
Cooperation of CIC officer and EMO	1
Instilling attitude of responsibility in ETs	1
Better trained more responsible personnel	1
Put ETs in operations department	1
Adequate test equipment	1
Leading petty officer of ETs should be at least an ET/1	1

One way to encourage an emphasis on preventive maintenance is to employ a formalized maintenance test schedule. This is simply a tabulation of the periodic checks which should be made into a time schedule according to which the tasks may be accomplished. In an attempt to determine the extent to which such schedules were used, questions in the interview were directed at the present status of preventive maintenance; and questionnaire items inquired of the frequency of regular inspections of electronics equipment and asked who prepared the maintenance schedule. The responses of 71 electronics technicians regarding who prepared their maintenance schedule is compared with responses of electronics material officers in Table 14. From this it is evident that the chief responsibility for organizing preventive maintenance activities rests on the leading electronics technician.

Table 14

Persons Who Prepare the Electronics Maintenance Schedule
Tabulated by Ships

Persons preparing schedule	No. of Ships
Leading electronics technician	9
Electronics material officer	6
Electronics officer and lead ET	4
None is prepared	1
	20

(Source: General Questionnaire, item No. 28)

It was the volunteered response (unsolicited) from some technicians that in many instances the completion of the maintenance schedule was completely perfunctory. It was viewed as "paper work" by some, or a matter of a few check marks on paper. A few supervisory men were very diligent in their support of a systematic preventive maintenance program, but the situation was by no means uniform. Some of this can be seen from the table below which lists the percentage of persons responding "yes" or "no" to the question whether regularly scheduled inspections of equipment were made by electronic material officers, and the frequency with which they were made if they occurred at all.

Table 15

Answers to Question "Are Regularly Scheduled Inspections of the Electronics Equipment Made by the Electronics Officers"

Respondent	Response %Yes	%No	%No Response	Frequency Weekly	Bi-weekly	Monthly	Other
Electronics Technicians	42	55	3	14	9	3	4
Electronics Material Officers	50	50	-	5	-	-	1

(Source: General Questionnaire, item No. 27)

When asked to rank several classes of activities which ETs could engage in when all equipment is functioning, all groups of respondents indicated preventive maintenance as the most appropriate. Other alternatives included (a) work on maintenance records (b) participate in organized electronics training, (c) study electronics publications and (d) engage in non-electronics activities. When a comparable question of whether there should be one electronics technician who is trained solely and specifically for preventive maintenance was asked, there was a nearly unanimous opposition expressed by the ET and electronic officer groups.

Before leaving the general topic of preventive maintenance it may be appropriate to list some of the activities which were observed and which fall into this class of behavior. These are listed in Table 16.

Table 16

Observed Activities Which Fall Into the Class of Preventive Maintenance Behavior

General Activities
Periodic measurements of transmitter power output and receiver sensitivity
Frequent determinations of ring time
Routine equipment cleanings

Table 16
(continued)

Keeping of a log on each equipment in order to record time factors in the operation and upkeep of the equipment
Routine visual inspections of equipment for signs of physical damage, such as burned resistors, damaged capacitors, frayed insulation, kinked cables, etc.
More Specific Activities
Adjust controls to see if operation smooth and even
Test for loose controls, loose plugs in jacks
Test mountings and tube sockets. Tighten if loose
Clear air filters
Lubricate mechanical moving parts
Inspect wave guides
Tighten terminal board connections
Check motor and generator brushes
Compare front panel meter readings against normal readings
Periodic tube checks (keep an hours of service record)
Clean fuse ends
Check switches, relays, and interlocks for general operation, burned or pitted contacts
Check calibrations--range marks, frequency, tracking
Measure temperature of control ovens
Check antenna rotation for alignment, binding, or noise during operation

IV. MAINTENANCE SUB-TASKS: THEIR FREQUENCY AND COMPLEXITY LEVELS

A. Representativeness of the Sub-tasks

A description and analysis of the specific activities of the electronics technician may be accomplished by use of the card sort. The card sort method, described more fully in a previous report, consisted of presenting to the technician a large number of job activity statements printed on individual cards which were to be sorted in various ways. The technician was required to make judgments about the job statements according to relevance, frequency of performance, comprehension, and skill. Since all ET rates participated in the card sort, certain comparison may be made between rates or groups of rates as to the differences in job activities. Frequency of performance and complexity level may also be evaluated.

The card sort will first be used to obtain information on the activities that are representative of all ETs. In the first sorting of the cards, the ETs were asked to select all job activities they had ever done aboard ship. The cards selected usually included activities that were rarely done or irrelevant; therefore the ETs were required to refine the selected cards in a second sort to activities that "best" described their job. It is among these activities retained by each ET on the second sort that a search will be made for representativeness and for inferences concerning the common characteristics of the activities.

Table 17 lists the activities that were selected by nearly all ETs. Only the results of rated personnel are included, and only activities reported by at least 75% of the group are included. This high criterion of selection (75% or more indicating the activity) was chosen in order to achieve a select list representative of "nearly all" ETs.

Table 17

Activities That "Best" Describe the ETs Job. Card Sort Items Selected by at Least 75% of the Rated ETs

Item No.	Activity Statements	Per Cent Selecting Item
145	Read schematic diagrams	100
151a	Check circuit continuity	100
161	Replace rectifier tubes	98
157a	Replace fixed fuses	96
178	Determine value of component from color coding	96

186a	Measure tube transconductance with tube tester	96
225	Visually inspect tubes for gas	96
90	Tune TDZ manually	95
147	Use voltmeter	95
159a	Replace fixed resistor	95
232a	Use shorting bar	95
175a	Test vacuum tube for intermittent shorts	93
182	Fill out failure report	91
77	Repair terminal posts, plugs, and connections	91
158a	Replace fixed capacitors	91
199a	Clean switch contact points	91
226	Visually inspect tubes for open filament	91
142	Replace lighthouse tubes	89
32	Replace potentiometers	89
4	Replace magnetron tubes	87
141	Replace indicator lamps	87
210	Measure ring time	86
152a	Check for open coil	84
220	Meg antenna lines	84
155	Measure transformer voltage	82
25	Adjust antenna coupling	82
180a	Repair headphone and headset	82
201a	Clean interior of equipment	80
278	Measure transformer resistance	79
65	Check crystals	77
81	Requisition spare parts	77
212	Replace transformers	77
228	Obtain information from operators on how gear broke down	77
79	Repair phone cable	77
238	Replace crystal detectors or rectifiers	75
224	Visually inspect brushes in generators	75
146	Observe waveforms with portable scope	75
82	Replace TR tube	75

Further information can be gained by comparing these representative items with those which were selected by only a very few men. Later the manner in which the representative activities divide between high and low rate groups will be compared. For example, table 18 lists the thirteen activities which were chosen by only 3 of the men, or about five per cent of the ET group.

Table 18

Activities Selected with Lowest Frequency
(by 3 individuals only)

Item	Activities
9	Rebuild electric motors
34	Install communications transmitter
50	Wind coil
56	Compute power factor
68a	Calculate output impedance of transmitter
106	Compute Q
107a	Repair cooling system pumps and lines in electronic gear
109a	Measure Q of individual circuit
121a	Compute shunt resistance in order to calibrate meter
123	Compute signal traverse times
206	Charge battery
241	Vary tank circuit capacitance by installing another fixed capacitor
280	Replace tuning capacitor in three band RF coil

The quality of "importance" or "commonness" on the job can be observed in another situation. These were a number of activities which were selected by at least a third of the ETs as being part of their jobs, but were later discarded by half of these men as not "best" describing their job.

14	Replace servo motors	22	13	1.78
39	Install coaxial cables	40	23	2.35
49	Dry out wave guide	21	11	1.70
55	Compute capacitive reactance	22	14	2.62
72	Repair cooling system fans and lines in electronic gear	26	14	1.92
120	Compute resistance-capacitance time constant	22	14	2.00
122a	Compute resonant frequencies in tank circuit	21	11	2.30
139a	Make mechanical adjustment of worm gears in equipment like VF or VG	24	15	2.36
171	Compute current requirements in a given circuit	26	15	2.62
207	Test battery for low cells	25	16	2.56

*For description see text following.

The substantial drop in number of ETs selecting the activities indicated above is supported by the relatively low frequency with which these activities are performed (right hand column, Table 19). Many ETs have performed these activities at one time or another but apparently not often enough to warrant considering them important to the ET's job. The frequency index numbers given in the last column are averages of the judgments of how often the activity is done on a five-point scale with the category of "very often done" given a value of 5 and "rarely or never done" given a value of 1. The frequency index numbers given above roughly indicate that these activities are "seldom" or "sometimes" done.

In summary of the characteristics of those specific activities that ETs do not consider important to their job the following may be noted:

Table 19

Activities Originally Selected as Descriptive of the Job of the ET and Later Largely Discarded

Item	Activities	Number Originally Selecting	Number Subsequently Discarded	Frequency Index*
14	Replace servo motors	22	13	1.78
39	Install coaxial cables	40	23	2.35
49	Dry out wave guide	21	11	1.70
55	Compute capacitive reactance	22	14	2.62
72	Repair cooling system fans and lines in electronic gear	26	14	1.92
120	Compute resistance-capacitance time constant	22	14	2.00
122a	Compute resonant frequencies in tank circuit	21	11	2.30
139a	Make mechanical adjustment of worm gears in equipment like VF or VG	24	15	2.36
171	Compute current requirements in a given circuit	28	15	2.62
207	Test battery for low cells	25	16	2.56

*For description see text following.

The substantial drop in number of ETs selecting the activities indicated above is supported by the relatively low frequency with which these activities are performed (right hand column, Table 19). Many ETs have performed those activities at one time or another but apparently not often enough to warrant considering them important to the ET's job. The frequency index numbers given in the last column are averages of the judgments of how often the activity [illegible] done on a five-point scale with the category of "very often done" given a value of 5 and "rarely or never done" given a value of 1. The frequency index numbers given above roughly indicate that these activities are "seldom" or "sometimes" done.

In summary of the characteristics of these specific activities that ETs do not consider important to their job the following may be noted

(1) Activities that are usually done in the shipyard; these include rebuilding and installation of equipment.

(2) Activities that require test equipment not usually available aboard ship.

(3) Activities of a computational nature that are not used by the ETs in these trouble-shooting procedures.

(4) Activities that depend on certain types of equipment failure that rarely occur.

A comparison of two groups of ETs (one composed of chiefs, firsts, and seconds; the other group made up only of thirds) was made in terms of the differences in selection of the card sort activities. The activities that the two groups have in common have already been indicated. Using a lowered criterion of selection at 50%, those activities that are "unique" to the C-1-2 groups and those activities that are "unique" to the 3rds have been singled out. When 50% or more of a group selected an activity and less than 50% of the other group selected the activity, the activity has been termed "unique" to the group with the higher percentage of selection.

Using this criterion of uniqueness there were 33 activities unique to the C-1-2 group and five activities unique to the 3rds. These are listed in the following two tables.

Table 20

Activities that are Unique* to the Group Composed of Chiefs, 1sts, and 2nds

Item	Activities	% of Group Selecting Activity C-1-2	% of Group Selecting Activity 3	Frequency Index	Comprehension Index
183	Supervise corrective maintenance actitities	94	36	3.81	117
74	Instruct ETs in maintenance fine points	88	32	3.78	136

Table 20
(continued)

184	Supervise preventive maintenance schedule	81	46	3.86	102
73	Instruct personnel in safety precautions	75	43	3.36	100
83	Replace ATR tube	75	46	2.76	82
63	Measure output frequency of radio transmitter	69	36	3.67	99
237a	Determine front to back ratio of crystals	69	46	2.97	91
240	Synchronize PPI sweeps in corrective maintenance	62	32	2.62	100
11	Adjust pulse frequency	62	39	2.67	117
19	Adjust local oscillator coupling	62	46	3.38	113
60a	Repair ohmmeter	62	36	2.24	82
76	Tune transmitter under radio silence using dummy antennas	62	39	3.18	95
104	Replace helipot assembly	62	25	2.25	103
162	Mechanically adjust scope focus coil	62	39	3.86	87
221	Correct instruction books when field change is made	62	39	2.85	55
223	Submit field change report card	62	28	2.95	58
1	Replace variable capacitors	56	39	2.33	82
3	Adjust range mark gating multi-vibrator	56	36	2.44	120
21a	Calibrate range markers according to a fixed range	56	36	3.00	106
85b	Reinstall parts of gear due to new specifications as in making field change	56	25	2.10	110
101	Align helipot tracking	56	18	2.63	124
105	Align synchro systems	56	28	2.21	117
164	Calibrate radar range marks according to a given known range	56	39	3.00	105
170	Compute voltage requirements in a given circuit	56	28	2.84	124
217	Make monthly report of operation and performance of certain electronic equipment	56	39	3.79	79
273	Take inventory of all portable testing equipment	56	46	2.79	41
274	Take inventory of ordinary hand tools	56	46	2.81	36
2a	Synchronize PPI sweeps in preventive maintenance	50	25	2.79	103
22a	Adjust number of pulses of range mark multivibrator	50	43	2.81	117
88	Adjust magnitude of STC	50	21	3.06	102
156	Measure oscillator output	50	32	3.18	107
179	Instruct radar operators in maintenance	50	46	3.04	111
191	Determine receiver sensitivity	50	43	2.81	116

*The criterion of "uniqueness" is given in the preceding paragraph.

Table 21

Activities that Are Unique to the Group of ET-3s When the Criterion of Selection is 50 Per Cent or Greater

Item	Activities	% of Group Selecting Activity		Frequency Index	Comprehension Index
		3	C-1-2		
117a	Determine power output of communications transmitter	75	44	3.86	99
176a	Make electrical loudspeaker repairs	68	44	2.67	86
33a	Replace electronically operating keying relays	50	38	2.33	97
233a	Check the grounding of electronics equipment by using voltmeter	50	44	3.54	74
239a	Replace of repair mechanical keying relays	50	38	2.58	81

The first four activities "unique" to the C-1-2 group have to do with supervision and instruction. In fact the greatest difference between the two groups of ETs for all activities occurs with the top item: "Supervise corrective maintenance activities." When an attempt is made to fit the activities here under the classification scheme that is used in the Manual of Qualifications for Advancement in Rating, it is found that although practically all the activities in the first list are expected of the C-1-2 group only, four of the five activities in the second list ("unique" to 3rds) are also expected only of the C-1-2 group. In the first list "repair ohmmeter" is expected of a 3rd as well but this was selected by a greater percentage of the C-1-2 group as "best" describing their job. This may be due to the infrequency of occurrence of a need for such an activity and the greater chance for the higher rated group to have had occasion to do it.

The activities in the second list are of a type likely to be delegated to a lower rate. In general, the tasks are more routine, many of them mechanical.

It is profitable to examine the above activities from the standpoint of the level of electronics comprehension that each requires. The most likely prediction would be that the activities unique to the C-1-2 group would demand more comprehension than those for the 3rds. To check on this the comprehension level scores (as judged by the ETs themselves; see Report No. 2 of this series for details) for the activities unique to each group were arranged into frequency distributions, Table 22. These data indicate that most of the activities "unique" to the higher rates are in the upper half of the comprehension scores, whereas the activities of the lower rate cluster about the center of the comprehension scale. The conclusion can be made that activities unique to the C-1-2 group tend to require more than average comprehension.

Table 22

Comprehension Level of Activities Unique to
High and Low Rate Groups

Distribution of Comprehension Scores	No. of Activities Unique to C-1-2 Group	No. of Activities Unique to ET3s
Highest Quarter	12	
Third Quarter	12	
Second Quarter	5	2
Lowest Quarter	4	3

B. Frequency of Performance of Sub-tasks

A presentation of the specific activities rated highest by the ET group for frequency of performance is made in Table 23. Thirty activities are given in rank order. The ranking is based upon the frequency index number of each activity computed as an average of the judgments of the ET group.

Table 23

Most Frequently Performed Maintenance Activities

Item	Activities	Frequency Index*
145	Read schematic diagrams	4.72
186a	Measure tube transconductance with tube tester	4.61
147	Use voltmeter	4.61
175a	Test vacuum tube for intermittent shorts by rocking it in tube tester	4.49
151a	Check circuit continuity	4.43
178	Determine value of component from color coding	4.32
226	Visually inspect tubes for open filament	4.29
182	Fill out failure report	4.21
225	Visually inspect tubes for gas	4.18
81	Requisition spare parts	4.14
232a	Use shorting bar	4.13
157a	Replace fixed fuses	4.06
59a	Check tube for gaseous breakdown by meter	4.00
210	Measure ring time	3.89
169	Vary tank circuit capacitance with variable capacitor	3.87
90	Tune TDZ manually	3.87
184	Supervise preventive maintenance schedule	3.86
117a	Determine power output of communications transmitter	3.86
222	Keep file of stock tally cards	3.85
211	Use RF signal monitor to determine transmitter frequency	3.84
161	Replace rectifier tubes	3.82
183	Supervise corrective maintenance activities	3.81
217	Make monthly report of operation and performance of certain electronic equipment	3.79
74	Instruct ETs in maintenance fine points	3.78
25	Adjust antenna coupling	3.76
98a	Estimate and check to see whether frequency is within desired limits	3.75
53a	Measure interelectrode capacitance by means of tube checker	3.75
187	Review records for possible cause of failure	3.74
141	Replace indicator lamps	3.67
63	Measure output frequency of radio transmitter	3.67
180a	Repair headphone and headset	3.66

*Location of the item on a scale ranging from 1.00, very seldom or rarely done to 5.00, very often done.

The first 12 activities correspond closely with those of Table 17 which listed the activities which were designated by the largest percentage of the ET group. This supports the general conclusion that the tasks which are done by the most people are also the tasks which are most frequently done.

C. Comprehension Levels of the Activities

The card sort activities are examined, below, in terms of the comprehension that is required in their performance. The question of the level of electronics comprehension was mentioned in a previous section in connection with the activities "unique" to the C-1-2 group and those "unique" to the 3rds. Here, all the activities that meet the criterion of selection by at least three individuals will be considered. There are 208 of them.

It had been hoped to get independent measures of both the degree of comprehension and the amount of skill required to accomplish the activities. Although comprehension and skill were defined at length and examples of the differences involved were given, the ETs seemed to make little distinction between the two. Either the measures were not defined clearly enough, or, if the data is to be accepted at face value, there is no real difference between the comprehension and skill required for most activities.

In order to get a better estimate of the amount of relationship between the comprehension and skill judgments, a tetrachoric correlation was computed. The following procedure was used. Score distributions were made of the 208 activities for comprehension and skill, and the midpoint of each distribution was determined. On the basis of the score given by each midpoint any activity could be tallied for whether it fell in the upper or lower half of comprehension and the upper or lower half of the skill distribution. The tetrachoric correlation computed in this way amounted to .96. In view of this high correlation value it was assumed that essentially the same standard was used in judging the activities. For this reason, only the comprehension scale was considered further.

In examining the comprehension level of certain activities it becomes necessary to check for a possible relation between the judgments of comprehension level and the degree of familiarity of the men with the task. It is likely that tasks which are infrequently done may be judged differently from those which men do frequently. Therefore, in the discussion which follows, the activities are divided into two classes or sub-groups: those more frequently done and those less frequently done.

First, the activities have been arranged in order of the electronics comprehension that they are judged to require. The highest and lowest 25 per cent of the items have been separated as illustrative of high and low comprehension levels. Table 24 lists activities receiving highest comprehension ratings which were also selected by more than 20% of the ETs; and Table 25 lists the high comprehension items which were selected by less than one fifth of the men. Comparable data for the activities receiving low comprehension ratings are given in Tables 26 and 27.

Table 24

Activities in the Highest Quarter of the Comprehension Ratings Which Were Also Selected by More than 20 Per Cent of the Men as Representative of Their Job

Item	Activity	No. of ETs selecting item as part of job	Comprehension Rating Score*
74	Instruct ETs in maintenance fine points	23	136
216b	Check frequency spectrum of magnetron	13	128
170	Compute voltage requirements in a given circuit	25	124

Table 24
(continued)

171	Compute current requirements in a given circuit	13	124
101	Align helipot tracking	19	124
35a	Neutralize or balance power of amplifier stage by neutralizing capacitor	14	121
188	Draw schematic diagrams	27	121
3	Adjust range mark gating multivibrator	25	120
115	Align superheterodyne receiver	33	119
71	Match impedance of transmission line	14	118
12a	Vary (set) pulse width	19	118
183	Supervise corrective maintenance activities	27	117
105	Align synchro systems	19	117
11	Adjust pulse frequency	27	117
22a	Adjust number of pulses of range mark multivibrator	27	117
145	Read schematic diagram	65	116
191	Determine receiver sensitivity	27	116
172	Measure receiver performance with signal generator	34	115
135a	Measure signal to noise ratio using scope	13	114
148	Trace signal by means of scope	39	114
153	Trace signal by means of vacuum tube voltmeter	17	114
119	Adjust local oscillator coupling	29	113
20	Adjust bias of transmitter timing thyratron	11	113
151a	Check circuit continuity	65	113
60	Repair ohmmeter	20	112
113	Adjust transmission line slugs	15	112

*For a detailed description of the manner in which this comprehension score was achieved see Technical Report No. 2, of this series.

Table 25

Activities in the Highest Quarter of the Comprehension Ratings Which Were Selected by Less Than 20 Per Cent of the Men as Representative of Their Job

Item	Activity	No. of ETs selecting item as part of job	Comprehension Rating Score
51	Compute distributed capacitance	3	134
70b	Match impedance of transmission lines other than with lugs	6	133

Table 25
(continued)

209b	Compute timing sequences in electronics circuits	6	133
216a	Check frequency spectrum of tank circuit	3	131
198	Compute impedance requirements of a given circuit	7	129
68a	Calculate output impedance of transmitter	3	126
122a	Compute resonant frequencies in tank circuit	10	126
130a	Measure selectivity (band pass) of communications receiver	12	125
131a	Check standing waves with scope or voltmeter	8	123
125	Compute amplification factor	6	123
52	Calibrate multimeters	8	123
75	Measure percentage modulation using an oscilloscope	11	122
15	Repair amplidyne	7	121
103	Balance phasing bridge circuit	9	120
213	Measure pulse width	10	118
37	Match impedance in double slug transmission	8	118
123	Compute signal traverse times	3	117
255	Repair range indicator recorders	8	115
118	Measure output impedance	9	115
70	Use panoramic adapter to determine frequency	5	114
126	Compute standing wave ratio	10	114
55	Compute capacitive reactance	8	113
56	Compute power factor	3	113
109a	Measure Q of individual circuit	3	112

Table 26

Activities in the Lowest Quarter of the Comprehension Ratings Which Were Selected by More Than 20 Per Cent of the Men as Representative of Their Job

Item	Activity	No. of ETs selecting item as part of job	Comprehension Rating Score
142	Replace lighthouse tubes	56	69
159a	Replace fixed resistor	58	69
192a	Measure generator voltage output	39	69
278	Measure transformer resistance	46	69
77	Repair terminal posts, plugs, and connections	58	68

Table 26
(continued)

158a	Replace fixed capacitors	57	68
100a	Inspect for moisture leaks in electronics gear	32	66
47a	Clean duplexer with solvents	13	66
226	Visually inspect tubes for open filament	55	64
163	Fill out installation record	15	64
182	Fill out failure report	58	64
175a	Test vacuum tubes for intermittent shorts by rocking in tube tester	61	63
178	Determine value of component from color coding	63	61
185b	Replace blower fans in electronic gear	17	60
161	Replace rectifier tubes	65	60
45	Check antenna for binding	18	59
232a	Use shorting bar	62	59
277a	Check continuity of transmission lines with ohmmeter	36	59
223	Submit field change report card	22	58
220	Meg antenna lines	54	57
79	Repair phone cable	43	57
199a	Clean switch contact points	54	56
201a	Clean interior of equipment	52	55
193	Repair brushes in motors	35	53
58a	Clean or polish ferruled resistor	18	51
81	Requisition spare parts	50	51
137a	Replace broken interlocks	27	51
160	Replace brushes in generators	32	51
173	Inspect tube pins for burning or corrosion	39	51
272	Take inventory of all spare parts	32	48
174	Inspect fuse and resistor clips for pitting or burning	41	48
140	Lubricate gears	37	45
222	Keep file of stock tally cards	39	44
8	Lubricate bearings	42	44
157a	Replace fixed fuses	62	42
102	Lubricate shaft couplings	22	41
273	Take inventory of all portable testing equipment	29	41
229a	Check spare parts bins	39	37
96	Clean air filters	33	36
243	Clean exterior of electronics gear	36	34
141	Replace indicator lamps	54	34

Table 27

Activities in the Lowest Quarter of the Comprehension Ratings Which Were Selected by Less Than 20 Per Cent of the Men as Representative of Their Job

Item	Activity	No. of ETs selecting item as part of job	Comprehension Rating Score
107a	Repair cooling system pumps and lines in electronic gear	3	66
218	Lubricate spur gears in IFF coordinator and indicator unit	5	65
48a	Drain coaxial transmission lines	6	65
206	Charge battery	3	60
49	Dry out wave guide	10	60
72	Repair cooling system fans and lines in electronic gear	12	59
207	Test battery for low cells	9	59
265	Repair hoist-lower systems on sound heads	5	39

The most striking features of these tables are: (a)Most of the ETs' tasks (those which are performed by the most people) are judged to involve a small amount of comprehension. This can be seen by comparing Tables 24 and 25. (b)Most of the activities which involve computation or calculation of values are rated high in comprehension. However, they are also not highly representative of the job in the sense of being chosen by a large percentage of the ETs (note Table 25). (c)There is a definite relation between the rated comprehension level and the frequency with which the tasks are performed. Of the activities that are not frequently done, more are rated as high in comprehension than are rated low. (d)The activities which occur predominately at the lower end of the comprehension scale involve the replacement of components, the cleaning and lubrication of equipment, and the keeping of records of repairs and stock. (e)Ratings high in comprehension were given to the tasks of alignment and the more delicate adjustments of the equipment; also to instruction and supervision.

The relation of the rate of the men and the comprehension level of the activities representing their job was discussed earlier, Table 22. This can be evaluated in still another way through the use of a correlation coefficient. Each card sort activity can be considered as a case, and a frequency distribution can be made for each of the two rate groups (0-1-2, and 3) arranging the items according to the number of men selecting each activity as "best" describing their job. This permits dividing the items into two classes: one "representative" of the rate group, the other "not representative" of the rate group. The items can be divided into a second dichotomy according to the scores on the comprehension rating.

This provides the material for constructing a 2 x 2 table for each rate group, correlating items which are high or low in representing the job with those which have high or low comprehension score (each group split at the median). Tetrachoric correlations thus received are -.37 for the C-1-2 group and -.53 for the 3rds group. They show a tendency for low comprehension ratings to be characteristic of the activities which are most often chosen by both groups. There appears to be a stronger tendency for the lower rate group to have more lower comprehension activities since the magnitude difference between the correlations is in that direction (that is, the negative relationship is greater for the 3rds than for the C-1-2 group).

This suggests rephrasing the conclusion (a)above to read: Most of the ETs tasks are judged to involve a small amount of comprehension, and the tasks representative of the low rate group involve lower comprehension than those of the high rate group.

V. MATERIAL FACTORS INFLUENCING REPAIR

Any repair that occurs, whether it be completely or only partially successful, is fundamentally dependent upon various aids that an electronics technician uses in the course of his maintenance activity. If it can be assumed that the man trying to effect the repair is trained in the theoretical aspects of his job, what are the additional factors that directly influence the effectiveness of the repair?

First, the adequacy and availability of the different types of tools that he uses must be taken into consideration. Tools, in this case, are considered in the ordinary sense of the word, that is, a group of instruments which include screwdrivers, pliers, wrenches, and others of the same general nature. Another type of tool which is equally important is usually referred to as test equipment.

In addition to these instruments which are used in direct contact with the equipment, there are a number of additional aids which are intended to contribute to a repair job. Equipment records and publications are sources of information that may guide the electronics technician in the right direction at a very early point in his maintenance effort or act as guides for preventive maintenance.

The physical space within which a technician may work, its adequacy and availability, as well as the problems encountered in obtaining spare parts to correct defective equipment must also be taken into consideration if a realistic picture of the electronics technician's repair activity is to be obtained.

The three major divisions of this discussion, namely (A) work spaces and spare parts, (B) publications and records, and (C) tools and test equipment are equally important as far as their relationship to repair is concerned although the degree to which their presence or absence affected maintenance varied considerably among the ships studied in the course of the present research. In some cases, maintenance was a well controlled function although records were not kept up and tools and test equipment relatively inadequate. In other cases, tools, records, and work spaces were optimum for efficient repair yet the equipment was down a considerable portion of its usual operating time. The maintenance picture for most of the ships, however, is found somewhere between these two extremes.

A. Work Spaces and Spare Parts

One of the first considerations for the electronics technician is the problem of a work space or workshop. The attitude of all of the technicians in the sample was investigated with a question in the general questionnaire which asked the technicians and the electronic material officers to indicate whether or not an electronics workshop was absolutely essential on a destroyer or destroyer escort. Table 25 summarizes the responses to this item.

Table 28

Opinions as to Whether or Not an Electronics Workshop is Essential on Destroyers and on Destroyer Escorts Expressed in Terms of the Percentage Selecting a Given Response

N	Respondent Groups Designation	Workshop Essential on DD %Yes	%No	%NR*	Workshop Essential on DE %Yes	%No	%NR
71	ET	92	8	0	83	10	7
12	EMO	100	0	0	58	0	42

*NR = No Response
(Source: General Questionnaire, item No. 10)

It is readily apparent that the great majority felt the need of a work space primarily designated for electronics technicians. In fact, the electronics material officers were unanimous in their opinions regarding DDs.

A review of the data shows that an electronics workshop was available for the technicians on most ships observed. The physical size and location of these workshops, however, varied considerably. Whether or not the existence of a workshop was a problem was also investigated and, as can be seen from the table below, the alternative "no electronics repair shop" was neither the most nor the least serious problem facing electronics technicians.

On the other hand, responses given to questions in the general interview included numerous references to difficulties involving the work shop. Several of the electronics technicians felt that a crowded work space was a definite factor standing in the way of their doing a better job. Others felt that the lack of shop facilities was a limiting factor while a few stated that the distance of the workshop from the electronics gear reduced their efficiency. In addition, one of the electronics material officers felt that the lack of a work shop stood in the way of his doing a better job.

Table 29

Opinions Concerning the Most and Least Serious Problems Facing an Electronics Technician Expressed in Terms of the Percentage of a Respondent Group Selecting a Given Response

Respondent Groups		Problems: Inadequate Electronics Training		Too Few ETs Per Ship		Operators Fouling the Gear		No Elect. Repair Shop		Inadequate Tools and Equipment		Lack of Spare Parts		NR	NR	NR
N	Desig.	M*	L*	M	L	M	L	M	L	M	L	M	L	M	L	Both
71	ET	24	10	4	25	11	21	7	11	28	3	14	21	12	8	0
12	EMO	50	8	8	17	8	17	0	17	25	0	0	42	9	0	0
15	CIC	13	27	46	0	7	0	0	0	7	33	7	13	0	7	20
14	ASW	21	21	29	0	0	36	0	0	14	7	14	14	0	0	22
13	COMM.	31	0	31	8	0	23	0	8	8	8	8	31	0	0	22
13	OPER.	8	8	45	0	0	38	0	8	8	15	8	8	8	0	23
18	GUN.	28	6	28	6	0	17	0	6	0	6	6	21	0	0	38
12	ENG.	17	17	25	8	25	0	8	24	0	17	0	17	8	0	17
11	EXEC.	54	0	27	18	0	9	0	27	9	18	0	18	0	0	10

*M represents the percentage of a respondent group designating the problem as the most serious, and L represents the percentage designating the problem as the least serious.

(Source: General Questionnaire, item No. 9)

As a further consideration, the electronics technicians were asked to indicate what the chief function of the workshop should be. Four alternatives were provided in the general questionnaire and two were selected most frequently.

Table 30

Opinions Concerning What the Chief Function of an Electronics Workshop Should be Expressed in Terms of the Percentage of a Respondent Group Selecting a Given Response

Respondent Groups N	Desig.	% Selecting the Chief Function of a Workshop to Be a: Hdqtrs. for ETs	Place to Work on Broken Gear	Store for Test Equip., Tubes, etc.	Place to Stand ET Watches	% Giving No Response
71	ET	8	52	32	0	8
12	EMO	9	33	58	0	0
15	OIC	7	27	46	0	20
14	ASW	0	21	64	0	15
13	COMM.	0	23	69	0	8
13	OPER.	15	62	15	0	8
18	GUN.	6	22	50	0	22
12	ENG.	0	33	50	0	17
11	EXEC.	10	45	45	0	0

(Source: General Questionnaire, item No.11)

Most of the technicians and officers felt that a workshop should be either a place to take broken gear to work on or a central room for test instruments, power supplies, parts, and tubes. Most of the repair shacks observed were found to function in either or both of these capacities.

More than half of the electronics technicians indicated that they were responsible for the ordering, storing, and inventorying of electronic spare parts and almost fifty per cent reported being responsible for distributing and maintaining a full allowance of these parts. The technicians felt that "spare parts difficulties" was the most frequent contributor to excessive shutdown time of electronic gear as shown in Table 31.

Table 31

Opinions as to the Most Frequent Contributor to Excessive Shutdown Time of Electronic Gear Expressed in Terms of the Median of the Ranks Assigned By the Members of a Respondent Group*

Respondent Groups N	Respondent Groups Desig.	Median Rank Assigned to: Insufficient Preventive Maintenance	Spare Parts Difficulties	Poor Coordination Between Ship's Depts.	Inexperienced Personnel	Carelessness of Personnel
69	ET	2.8	2.3	4.0	2.7	3.2
12	EMO	1.5	4.0	3.5	2.2	3.5
13	CIC	1.9	2.6	4.8	2.6	3.9
9	ASW	1.7	3.0	4.8	2.6	3.2
12	COMM.	2.2	3.5	4.2	1.8	3.5
7	OPER.	1.75	1.5	4.4	2.3	4.6
10	GUN.	1.2	3.8	4.7	2.3	2.5
11	ENG.	1.2	4.2	4.2	3.0	2.8
10	EXEC.	1.9	2.0	4.8	2.8	4.0

*Most frequent contributor was ranked 1; least frequent was ranked 6.
(Source: General Questionnaire, item No. 29)

The category "spare parts difficulties" is general enough to cover almost any aspect of the spare parts situation. However, the fact that it was ranked first by the electronics technicians warrants a more detailed study. Questions involving spare parts could range from "How are spare parts obtained?" "Where are they stored?" and "Are there enough of them to cover most maintenance jobs?" to a consideration of the quality of the parts which are available. Only a select few of the possible questions were asked during this study, and a number of responses related to these are worthy of note.

Neither the electronics technicians nor the electronics material officers felt that the lack of spare parts was a serious problem. In fact, almost half of the officers indicated that they felt it to be the least serious problem (Table 29). Reference to the problem of spare parts occurs in some of the other data obtained. In the general interviews, electronics technicians occasionally referred to spare parts difficulties as a factor affecting their efficiency. They mentioned specifically slowness in procuring ordered parts, lack of spare parts, lack of stowage space, defective spare parts, and difficulty in obtaining spare parts.

There were two occasions in critical incident interviewing that reference was made to spare parts. In one case, spare parts boxes were allowed to be stowed around the equipment, and, in the other, a failure to order spare parts resulted in excessive shutdown time.

Numerous instances are reported wherein electronics technicians had to improvise spare parts when the actual ones were not available. Some of these instances are abstracted from the responses given by the technicians to one of the questions used in the critical incident method and listed below:

Table 32

Examples of the Improvisation of Spare Parts When the Regular Spares Were not Immediately Available

1. Manufactured barrel clips for damaged radar.
2. Rigged up temporary blower motor to replace burned out one.
3. Replaced shorted-out wires in a circuit by using graphite pencil.
4. Manufactured clamp to hold antenna together.
5. Substituted TDZ generator for unfixable AN/ARC generator.
6. Rewound transformer when no replacement was available.
7. Put in a jury rig for a bad rectifier unit that had no replacement.
8. Repaired badly damaged telescopic capacitor when no spares were available.
9. Devised a rectifier circuit to replace a faulty motor generator.
10. Rigged up a fuse holder to replace a bad one that had no replacement.

Table 32
(continued)

11.	Combined six transformers to replace a burned out one they did not have a replacement for.
12.	Rewound motor field.
13.	Substituted amplifier power supply for burned out dynamotor.
14.	Rewound burned out transformer.
15.	Made brushes for motor generator when none were available.

B. Publications and Records

Published materials are a key source of information for the electronics technician. Not only do publications give specific information about a piece of gear, but they often include many points of information applicable to electronics equipment in general. In order to determine the role that publications play in the overall activity of the electronics technician, items were included in both the job questionnaire and general questionnaire methods to cover a number of different aspects.

Twenty-one publications were presented to the technician, and he was asked to indicate by a checkmark which of this group he used in the course of his work aboard ship. Only seven publications were checked by more than fifty per cent of the ETs, namely: general instruction books, Electron, NavShips equipment instruction books, Communications Electronics Maintenance Bulletin, Radar Maintenance Bulletin, electronics textbooks (educational publications) and BuShips manuals.

The majority of the electronics technicians and officers felt that publications were both adequate and available for their intended purpose. In addition to these two points, the technicians and officers were asked to indicate the major use they made of publications and what they considered to be the most important limitations to the use of this material.

Statements concerning the major use of publications grouped themselves into four categories, namely: (1) training and information, (2) reference for trouble shooting, (3) reference for maintenance and operating of equipment, and (4) keeping up on new developments. There is an approximately equal number of technician's responses in each of the four categories. Officers' responses are contained in the first three categories but none of the officers reported that they used publications to keep up on new developments.

Almost half of all of the responses given to the item which asked about the limitations of electronics publications could be placed in either of the following two categories; (1) not detailed enough, and (2) too highly technical. The remainder of the responses are distributed among reported limitations categorized as "too time consuming to keep up on," "inadequate indexing," and "too limited in application."

In a manner similar to the one described for publications, a group of records were listed in the job questionnaire, and the electronics technicians were asked to indicate which of these records they kept as a part of their job. More than fifty per cent of the group reported the use of the following records:

- Failure Report
- Repair Records
- Electronic Equipment History
- Field Change Records
- Monthly Check Lists (Equip.)
- Spare Parts Records
- Corrective Maintenance Record
- Standard Navy Stock Cards
- Electronics Service Repair Record

Eighty-seven per cent of the electronics technicians stated that equipment records were used in trouble shooting. When an individual stated that equipment records were used in trouble shooting, he was asked to indicate how they were used. Responses to the latter question grouped themselves into four major categories. Representative statements are shown within each of the categories listed below:

I

As a reference, locating similar troubles

"Noting if similar troubles occured previously and what corrected them."

"Noting what type of troubles are recurrent in that piece of gear."

"Many times the same trouble appears. These records save time in locating those which have occurred before."

II

To ascertain possible cause and to use it as a starting point in trouble shooting

"A check of equipment records may well show that a similar trouble had occurred previously, and exactly how that trouble was eliminated."

"If it is a difficult trouble with just a few symptoms, you can check to see if it has appeared before in that piece of gear and what the trouble was."

III

To attempt to fix a reason or pattern for breakdown

"To see if any chronic trouble is reappearing, and how long since tube was changed."

"Total output over a period of time in certain metering circuits indicates failure of particular component."

IV

To check past performance and condition of components

"For modifications in gear, contimued troubles."

"Check on past failures and age of equipment."

The technicians consider "work on maintenance records" as the second most important thing to do when all of the gear is working. Most of them report that they spend ten per cent of their time in the preparation of these records; some considered record keeping a factor standing in the way of their doing a better job. One stated, in the course of the general interview that "too much record keeping" reduced his efficiency while another felt that "inefficient record keeping of previous ET personnel" was a factor affecting his work.

It is interesting to note that the spare parts record was the only one which the electronics technicians were observed using during the course of the many diaries prepared by the observational teams. Although 87 per cent of the ETs stated that they used equipment records in trouble shooting and close to 50 per cent indicated that these records were a good source of information for determining possible causes of equipment failure, the regular use of these records was not apparent. Instead, instruction books and various publications were used to establish reasons for equipment failure or to initiate corrective maintenance procedures. There seems to be a wide gap between the appreciation of records as a guide in maintenance and the practical use of these records in repair problems.

C. Tools and Test Equipment

The two principal aids of the electronics technician in any type of maintenance activity are tools and test equipment. Practically every repair calls for the application of either one or both. An effort was made in this research to determine what types of instruments were available to the electronics technician, whether or not their quantity and quality were adequate, and the frequency with which they were used.

A list of tools was presented to the electronics technicians and they were asked to indicate those which they used in their work aboard ship. With the exception of a few specialized tools such as the power drill, alignment tools, and typewriter, most of the other tools checked by more than fifty per cent of the technicians could be categorized as common hand tools to include such items as screwdrivers, pliers, wrenches, and soldering irons. These tools are also reported as being used most frequently on the sample of forty repair records which were discussed earlier.

There was little difference of opinion with respect to the quality of these tools. More than eighty per cent of the electronics technicians and officers felt that the quality of tools used was adequate. However, when men were questioned about the quantity of these tools, their opinions differed markedly. The ETs opinions were divided almost equally, with 41 per cent stating that the quantity was adequate whereas 59 per cent felt that it was not. The majority of the electronics material officers (75 per cent) felt that the quantity was inadequate.

The fact that a problem existed with respect to the quantity of tools is also indicated by the responses of the technicians to questions in the general interview. When they were asked to state which factors stood in the way of their doing a better job, the most frequent response was "lack of proper tools." One of the officers also referred to "lack of tools" as a primary factor reducing efficiency. In addition, when ETs were asked to rank six alternative problems facing them in terms of seriousness, the highest percentage of them felt that "inadequate tools and equipment" was the most serious (Table 29).

Observations made of test equipment used aboard ship were very similar to the ones described for tools. A list of different pieces of test equipment was given to the technicians, and the men were asked to indicate which of these instruments they used in their work. In addition, a frequency count was made of the test equipment used in the course of forty repair records. Again, a relatively good agreement was found between the test equipment that ETs report that they use and the test equipment recorded as being used in maintenance. Instruments most frequently referred to in both instances include tube tester, oscilloscope, voltmeter, ohmmeter, meggar, multimeter, milliammeter, frequency meter, echo box, signal generator, wattmeter, and vacuum-tube voltmeter.

The majority of ETs and officers felt that the quality of available test equipment was adequate. In fact, test equipment quality was referred to seldom in other observational data. In a few instances equipment was shut down longer than it should have been because the technician failed to consider the possibility of faulty test equipment.

On the other hand, only one half of the electronics technicians and about one fourth of the electronics material officers felt that there was an adequate quantity of test equipment. "Lack of proper tools" was reported most frequently by electronics technicians during the general interview as the factor standing in the way of their doing a better job (see Table 36). And the factor of "inadequate test equipment" was reported with high frequency.

The data do not contain any instance in which the quality of the tools used is questioned or considered by anyone to affect electronics maintenance activities, and only two minor references were made concerning the quality of test equipment. This is quite different from the situation with reference to quantity.

VI. CONDITIONS LIMITING MAINTENANCE

It is the purpose of this section to seek potential trouble spots as they relate to personnel and electronics maintenance behavior. By consideration of such areas of weakness it may be possible to determine procedures for improving present conditions. The search takes several somewhat different approaches. One evaluates principal causes for unsuccessful maintenance. Another observes equipment limitations on repair. Still others depend upon reports of the men regarding factors keeping them from doing a better job.

A. Contributors to Unsuccessful Maintenance

In an attempt to discover and evaluate the relative importance of conditions which differentiate between successful and unsuccessful maintenance behavior, critical incidents were collected to indicate "occasions when the repair of electronics gear was not accomplished as quickly as it might have been - incidents where gear was shut down for a longer time than it should have been." The eighty-two situations collected can be categorized according to their salient differences. This is presented in Table 33.

Table 33

Factors Contributing to Unsuccessful Maintenance

Classes of incidents and examples of each	Frequency of occurrence
Failure to make adequate visual checks early in trouble shooting	15
Failed to check fuses before proceeding	
Failed to check switches before proceeding	
Overlooked difficulties easily visible	

Table 33
(continued)

Classes of incidents and examples of each	Frequency
Overlooked that which was faulty	10
Missed a stage in trouble shooting	
Failed to consider possibility of faulty test equipment	
Neglected to test a spare part before using as replacement	
Failure to begin or complete repair because of unfavorable attitude	9
Put off cleaning equipment	
Avoided a repair because of its complexity	
Did not complete repair due to lack of interest	
Slowness or failure to make repair because of inability	7
Failed to locate intermittent short in TR tube	
Checked component incorrectly	
Did not find trouble in spite of repeated attempts	
Failure to make adequate use of instruction books, schematics and blueprints	6
Failed to consult appropriate schematics	
Did not use instruction book in setting up gear	
Could not understand instruction book	
Replaced faulty component without considering a more basic cause of failure	4
Continued replacing tubes as they burned out rather than locate the source of trouble	
Replaced burned out magnetrons before locating the source of the difficulty	
Assumed something was faulty when it actually was not	4
Disassembled switch when trouble was elsewhere	
Attempted repar by adjustment of relays when source of trouble was in a power stage	
Failure to report faulty equipment	4
Did not notify ETs when obtained jerky sweep on PPI	
Failure to volunteer information that would aid in repair	3
Did not report twisting band switch past stops	
Interferred with ETs work	3
Got in ETs way when he was trouble shooting gear	
Assignment of inadequate personnel to make repairs without supervision	3
Failure to keep up book work	3
Failed to order spare parts	
Did not record circuit change in instruction book	

Table 33
(continued)

Classes of incidents and examples of each	Frequency
Failure to make adequate check in operation before reporting gear failure	2
Refused to assist or be assisted in repair	2
Improper stowage	2
Refused to allow repairman to do repair	2

Reviewing these situations, it is evident that the most important contributors relate to lack of skill and thoroughness on the part of the electronics technician. Factors associated with work habits, such as taking care of book work and attending to parts supply and stowage, are also present. Of less frequency but considerable significance are administrative matters such as not reporting failure promptly and in detail to ETs, or in some way hindering ETs' work.

B. Equipment Limitations on Repair

One of the more obvious limitations on equipment repair is provided by the equipment itself. Equipments vary widely in the ease with which they can be maintained. Some of this is due to circuit complexity, although a significant amount stems from considerations related to questions of layout and spacial design. An analysis of incidents cited as indicating restrictions due to equipment design is given in the following Table 34.

Table 34

Behavior Restrictions Brought About by Equipment Design

Classes of Restrictions with Typical Incidents	Frequency
Removal of unit or component requires excessive removal of surrounding parts	17
Removal of the SG high voltage transformer necessitated prior removal of much of the transmitter unit	
To get oscillator circuit in MK25 had to remove part of wave guide and mixer chassis	
TBL capacitor C-45 difficult to replace because had to remove other parts to get at it.	
Needed to remove PPI tube to get at some of the terminal boards in the VF	
Equipment too compact to reach and work with components	16
Compactness of the AN/ARC makes it difficult to test components and impossible to test some without unsoldering connections and taking them out	
MK25 is so compact that it requires excessive removal of components in order to locate intermittent shorts	
Compactness of the RDZ makes it difficult and unsafe to remove and replace some of the vacuum tubes	
Parts too difficult to reach because too far from panel or drawer or behind or under other parts	13
Difficult to reach the leads of resistors and capacitors in the TBL to test them because of surrounding parts	
Difficult to reach the tuning capacitor on the TDQ to adjust it because of all the gears around it.	
Difficult to loosen collar to unfreeze master oscillator tuning control of the TBL because surrounding parts make screws almost inaccessible	
Inadequate provision for trouble shooting while set is operating	9
The fact that you have to use an extension to work on the TDZ with the power on is an inconvenience and slows one down	
Lack of battle short switch on VF makes it difficult to trace trouble while set is running	
Lack of systematic arrangement of parts makes set hard to work on	5
Organization of parts in the MK34 made soldering of parts difficult	
Unsystematic arrangement of parts on AN/SPS 6 created difficulty	

Table 34
(continued)

Classes of Restrictions and Typical Incidents	Frequency
Poor arrangement of cables External cables on MK34 makes opening the drawer difficult and causes excessive strain on the cables	3
Parts fastened by too many elements RBS has to have 25 to 30 screws removed in order to take it out of the case	3
Parts facing in wrong direction from panel or drawer Terminal board for resistors in SC faces back of equipment making it necessary to remove drawer and shut down equipment in order to get at it	2
Removal of unit requires excessive removal and tagging of leads SC console drawer AN/ARC single terminal strip	2
Improper construction of knobs and switches TDZ, ridges on knobs; dial system too small	2
Parts secured too strongly TDZ tubes in tripler stages MK34 locks on tubes	2
Poor identification of parts or leads	1
Inadequate independence of function of separate units	1
Parts too bulky	1
Parts fastened by improper fastening elements	1
Insufficient or inadequate indicators	1

C. Behavioral Causes of Equipment Breakdown

One further set of information of this same type was collected in an attempt to determine the behavioral causes of breakdown of electronic equipment. Most persons when considering the problem of reducing the number of failures of electronic equipment think of improving the engineering design of the instrument. In such cases, the way in which the behavior of the operators and technicians contribute is likely to be overlooked. To evaluate this problem, 129 incidents were collected as representative of situations where somebody did something that "fouled up" some electronic equipment. The abbreviated statements have been organized into categories and are presented in detail below in Table 35.

Table 35

Behavior Contributing to Breakdown of Electronic Equipment

Categories of Abbreviated Incidents
Handled gear roughly when using it in operation
Jammed sliding capacitor
Dropped hand set on deck
Cranked range helipot into stops
Turned tuning knob past stops
Cranked range counter fast into stops
Cranked range crank past zero stop
Twisted tuning knob past stops
Cranked range crank into stop
Twisted switch past stop
Twisted band switch past stop
Turned range indicator beyond stops
Twisted receiver band switch past stop
Kicked switches on and off
Flicked switch past stop
Cranked manual control on antenna roughly
Cranked range crank past stop
Jerked cable loose on handset
Connected correct wire or correct component to wrong place or in wrong position
Replaced plugs in wrong sockets while cleaning gear
Connected power cables to wrong terminals
Attached wire to wrong terminal
Mistakenly connected chassis to AC power line
Connected leads to chassis backwards
Put RF tube in backwards
Replaced lead on wrong terminal
Made wrong connections on patch panel
Replaced wires without regard to proper connections

Table 35
(continued)

Categories of Abbreviated Incidents
Replaced leads in reverse after cleaning
Connected a wire in the wrong place
Connected transmitter-receivers to wrong terminals
Put tube in wrong position in socket
Replaced unit so that small gear rubbed against frame
Attempted to operate gear before making proper checks and adjustments
Failed to throw gyro switch before operating gear
Failed to put antenna transmit switch in receive position before keying
Forgot to turn on power switch
Keyed transmitter while there was a jumper between a transmitter antenna and a receiver antenna
Allowed operation of equipment before repair gear was removed
Failed to check zenith search switch before attempting to operate equipment
Failed to shut down radiation before changing pulse width
Failed to put gear in stand-by before applying power
Fired up set before taking voltage checks on power unit
Switched frequencies while tuning knobs were unlocked
Neglected to adjust gain control when putting equipment in operation
Failed to make operator adjustments on repeater
Failed to press start button before calling an ET
Removed or replaced part of the equipment in a rough manner in maintenance
Unscrewed cable at solder connections end rather than at socket end
Pulled tube out of set too vigorously
Failed to take proper precaution when opening magnetron carton
Forced a reduction gear which had a bent key onto armature arbor with a hammer
Shoved drawer back into set too vigorously
Broke off metal rod from insulator when trying to remove it
Broke off three cables when pulling out drawer of equipment
Manipulated wrong switch or switch in wrong direction
Turned on the regulating transformers instead of line voltage
Threw wrong switches on gear trying to turn it on
Turned switch in the wrong position
Turned off wrong switch
Turned selector switch to wrong position
Threw synchro switch in wrong position
Opened switch while cleaning equipment and failed to return it to its original position

Table 35
(continued)

Categories of Abbreviated Incidents
Performed act contrary to direct instructions
Used both automatic and manual antenna train at same time contrary to instructions
After instructed not to, deliberately placed jumper between receiver antenna and transmitter antenna
Adjusted relays contrary to orders
Left transmitter door open contrary to posted instructions
Threw a switch which he was instructed not to touch
Willfully made adjustments on transmitter contrary to instruction book
Improperly stowed or improperly secured material (Not including the shutting down of electronic equipment.)
Stored powdered soap box on generator unit
Failed to close watertight cover on phones on bridge
Failed to secure coffee pot
Failed to secure gear to keep it from falling to the deck
Neglected to turn off steam in scullery before going to battle station
Placed side panel of transmitter against electrically charged circuit
Attempted repair or adjustment on equipment when unauthorized
Attempted to tune director without authorization
Attempted to repair gear when not authorized
Attempted to repair set when unauthorized to do so
Pulled all the tubes from set without authorization
Used motor generator unit when not authorized
Unauthorized person pounded on the IF section of a receiver in attempting repair
Failed to completely replace components or part
Reassembled search switch leaving out certain components
Failed to replace critical bracket after repair of equipment
Failed to push plug back in transmitter completely
Failed to replace light shield on radar
Forgot to hook up leads when replacing magnetron

Table 35
(continued)

Categories of Abbreviated Incidents
Used a part of some electronic equipment for recreational purposes
Dialed girl friend's phone number on transmitter remote unit
Removed side panels of transmitter to play cards on
Used transmitter switch to indicate dealer in card game
Keyed detuned transmitter while playing around
Wiggled neon bulb to see it flash
Adjusted stage to wrong value when tuning gear
Failed to resonate peak on IPA stage in tuning gear
Attempted tuning adjustment without proper equipment
Made wrong adjustments in tuning transmitter (2)
Loaded PA stage too high in tuning gear
Indiscriminately adjusted knobs in attempt to tune up transmitter
Exceeded time limitations in operation of gear
Keyed transmitter too long
Keyed transmitter too long
Held sonar slew knob down too long
Slewed sonar too long
Inadequate care when moving in vicinity of electronic equipment
Stepped on power cord pulling it from socket
Jarred equipment with boxes when moving them around
Bumped interlock when walking by set
Broke crystal meter when moving steel boxes
Did trouble shooting inside set when gear was operating
Propped shorting bar open with screwdriver when trouble shooting
Left shorting bar across high voltage while trouble shooting in set
Prodding for loose connection with a screwdriver when set was operating
Tried to run test leads into difficult place with set in operation
Used equipment for foot rest
Rested knee against receiver
Rested foot on high voltage variac
Propped feet up on equipments

Table 35
(continued)

Categories of Abbreviated Incidents
Put wrong component in circuit
Put transmitter crystal in receiver and receiver crystal in transmitter
Put an overamperage fuse in a piece of gear
Put wrong tube in socket
Overlooked something in preventive maintenance
Failed to clean antenna insulators when performing preventive maintenance checks
Failed to clean insulators in routine cleaning
Failed to discover loose potentiometer on bulkhead during routine checks
Removed leads without identifying them
Neglected to identify leads when removing them for cleaning
Failed to tag leads when disconnecting them
Failed to identity wires when removing them for cleaning
Used improper tools or materials in preventive maintenance
Used bellows to clean dirt out of equipment
Painted antenna insulators
Put anti-rust compound on rotating shaft
Made improper changes in circuit design
Soldered a short across a fuse terminal
Made circuit change so antenna would operate manually and automatically at the same time
Improperly adjusted test equipment
Took voltage reading without switching to proper meter scale
Failed to switch ohmmeter to voltage scale before making voltage measurements
Made untidy repair
Left large globs of solder when soldering connections
Left solder drippings in gear

Table 35
(continued)

Categories of Abbreviated Incidents
Interrupted transmission without warning
Detuned transmitter while operator was transmitting
Allowed removal of needed equipment
Authorized removal of needed sound power circuit
Threw refuse in gear
Threw refuse into transmitter
Failed to lock down tuning knobs after tuning set
Failed to lock tuning heads down on TDZ

D. Factors Keeping Personnel From Doing a Better Job

During the course of the interview with the ETs and the electronics material officers these men were asked to express their opinions concerning factors which stood in the way of their doing a better job. The responses received were varied as can be seen in the two accompanying tables (Table 36 for the ETs and Table 37 for the officers). The list for the technicians omits any factor which was mentioned only once. The remaining 17 different responses fall into three general classes (1) equipment and material factors (2) administrative matters, and (3) training needs.

Table 36

Abstracted Answers to Interview Question Concerning Factors Which Stand in the Way of ETs Doing a Better Job*
N = 56**

Factors	Frequency
Lack of proper tools	11
Inadequate test equipment	11
Lack of experience	10
Crowded work space	6
Lack of schooling particular types of gear	5
No factors standing in the way	5
Inability to get equipment secured to work on it while at sea	5
Lack of shop facilities	5
Lack of theory in training (went too fast in school)	3
Inability to get further schooling (Class B and special schools)	3
Distance of workshop from electronic gear	3
Lack of class A school training	3
Lack of incentive (poor officer supervision)	3
Slowness in procuring ordered spare parts	3
Lack of spare parts	2
Lack of trained personnel due to complements being filled with low rated men	2
Lack of spare parts stowage space	2

*In terms of frequency of response
**There may be more than one answer for each respondent. Therefore, the number of responses will not equal the N of respondents

Conditions affecting the electronics material officers are even more diversified, Table 37.

Table 37

Abstracted Answers to Interview Question Asked of EMOs Concerning Those Things That More Than Anything Else Stand in the Way of Their Doing a Better Job*
N = 11**

Interfering Factors	Frequency
"Short timers" attitude	3
Lack of proper test equipment	3
Too much paper work	2
Lack of well trained ETs	2
Lack of interest by others (officers and men) in preventive maintenance	2
ETs doing non-electronic duties (such as mess duty, watches outside electronics, etc.)	2
Own inexperience	2
Difficulty in obtaining spare parts	2
Lack of time to work with ETs	2
Lack of tools	1
Lack of cooperation between departments	1
Lack of work shop	1
By-passing in chain of command	1
Poorly trained radiomen	1
Poorly trained radarmen	1
Insufficient number of personnel	1
Operators' failure to report equipment malfunctions	1
Unclear delineation of EMO duties	1
Lack of knowledge of other officers as to EMO's duties	1
ETs in wrong department (are in Eng. but should be Oper.)	1
Overlap between SOs and ETs making repairs	1
Poorly designed equipment	1

*In terms of frequency of response.
**For this item, there may be more than one answer for each respondent. Therefore, the sum of the responses will not equal the N of the respondents.

Casual observations had suggested the possibility that maintenance operations might be hindered by demands being made on the ET by persons who are perhaps not very intimately acquainted with electronics problems.

For this reason all ETs were asked whether they felt any unreasonable maintenance demands were made of them. As can be seen from Table 38 most men reported an absence of such demands. Those which were mentioned are interesting in that they suggest some sources of difficulty.

Table 38

Abstracted Answers to Interview Question Concerning Unreasonable Maintenance Demands Made of ETs.
(In terms of Frequency of Response)

Unreasonable Demands	Frequency
a. No unreasonable demands	37
b. Officers demand repair sooner than it can be done	6
c. Officers lack knowledge of equipment	3
d. Officers call ETs to make adjustments that officer or operator can make	2
e. Officers expect more from equipment than it is capable of giving	2
f. ET required to do all preventive maintenance that operator should do	2
g. Officers do not understand ET repair problems	2
h. Officer demands time estimate for fixing gear before ET can make diagnosis	1
i. Having to maintain obsolete gear	1
j. Having to work under EMO who doesn't know any electronics	1
k. Having to drop complicated jobs to take care of unimportant duties	1
l. Having EMO stand over ET asking frequently what is wrong with gear	1
m. Red tape - having to secure OD permission to shut down equipment that isn't working already	1
n. Drills interfere with maintenance work and cause ETs to work at night	1
o. Safety precautions - 2 men on gear when not enough ETs, and must wear safety belt when climbing mast	1

An examination of the last table (No. 38) suggests many factors which are related to the attitude of the man and his interest in his job. Some of these factors as they concern training of the men have been mentioned previously in a report on training implications. Others will be considered, later in the report on operational and administrative problems. One of the most important of these is the problem of turnover and the fact that training and the acquisition of on the job skills takes up such a significant portion of the enlistment period.

One of the goals of the last few sections has been to search for areas in which improvements might be achieved. Several of these are evident. They are: (1) improved corrective and preventive maintenance procedures (2) improved attitude and motivation of technicians (3) improved administrative cooperation particularly between operators and technicians and (4) improvements in equipment layout.

Procedural weaknesses showed a tendency to overlook simple checks (as on switches and fuses) before beginning trouble shooting. There were a number of occasions where men would have equipment torn down, several tubes replaced, or some similar expenditure of time when another ET would come along and notice that a switch had accidentally been thrown or a high voltage fuse blown. Equally important appears to be a lack of thoroughness and carefulness. This is frequently accompanied by an unsystematic approach of "Easter egging."

Carelessness and rough handling of equipment were present in a significant number of situations. In other instances, technicians showed a tendency to take the "easy way out," as for example when one group replaced a certain tube as it burned out every twelve hours or so, rather than going to the trouble of uncovering the underlying cause of the tube failure.

Another prevalent attitude of "letting things slide" was evident in the condition of the maintenance records. In only a few instances was there indication of work being performed contrary to instructions.

In some cases there was considerable room for improvement in interdepartmental relations, particularly between the men who operate and the men who repair the equipment. This is evident in such behavior as failing to report equipment failure until the gear has gone out completely, holding back information which might help in repairing the gear, or in some way hindering the ET during his maintenance efforts. The coordination of operators and ETs on preventive maintenance is an important point in this context.

Difficulties which could be traced to the equipment itself, the way it was designed or laid out, were readily apparent. Some equipments were such that the men could not get at parts to test or replace them. Others were hard to take apart or to remove sections or parts. Still another major difficulty concerned inability to work with power on.

One set of information which was presented earlier in the report is relevant here. It (Table 31) ranked the most frequent contributors to excessive shutdown time. Electronics material officers ranked insufficient preventive maintenance as most frequent and inexperienced personnel next, with spare parts difficulties least frequent. Electronics technicians rated spare parts difficulties as most frequent, inexperienced personnel next, and poor coordination between departments as least frequent.

VII. CRITICAL REQUIREMENTS OF THE ELECTRONICS TECHNICIAN

Certain requirements of the electronics technician are highly critical to successful performance of the job. These requirements are viewed here in three ways. First, general abilities are discussed as they were observed through an abilities rating scale. Then other general characteristics, including interest and attitude factors, are discussed. Finally, these requirements are considered in job reference terms - with respect to on-the-job behavior.

A. Critical Requirements in Ability Reference Terms

In order to assess the ability requirements of the ET a scale was devised consisting of nineteen ability traits. The ability traits were each described in a single statement intended to give the central meaning of the ability. Judgments by the supervisory personnel (lead ETs and the EMOs) were made of the relative importance of these abilities to the ETs job performance. Each of the ability traits was rated in terms of the amount of ability required for successful mastery of the ET job. A five category scale was used in which at one extreme the A category stands for an exceptional amount of ability required, and, at the other extreme, the E category symbolizes very little of the ability required. The table below presents the abilities and the category of response which best describes each ability. The items are grouped into four gross classes according to the rating received, and the judgments of the lead ETs and the EMOs are presented together for comparison. The agreement between the two groups of judges is generally good; the ratings (with one exception) are either the same or in adjacent categories.

Table 39

The Rating of Selected Abilities on a Five Point Scale of Importance to the ET Job

	Ability	Group Making Rating ET	EMO
*5	Ability to recognize and define problems	B	A
6	Ability to show ingenuity	B	A,B
7	Ability to plan and anticipate problems	A	B
8	Ability to make sound decisions	A	B
16	Ability to accept personal responsibility	A	B
1	Ability to understand verbal materials	B	B
10	Ability to accurately read and record data	B	B,D
19	Ability to work effectively with others	B	B,C
17	Ability to accept organizational responsibility	A	C
2	Ability to learn and remember verbal materials	B	C
9	Ability to solve mechanical problems	C	B,C
18	Ability to maintain proficiency under emotional stress	B	C
3	Ability to make numerical computations	C	C
4	Ability to use mathematical reasoning	C	C
12	Ability to interpret spacial patterns	C	C
14	Ability to coordinate body movements	C	C
15	Ability to make accurate, quick, hand movements	C	C
11	Ability to interpret data from records and instruments	D	C
13	Ability to meet size and strength requirements	E	E

*These item numbers refer to the location of the item on the rating scale form. They are included for reference purposes only.

Key: A. An Exceptional Amount Required; B. Above Average But Not Exceptional Ability Required; C. About Average Ability is Needed; D. Somewhat Less Than Average Ability is Required; E. Very Little of This Particular Ability is Needed.

The abilities that group themselves at the upper end of the scale may be characterized as traits necessary in planning and decision making. It is interesting that the abilities here represent different stages of the planning process involved in problem solving. There is initial recognition and definition of the problem (5) which is necessary before the actual planning may be done and the anticipation of problems (7) which involves foresight that forms the basis for considering future action. The ability to make sound decisions (8) and the ability to show ingenuity (6) are the suitability aspects of planning in which the technician demonstrates that he not only can act in the face of a problem but can act efficiently and even ingeniously. The ability to accept personal responsibility (16) does not deal with the planning process, per se, but is an executive quality necessary for initiating and carrying through a plan or decision.

The next grouping of ability traits involving average and above average amounts of ability (B & C) seems to be of two kinds. Abilities numbered 1, 10, 2 and 9 deal with the comprehension of verbal and mechanical data. The other type of abilities, numbered 19, 17, and 18 deal with the man's effectiveness on an organizational level and on a personal level.

The job was rated as requiring only an average amount of mathematical or numerical operations and spatial pattern interpretations. This is also true of the rating of body and hand movements. Matters of physique and physical strength are rated uniformly low.

The traits were considered also in terms of their <u>relative</u> importance to the MTs job, comparing one with the others in importance. The lead MTs and the MMOs ranked all the traits for importance with the most important ranked as 1 and the least important as 19. The table below presents the median rankings of the 19 ability traits in order of importance.

Table 40

Ability Requirement Scale

Median Rank Values of Abilities Required for the Job of ET as Ranked by Electronics Technicians

Rank	Item	Median
1.	Ability to recognize and define problems	3.00
2.	Ability to maintain proficiency under emotional stress	4.17
3.	Ability to learn and remember verbal materials	4.50
4.	Ability to accept personal responsibility	5.75
5.	Ability to make sound decisions	5.83
6.	Ability to plan and anticipate problems	7.00
7.	Ability to accept organizational responsibility	7.50
8.5	Ability to understand verbal materials	8.00
8.5	Ability to show ingenuity	8.00
10.	Ability to work effectively with others	8.50
11.	Ability to solve mechanical problems	9.50
12.5	Ability to use mathematical reasoning	10.17
12.5	Ability to accurately read and record data	10.17
14.	Ability to make numerical computations	10.83
15.	Ability to coordinate body movements	12.50
16.	Ability to make accurate, quick, hand movements	13.50
17.	Ability to interpret spatial patterns	17.17
18.	Ability to interpret data from records and instruments	17.90
19.	Ability to meet size and strength requirements	18.63

Table 41

Ability Requirement Scale

Median Rank Values of Abilities Required for the Job of ET as Ranked by Electronics Materiel Officers

Rank	Item	Median
1.	Ability to recognize qnd define problems	1.40
2.	Ability to understand verbal materials	4.25
3.	Ability to make sound decisions	5.75
4.	Ability to learn and remember verbal materials	6.00
5.5	Ability to show ingenuity	6.75
5.5	Ability to accept personal responsibility	6.75
7.	Ability to plan and anticipate problems	8.25
8.5	Ability to solve mechanical problems	9.00
8.5	Ability to maintain proficiency under emotional stress	9.00
10.	Ability to accept organizational responsibility	9.25
11.	Ability to work effectively with others	11.00

Table 41
(continued)

Rank	Item	Median
13.	Ability to make numerical computations	13.00
13.	Ability to use mathematical reasoning	13.00
13.	Ability to make accurate, quick, hand movements	13.00
15.	Ability to accurately read and record data	14.75
16.	Ability to coordinate body movements	15.88
17.	Ability to interpret spatial patterns	16.00
18.	Ability to meet size and strength requirements	17.20
19.	Ability to interpret data from records and instruments	17.75

A comparison of the rankings made by the lead ETs and EMOs shows good agreement in the positions assigned the abilities in terms of relative importance. A few exceptions might be noted, however. "Ability to maintain proficiency under emotional stress" is ranked second by the ETs and about midway down the list by the EMOs. "The ability to understand verbal materials," is ranked second by the EMOs and about eighth by the ETs. For the rest of the abilities there are no great deviations in rank positions between the ETs and EMOs.

The rankings of the abilities indicate that relative importance is in line with the judgments on the amount of ability required. Those abilities concerned with problem recognition, planning and decision making, and assuming personal responsibilities are among the first; whereas abilities involving body size and coordination, hand movements, and interpreting spatial patterns are low on the lists.

What can be abstracted then from the information derived from the judgments made on the ability requirements scale? For one thing, those abilities emphasizing a general problem solving approach and decision making are required in greater amounts and are highest in relative importance. The abilities that may be required to perform the operations resulting from the problem-solving processes are usually lower on the scales of importance and amounts necessary.

B. Other General Job Requirements

There are numerous other sources of information on the general characteristics of successful ET behavior. Two of these are presented below—one based on direct observation of the men, the other on judgments by the men. Neither represents an attempt to remain in a single frame of reference such as abilities or job related skills. Instead they emphasize general consistencies of behavior such as motivation, attitude, and general work habits.

In an effort to determine the job requirements which could be based on first hand (direct) observation, the diaries were carefully scrutinized and a list assembled of the behavior uniformities which were noted with considerable frequency. Among the common elements running through the list is an emphasis on good work habits, thoroughness, carefulness, and the use of organized procedures for repair. It is also noticeable that items of planning, foresight, and sound decision making are important, causing these results to agree in general with those suggested by the ability ratings discussed in the last section. The list of behaviors follows.

1. Using systematic procedures in performing a task.
2. Seeing that a job is completed before leaving it.
3. Accepting and carrying out personal responsibility in seeing that a job is done.
4. Discerning the functional relationship between components.
5. Doing careful and precise work.
6. Relating a symbolic representation with the material system.
7. Realizing self-limitations.
8. Remembering and following instructions.

9. Foreseeing results of actions and making sound decisions.
10. Assigning qualified personnel to get a job done.
11. Supervising a job adequately.
12. Considering all possibilities in solving a problem.
13. Taking advantage of aids in performing the task.
14. Keeping up the necessary book work.
15. Making correct assumptions in performing a task.
16. Obtaining additional knowledge needed to complete the task.
17. Using cooperative or coordinated effort in making repair.
18. Using ingenious procedures in making repair.
19. Showing exceptional skill and ingenuity in performing task which is not required of the personnel.
20. Using basic knowledge and previous experience in solving a new problem.

Another source of information on these matters was obtained by asking select groups of people to rate each of nine characteristics in terms of its relative importance to the electronics technician. This rating is shown in Table 42. There is a great deal of consistency among the rating groups. All felt that a high interest in electronics is the most important characteristic. Next are initiative, being a hard worker, and a high GCT score. Lowest of all was the possession of above average stamina.

C. Critical Requirements in Job Reference Terms

A further source of critical requirements for the electronics technician's job is the specific behavior involved in performing the job. Several of the observational methods yielded statements of behaviors of ETs in the maintenance situation. These methods were the diary, repair record, critical incident interview, and the card sort. The data from these methods were examined, and statements of ET activities were abstracted.

All of the statements were examined and categorized in terms of the basic job requirements that might be involved. Eleven classes and thirty-six subclasses of job requirements were obtained from this categorization.

Table 42

Median Ranks of Some of the Characteristics Which an Electronics Technician Should Possess, Obtained From the Rankings Assigned By the Individuals of Each of a Number of Respondent Groups*

(General Questionnaire - Item 17)

Respondent Groups N	Desig.	Characteristics: High GCT Score	Above Avg. Physical Coordination	High Interest in Electronics	Above Avg. Physical Stamina	Ability to Withstand Monotony	Pleasant Person-ality	Takes Direction Well	Hard Worker	Initi-ative
71	ET	4.1	6.0	1.2	8.1	7.5	7.0	4.8	3.7	2.2
12	EMO	3.1	7.2	1.2	8.0	7.9	6.2	5.5	3.8	2.3
13	CIC	2.7	6.4	1.2	7.8	6.0	8.1	5.9	3.8	2.4
12	ASW	3.8	6.0	1.4	7.8	8.0	7.2	5.5	3.8	2.9
11	COMM.	2.0	6.8	1.3	8.0	6.0	8.2	5.9	3.8	3.2
13	OPER.	2.1	4.7	1.3	7.3	6.7	8.1	6.0	4.8	3.8
13	GUN.	3.0	6.0	1.2	7.7	7.2	8.7	5.2	4.2	2.3
11	ENG.	3.2	6.9	1.4	7.2	8.3	8.0	5.0	3.7	2.0
10	EXEC.	3.0	6.2	1.3	7.0	7.0	8.5	5.5	3.5	2.8

*Most important characteristic was ranked 1, least important was ranked 9.

The complex nature of the activities made it impossible to categorize them with no overlapping elements; therefore, the main differentiating characterisitic of each activity was used as a basis for categorizing it. The classes of requirements are given below along with the subclasses that were obtained.

I. Making simple discriminations

A. Discriminating by visual cues
B. Discriminating by tactile cues
C. Discriminating by kinesthetic cues

II. Making decisions

III. Systems tracing and making logical analyses

A. Tracing circuits or signals
B. Testing or checking circuits
C. Locating troubles by reasoning

IV. Using verbal and diagrammatic materials

A. Referring to information sources
B. Keeping records
C. Labeling circuitry

V. Making measurements

A. Using measuring instruments to determine circuit or component values
B. Using measuring instruments to determine continuity

VI. Making computations

VII. Devising and improving

A. Designing electrical circuits
B. Making ingenious emergency repairs

VIII. Performing simple manual operations

A. Moving buttons, switches, and knobs
B. Tightening and loosening bolts and screws
C. Cleaning
D. Lubricating
E. Stowing and arranging tools and spare parts
F. Shorting out components

IX. Performing discriminative manual operations

A. Making adjustments
B. Tapping, prodding, or jiggling components to locate trouble
C. Aligning equipment
D. Tuning
E. Operating gear

X. Performing skilled manual operations

A. Repairing
B. Manufacturing
C. Connecting parts
D. Assembling components and units
E. Making simple replacements
F. Making complex replacements
G. Removing components or units
H. Soldering electrical components

XI. Directing and assisting

A. Supervising
B. Instructing
C. Assisting

To more clearly define these job requirements, each of the major categories will be discussed in terms of the kinds of behavioral activities from which they were derived. Included in this discussion will be examples of the behavioral statements obtained.

Making simple discriminations. In trouble shooting, there are a number of checks that the repairman makes that involve mainly perception and simple discrimination of "is" or "is not." For example, in visually inspecting a tube, the ET may be interested in whether the tube is lighted or not. Instances were observed in which the ET made checks using the senses of sight, touch, and kinesthesis. Visual inspection was found to be the most frequent procedure in making these simple discriminations. This class includes such behavior activities as the following:

I. Discriminating by visual cues

A. Checks to make certain tubes are in sockets
B. Checks antenna for binding
C. Inspects tubes
D. Inspects for moisture
E. Inspects fuse indicator
F. Checks switches visually

II. Discriminating by tactile cues

A. Feels tube for warmth
B. Feels output transformer to see if warm

III. Discriminating by kinesthetic cues

A. Fingers external control for position
B. Feels wires for looseness

Making decisions. The trouble shooting procedure also requires the ET to make judgments as to the factors involved in a situation or the appropriate action to take. This job requirement can be inferred from many maintenance behaviors, but it stands out in a number of activity statements that were abstracted from the data. Some of the typical statements that represent this class are:

A. Doubts accuracy of tube tester
B. Decides set has too much output
C. Decides wattmeter is bad
D. Makes judgment that since windings are right, the voltages must be in phase.

Systems tracing and making logical analyses. This class is concerned with being systematic or following logical steps in the serial aspect of trouble shooting. It is not concerned with the individual activities that are involved in systems tracing. In order to locate a trouble it is frequently necessary to trace a signal through various stages of the gear or to check out a circuit by testing various test points. Therefore, it is important that the ET be able to follow an appropriate step by step procedure.

Some of the activities that are contained in this class are:

I. Tracing circuits or signals

A. Traces audio signal through audio amplifier
B. Traces wires to determine patch panel circuits
C. Traces circuit with vacuum tube voltmeter

II. Testing or checking circuits

A. Tests with selective analyzer at test points
B. Tests for shorts and open circuits
C. Makes systematic check of all stages

III. Locating troubles by reasoning

A. Locates poor solder connection by systematic analysis of the circuit
B. Locates noise source by process of elimination
C. Locates bad capacitor by logical deduction

Using verbal and diagrammatic materials. Included in this category are activities that are mainly verbal in nature. The use of reference materials such as instruction books and schematics are included here as well as written work such as keeping records. Referring to information sources is concerned with the reading and understanding of the verbal material and relating it to the situation involved. For example, in using a schematic the man studies it, obtains meaning from it, and determines the relationship between it and the equipment on which he is working. The using of verbal and diagrammatic materials refers to such activities as the following:

I. Referring to information sources

A. Reviews records for possible cause of failure
B. Follows instruction book to locate trouble
C. Uses schematic to adjust set
D. Obtains information from an operator on how gear broke down
E. Finds part needed for repair by consulting instruction book

II. Keeping records

A. Writes requisition for tender repairs
B. Prepares spare parts requisition

C. Prepares work orders
D. Records circuit change in instruction book
E. Fills out failure report

III. Labelling circuitry

A. Draws schematic
B. Identifies leads before removing them

Making measurements. The using of measuring instruments is an important part of trouble shooting. The instruments are used both for determining exact circuit or component values and for determining continuity. Included in this category are:

I. Using measuring instruments to determine circuit or component values

A. Measures resistance of resistor
B. Measures circuit voltages
C. Tests meter
D. Tests tubes with tube tester
E. Measures synchro voltage
F. Measures ring time
G. Measures oscillator output

II. Using measuring instruments to determine continuity

A. Checks a capacitor for short
B. Checks fuse continuity
C. Tests for an open coil
D. Tests switches and relays

Making computations. This class of job requirements refers to performing arithmetical computations. The ET activities categorized here are such things as:

A. Computes voltage requirements for a given circuit
B. Computes wave length for a given frequency
C. Calculates change in voltage divider network
D. Determines capacitor needed to eliminate DC component of voltage.

Devising and improvising. This category includes behaviors that are involved when an ET finds it necessary to design and build a circuit so that a repair can be made, or uses some other ingenious means for repairing the gear. Some typical activities are:

I. Designing electrical circuits

   A. Combines six transformers to replace one burned out transformer
   B. Devises rectifier circuit
   C. Designs bias supply
   D. Devises test instrument
   E. Devises squelch circuit

II. Making ingenious emergency repairs

   A. Substitutes tubes with different characteristics
   B. Substitutes repeater for inoperative console
   C. Rigs up temporary blower motor
   D. Makes emergency repair by bypassing the trouble
   E. Repairs burned out wiring with graphite

<u>Performing simple manual operations</u>. The behavioral activities that make up this category are those with the major characteristic of a physical manipulation of material by a simple movement or series of movements in which there is little control, coordination, and discrimination involved. The activities that were categorized here include such things as:

I. Moving buttons, switches, and knobs

   A. Presses operate button
   B. Switches selector switch
   C. Keys transmitter
   D. Rotates range crank

II. Tightening and loosening bolts and screws

   A. Unscrews covers
   B. Replaces set screw
   C. Tightens tube socket
   D. Places screws in cable mountings

III. Cleaning

   A. Cleans switch contacts
   B. Cleans exterior of equipment
   C. Cleans variable resistor with crocus cloth
   D. Cleans antenna insulators

IV. Lubricating

A. Lubricates bearings
B. Oils gears

V. Stowing and arranging tools and spare parts

A. Stows tools
B. Arranges spare parts

VI. Shorting out components

A. Shorts out high voltage capacitor
B. Uses shorting bar

Performing discriminative manual operations. The activities making up this category are those manual manipulations that involve a great deal of visual discrimination. Varying amounts of eye-hand coordination and physical control are involved but in general these factors are an important part of the activities. This job requirement consists of such activities as:

I. Making adjustments

A. Adjusts knob while observing effect on scope
B. Adjusts transmission line slugs
C. Balances power of amplifier stage
D. Adjusts local oscillator coupling
E. Adjusts sensitivity of range spot

II. Tapping, prodding, or juggling components to locate trouble

A. Jiggles set
B. Prods for loose connections
C. Taps tubes for loose elements

III. Aligning equipment

A. Aligns receiver
B. Aligns helipot tracking
C. Synchronizes PPI sweep

IV. Tuning

A. Tunes TDZ
B. Tunes receiver to eliminate distortion
C. Tunes director

V. Operating gear

A. Picks up target on set
B. Sets up desired frequency
C. Sets up tube tester

Performing skilled manual operations. This category is made up of a large number of different types of complex activities that demand a relatively high degree of skill but little discrimination. A fair amount of physical control and various kinds of coordination are necessary for these activities. The activities included in this category include such things as:

I. Repairing

A. Repairs modulation and keying circuit in microphone
B. Repairs motor generator
C. Repairs telescopic capacitor
D. Repairs cooling fans and lines

II. Manufacturing

A. Makes replacement shaft for potentiometer
B. Manufactures antenna clamp
C. Rewinds motor
D. Rewires high voltage unit

III. Connecting parts

A. Hooks up signal generator
B. Connects wattmeter to output
C. Makes connections on patch panel
D. Connects power cables

IV. Assembling components and units

A. Reassembles search switch
B. Disassembles crystal unit
C. Installs multi-jack plug

V. Making simple replacements

A. Replaces TR tube
B. Replaces meter front
C. Replaces fuse
D. Replaces rectifier tube

VI. Making complex replacements

A. Replaces magnetron
B. Replaces reduction gear
C. Replaces tuning capacitor
D. Replaces filter choke

VII. Removing components or units

A. Removes knob assembly
B. Removes transformer
C. Removes slip rings in focus coil
D. Removes wave guide

VIII. Soldering electrical components

A. Repairs poor wiring in patch panel
B. Solders rectifier in volt-ohmmeter
C. Resolders input cable

Directing and assisting. This job requirement category is made up of such activities as supervising corrective and preventive maintenance activities, instructing radar operators in maintenance, instructing personnel in safety precautions, instructing ETs in maintenance fine points, and assisting the repairman.

These job requirements are the titles used to represent the classes of behavioral statements that were placed in the same category. Of course, it is possible to make other categorizations of these statements by changing the frame of reference in which one is working. It is felt that the job requirements obtained and the behavioral statements that define them will be the most useful for the purposes that are usually intended for this type of information. These job requirements are not necessarily exhaustive for the job of electronics technician, for although an effort was made to obtain descriptive information on all aspects of the job, the main emphasis was on electronics maintenance.

The job requirements expressed in ability reference terms, that were discussed earlier, are independent of each other to a large degree. Such is not the case when requirements are expressed in job reference terms, since each job requirement represents a number of job activities, each of which has more than one behavioral characteristic. Although this difference between the two references exists, the job requirements obtained by the two references are in basic agreement throughout.

# # #

The electronics technician is a key man in the maintenance of the electronic equipment aboard ship. Comprehensive accounts of his job provide information to illuminate some of the chronic problems of maintenance. However, the problem of achieving and sustaining a maximum state of operational electronic readiness is not simply an ET matter. The next two reports of this series bring the observational information to bear upon two important factors which interact with the ET performance to produce the current situation. The next report (No. 5) contains descriptions of the maintenance aspects of related electronics jobs, and Report No. 6 deals with the influence of policy and shipboard organization upon the electronic maintenance situation.