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A PERSONNEL READINESS TRAINING PROGRAM: MAINTENANCE OF THE MISS--ETC(U)
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A PERSONNEL READINESS TRAINING PROGRAM:
MAINTENANCE OF THE BOMBERS TEST AND
READINESS EQUIPMENT (DTIC NS 7 400 2)

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A PERSONNEL READINESS TRAINING PROGRAM:
MAINTENANCE OF THE MISSILE TEST AND READINESS EQUIPMENT
(MTRE MK 7 MOD 2)

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Plant. In the present application, Missile Technicians from 12 Fleet Ballistic Missile submarines were given a diagnostic pretest and then retested approximately 5 months later. Four submarines were assigned to each of three experimental groups: (1) a Control Group in which the participants were given feedback on the pretest in terms of an overall percentage score, (2) a Feedback Group in which the members were given an outline indicating their specific weaknesses, and (3) a Feedback + Training Group in which the members were given the same type of information as the Feedback Group but, in addition, were assigned specific remedial training. Diagnostic testing was successful in detecting deficiencies of Fleet personnel on tasks related to the maintenance of MTRE. Neither feedback nor feedback plus training improved job performance. Partly because of the exceptional reliability of MTRE, the feedback and/or training were not considered essential to the job and, therefore, not used. Unfortunately, the exceptional reliability of MTRE results in little opportunity to practice maintenance skills, and this sets the stage for the deterioration of these skills.

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FOREWORD

This Advanced Development effort was conducted in support of Project Z0108-PN (ZPN07), Education and Training Development, under the sponsorship of the Chief of Naval Operations (OP-099). This is the third in a series of reports relating to Subproject Z0108-PN.24, Personnel Readiness Training. The first report, NPRDC Special Report 75-8, A Personnel Readiness Training Program: Initial Project Developments, provided an overview of the project. The second report, NPRDC Technical Report 77-4, A Personnel Readiness Training Program: Operation of the AN/BQR-20A, described the program for the submarine Sonar Technician. A subsequent report will describe the program for the Boiler Technician, and a final report will summarize findings and conclusions across all three applications.

The diagnostic tests and shipboard training materials for the Missile Technician program, which are described in this report, were developed under contract NU0123-74-C1579, awarded to Data Design Laboratories, Cucamonga, California.

Appreciation is expressed to the following:

- Commander Submarine Forces Atlantic and Commander Strategic Systems Project Office, Training Systems Branch, for cooperation and support in carrying out this research.
- Commander Submarine School, New London and Commander Fleet Ballistic Missile Submarine Training Center, Charleston for providing facilities and assistance in testing.
- Commanding Officers and Missile Technicians of the 12 submarines who participated in the testing program.

Special appreciation is expressed to the Officer in Charge of the Central Test Site for the Personnel and Training Evaluation Program, the Directors of the Central Test Site Detachments in New London and Charleston, and their respective staffs for outstanding assistance in scheduling submarine crews and collecting the data. Also, the valuable assistance of STCS(SS) John G. Myers and Hervey Stern in conducting Fleet testing is gratefully acknowledged.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

The Personnel Readiness Training Program is concerned with the feasibility of using a diagnostic testing/shipboard training system to improve the readiness levels of Fleet personnel. In such a system, performance-oriented tests are used to diagnose deficiencies in job performance and shipboard self-instructional materials are individually prescribed to correct deficiencies revealed by the diagnostic tests. To obtain information on how and where this type of system might work, testing and training programs were developed for three applications: (1) the submarine Sonar Technician (ST) operating the AN/BQR-20A, (2) the submarine Missile Technician (MT) maintaining the Missile Test and Readiness Equipment (MTRE Mk 7 Mod 2), and (3) the Boiler Technician (BT) operating and maintaining the 1200 PSI Steam Propulsion Plant.

Purpose

The purpose of the effort described in this report was to determine whether the testing and training programs developed for the MT application were instrumental in improving maintenance performance.

Approach

Missile Technicians from 12 Fleet Ballistic Missile (FBM) submarines were given diagnostic pretests and then retested approximately 5 months later. The tests covered MTRE troubleshooting, Standard Maintenance Procedures, and the operation of test equipments used in MTRE maintenance. Three experimental groups, each consisting of the MTs from four submarines, were used in the evaluation: a Control Group, a Diagnostic Feedback Group, and a Diagnostic Feedback + Training Group. Following the pretests, members of the Control Group were given feedback on their performance in terms of an overall percentage score. Members of the Feedback Group were provided with a list of their individual areas of weakness. Members of the Diagnostic Feedback + Training Group were provided with the same type of information as the Feedback Group, but they were also assigned specific remedial training materials that covered their individual weaknesses.

Findings

Diagnostic testing was successful in detecting deficiencies of Fleet personnel on tasks related to the maintenance of MTRE. Those MTs who had completed the MTRE Maintenance Course and/or appropriate test equipment course had fewer deficiencies. Neither feedback in the form of specific performance deficiencies nor feedback plus specifically assigned remedial training improved job performance. Apparently, one of the reasons the MTs showed deficiencies is that they do not get to practice maintenance skills because MTRE is exceptionally reliable. The reliability of MTRE may also be one of the reasons that the feedback and/or remedial training were not perceived as essential to the job. The following additional factors may have further contributed to the nonuse of the feedback and/or remedial training:

1. On a given patrol, only one MT has responsibility for MTRE and this assignment usually occurs only once during his tour on an FBM submarine.

2. The training packages for most MT's were relatively large and the individual lessons were relatively long.

Conclusions

There are serious deficiencies in tasks related to the maintenance of MTRE, but an MT will not be sufficiently motivated to study remedial training materials unless he is about to be given responsibility for MTRE. Appropriate formal courses and remedial training, if needed, should remedy the deficiencies.

Recommendations

To improve the proficiency level of the MT designated to have responsibility for operating and maintaining MTRE, it is recommended that:

1. If the designated MT has not already attended the MTRE maintenance and test equipment courses, he should attend these courses during the off-crew period immediately preceding the patrol on which he will assume MTRE responsibility.

2. If the designated MT has attended the MTRE maintenance and test equipment courses, he should be given the MTRE diagnostic test at the beginning of the off-crew period immediately preceding the patrol on which he will assume MTRE responsibility. He should then be assigned the appropriate remedial training packages and be retested at the completion of training.

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INTRODUCTION

Problem

The Personnel Readiness Training Program is concerned with the feasibility of using a diagnostic testing/shipboard training system to improve the readiness levels of Fleet personnel. In such a system, performance-oriented tests are used to diagnose deficiencies in job performance and shipboard self-instructional materials are individually prescribed to correct deficiencies revealed by the diagnostic tests.

Background

The degree to which critical job skills can be improved through a system of diagnostic testing and shipboard training may depend on the rating and/or the type of task involved. Therefore, to obtain information on how and where the system might work, testing and training programs were developed for three applications. The ratings and related equipments selected for the program evaluation were: (1) the submarine Sonar Technician (ST) operating the AN/BQR-20A, (2) the submarine Missile Technician (MT) maintaining the Missile Test and Readiness Equipment (MTRE Mk 7 Mod 2), and (3) the Boiler Technician (BT) operating and maintaining the 1200 PSI Steam Propulsion Plant. These ratings and equipments were chosen because they were critical to the missions of their ships and they contained a sufficient variety of operator and maintenance tasks to permit the results to be generalized to other areas. Additionally, there were indications that performance deficiencies might be present in these areas.

The first report in this series (Laabs, Main, Abrams, & Steinemann, Note 1) described the general approach and how it was being applied in the three areas. The second report (Winchell, Panell, & Pickering, 1976) described the Personnel Readiness Training Program for the ST. A subsequent report will describe the program for the BT; a final report will summarize findings and conclusions across all three applications.

Purpose and Scope

MTRE is used onboard Fleet Ballistic Missile (FBM) submarines to perform functional tests on POSEIDON missiles and to verify their operational readiness for launch. This piece of equipment requires a single operator who, in practice, is the equipment's sole maintainer. The responsibility for the maintenance of MTRE, which is assigned to a designated MT for each patrol, carries along with it a unique problem because of the equipment's exceptional reliability. Since MTRE operates without failure for extended periods of time, MTs have little opportunity to practice maintenance skills. Consequently, their MTRE maintenance proficiency can be expected to decline.

The purpose of the present effort was to determine whether the testing and training programs developed for the MT were instrumental in improving performance on tasks related to the maintenance of MTRE Mk 7 Mod 2.

Not all of the knowledges and skills required to maintain MTRE could be tested within acceptable time limits. Therefore, a selection from critical tasks was made, and the scope of the program was limited to a reasonable number of problems related to MTRE troubleshooting, Standard Maintenance Procedures, and the operation of test equipment used in MTRE maintenance. Testing was accomplished in shore-

based training facilities with the actual equipment during FBM submarine off-crew periods. All MTs are currently tested by the FBM Personnel and Training Evaluation Program (PTEP) with paper-and-pencil tests during each off-crew period. The performance testing of the present program was integrated with this existing evaluation system.

METHOD

The diagnostic tests and training materials were developed under contract by Data Design Laboratories, Cucamonga, California. The contract effort consisted of the following four phases:¹

- Phase I. Survey of knowledges and skills required by the MT who maintains MTRE, and selection of critical tasks to be covered by a performance-oriented diagnostic test.
- Phase II. Development of a performance-oriented diagnostic test to provide information on distinct and separate areas of potential deficiency.
- Phase III. Review of recent developments in education and training, and the identification of instructional formats suitable for shipboard training.
- Phase IV. Development of shipboard-training packages that correspond to the areas of potential deficiency.

Task Selection

Personnel Performance Profiles (PPPs), which are contained in Navy Ordinance documents, were used as a guide for task selection. These profiles are tables that list the knowledges and skills required to operate and maintain a subsystem or piece of equipment of the FBM Weapon System. In effect, each table is a very general task analysis. The table that contains the PPPs related to MTRE maintenance (Note 2, Table 310) is quite extensive, and time constraints made it impossible to test all items with hands-on performance tests. Therefore, Trouble and Failure Reports were examined to find areas suitable for the development of hands-on performance tests. From an analysis of equipment failures, nine critical malfunctions were identified. Maintenance procedures were selected that would either lead to the discovery of the malfunctions or be used in the correction of the malfunctions. The maintenance skill and knowledge PPP items that are required to complete these procedures were then listed and used in constructing a performance test. Since a performance test covering all nine malfunctions would require approximately 10 hours, only three malfunctions were used as the basis for developing a 1½-hour preventive maintenance test. Two of the remaining malfunctions were used as the basis for developing a 1½-hour hands-on troubleshooting test. One of these two malfunctions and the four remaining ones were used as the basis for developing five written troubleshooting problems. The time needed to complete these problems ranged from about 20 to 90 minutes.

To minimize the demand on MTRE equipment, test equipment performance testing was divorced from the MTRE test situation. Instead, separate problems using electronic signals from a specially designed Test-Signal Generator were devised for the three pieces of test equipment. The technical manuals for the test equipment were used as the basis for developing a 1-hour Test Equipment Test. The separation of test equipment use from other aspects of MTRE maintenance performance

¹Requests for information concerning the informal reports for Phase I and III and the end-products for Phase II and IV of the Data Design Laboratory contract should be addressed to the senior author of the present report.

resulted in a test equipment testing-and-training program that could be used with other technical ratings. In addition, by separating test equipment performance from MTRE maintenance tasks, potential confounding of the MTRE test situation due to the inability of MTs to operate the test equipment was eliminated.

Diagnostic Tests

MTRE Preventive Maintenance Test

This test consisted of three problems. The observer's checksheet for each problem listed observable performance steps that replicated steps in a Standard Maintenance Procedure or a step-by-step procedural guide in a maintenance manual. The first problem involved a tape fault and required the completion of 27 performance steps involving tape splicing and canister reloading. The second problem required the MT to complete 19 performance steps of the Digital Multimeter Electrical Adjustment Check. The third problem involved a potentiometer which was out-of-tolerance and required the completion of 20 performance steps of the Tape Reader Electrical Check and Adjustment Procedure. Each performance step was marked as either correct or incorrect. The MT was supplied with all documentation, tools, and test equipments necessary to solve the problem. Prior to each test session, the test equipments were calibrated and completely set-up by the observer.

MTRE Corrective Maintenance Test

This test consisted of two troubleshooting problems on MTRE. It was administered in place of the preventive maintenance problem to the one MT on each submarine who had primary responsibility for the operation and maintenance of MTRE on his submarine's last patrol. One test problem used a prefaulted module and was assessed as being moderately difficult; the other involved the misadjustment of a potentiometer on an amplifier card and was assessed as being very difficult. The observer's checksheet for these problems provided for (1) a count of the number of measurements made while troubleshooting along with an indication of whether or not the fault had been corrected and (2) the observation of a limited number of performance steps that replicated those in the preventive maintenance problems. The former was used along with the results of a simulated troubleshooting test to assign remedial instruction related to corrective maintenance. The latter was used to assign remedial instruction relative to preventive maintenance.

Decision Measurement System (DMS) Test

This simulated troubleshooting test was comprised of five problems designed to measure the ability of the MT to logically apply his knowledge of equipment maintenance. This test is related to the early "Trainer-Tester" devices developed by Van Valkenburgh, Nooger, and Neville, Inc. (e.g., Notes 3 and 4). For a given set of conditions, the "Trainer-Tester" allows free exploration of test points, pins, contacts, terminals of modules, relays, etc. Thus, multiple-path solutions exist when using this device. In the DMS Test, however, only four selections are allowed for each major step in a single-path troubleshooting sequence. The DMS Test sheets use latent image (invisible ink) printing, which refers to the next step only when a correct selection is made. The MT continues to make selections until the correct one is made. Performance on a problem was scored according to the normal PTEP scoring procedure in which nine points are assigned

for making the correct selection in one try, eight points for making it in two tries, six points for making it in three tries, and zero points for making it on the fourth try.

Test Equipment Test

This test consisted of eight problems on three different pieces of test equipment. The specially designed Test-Signal Generator was used to provide the electronic signals for the test problems. Three problems on the AN/USM-281A oscilloscope involved initial turn-on procedures and calibrations, periodic signal analysis, and two-signal phase analysis. Three problems involved the use of the John Fluke 803D/AG differential voltmeter to measure negative DC voltage, AC voltage, and, as a conventional vacuum tube voltmeter, DC voltage. Two problems involved the measurement of ripple voltage and negative DC voltage using the Simpson volt-ohm-microammeter, Model 269, Series 11. The observer's checksheet for each problem was divided into the four main areas of (1) initial procedures, (2) control settings, (3) problem solution, and (4) safety. Relevant switches were listed under the first two areas so that their positions could be checked-off. Each of the main areas was scored with a zero, one, or two, according to the criteria shown in Table 1. In general, a zero, one, or two was assigned for inadequate, weak, and strong performance, respectively.

Remedial Shipboard Training Materials

To develop training corresponding to areas of potential deficiencies, the PPPs covered by all of the tests were grouped and matched to lesson objectives so that each PPP item was included in at least one lesson. The PPP skill items pertaining to the operation of MTRE and use of test equipment tended to be very general. Therefore, the lessons associated with the MTRE Preventive Maintenance Test and the Test Equipment Test were organized around the test problems. The assignment of a lesson was based on noncompletion of performance steps and inadequate or weak performance. On the other hand, the PPP knowledge items addressed by the DMS problems tended to be more detailed. Therefore, the lessons associated with this test were defined primarily in terms of the PPP groupings and the assignment of a lesson, which was based on wrong test answers, cut across several different problems.

The training materials were developed in accordance with Navy Ordinance documents concerned with developing and preparing FBM Weapon System curricula (Note 5). The primary type of material was the trainee guide in the form of four self-study workbooks. Some reading materials were provided in the workbooks, but, in other cases, reading materials were assigned in various technical manuals. Training aids in the form of practice troubleshooting exercises, audiovisual material, and a test-signal generator supplemented the self-study materials.

Review of Safety Precautions

This self-study workbook was a short, programmed instruction booklet designed to provide a review of general personal and equipment safety precautions. It was assigned as remedial instruction if any safety violation was observed (e.g., failure to remove jewelry or watches before working on energized equipment) during the Test Equipment Test or the MTRE performance tests.

Table 1

Performance Scoring Guide for the Test Equipment Test

Check Sheet Scoring Areas	Point Requirements		
	0	1	2
Initial Procedures	Assembled < 80% of equipment OR Preset < 80% of controls OR Set < 80% of controls after power turn-on OR Required exten- sive assistance	Assembled 80% of equipment AND Preset 80% of controls AND Set > 80% of controls after power turn-on AND Minor or no assistance	Assembled all equipment AND Preset all controls AND Set all controls after power turn-on AND No assistance
Control Settings	More than one error OR Extensive assistance	One error OR Minor assistance	No errors AND No assistance
Problem Solution	> ± 10% error OR Extensive assistance (some prompting)	≤ ± 10% error OR Minor assistance (one prompt)	≤ ± 1% error AND No assistance
Safety	More than one violation	One violation	No violations

Troubleshooting MTRE Faults

This self-study workbook followed the typical format of a trainee's guide; that is, each lesson consisted of an assignment sheet containing study assignments in a technical manual and a job sheet containing self-test exercises. The workbook consisted of seven lessons. In addition to the usual study assignments and self-test items, three of the lessons in the workbook required the MT to complete a set of written troubleshooting problems. A specific lesson was assigned if questions across different DMS problems relating to the lesson were answered incorrectly. The cut-off score or criterion for assigning each lesson was arbitrarily set at 70 percent of the set of questions involved. In addition, one of the lessons was assigned if one of the steps (i.e., evaluation of malfunction) in the MTRE Corrective Maintenance Test exceeded a 10-minute time limit.

MTRE Maintenance Procedures

This self-study workbook also followed the typical format of a trainee's guide. However, in addition to the usual study assignments and self-test items, each lesson included an exercise that required the MT to view an audiovisual module and to complete a physical task using MTRE. The workbook consisted of eight lessons keyed to different parts of the MTRE Preventive and Corrective Maintenance Tests. A lesson was assigned if any of the performance steps keyed to that lesson were done incorrectly.

Test Equipment Measurements

This self-study workbook contained all of the instructional materials needed to complete 18 lessons covering three different pieces of test equipment: the oscilloscope, the differential voltmeter, and the volt-ohm-microammeter. Three of the 18 lessons were introductions to each of the three pieces of test equipment. The remaining procedural lessons were keyed to calibrations or measurements covered in the test equipment test. One of the procedural lessons was assigned if an MT's performance was either weak or inadequate on the problem to which it was keyed. If any procedural lesson on a piece of equipment was assigned as remedial instruction, the associated introductory lesson was also assigned.

Experimental Design

The experimental design shown in Table 2 was used to evaluate the MT application of the Personnel Readiness Training Program. As depicted in the design, three experimental groups, each consisting of four submarine MT crews, were used in the evaluation: a Control Group, a Diagnostic Feedback Group, and a Diagnostic Feedback + Training Group. The MT crews were randomly assigned to one of the groups. Members of all three groups were given diagnostic tests and then were retested approximately 5 months later using the same tests. What happened to the individuals during the interim depended upon the group to which they were assigned.

Control Group

Following the pretest, members of this group were given feedback on their test performance in terms of an overall percentage score. For example, an MT was told that his scores were 65 percent for the MTRE Preventive Maintenance Test, 68 percent for the DMSs Test, and 56 percent for the Test Equipment Test.

Table 2

Experimental Design Used in the MT Application of the
Personnel Readiness Training Program

Group	Experimental Conditions		
Control	Pretest with non-specific feedback	Patrol	Posttest
Diagnostic Feedback	Pretest with specific feedback on weaknesses	Patrol	Posttest
Diagnostic Feedback + Training	Pretest with specific feedback on weaknesses and remedial training assigned	Patrol Special Training Packages Onboard	Posttest

Members of this group were not provided with any information concerning their specific deficiencies, but they were not given suggestions or directions as to how their deficiencies might be corrected.

Diagnostic Feedback Group

Following the pretest, members of this group were provided with an outline indicating their individual weaknesses. For example, if an MT missed any of the performance steps related to reloading the tape cannister, he was informed he was weak in that area. Likewise, if an MT could not determine phase difference using an oscilloscope, he was informed he was weak in that area. As with the Control Group, members of this group were not provided with any information as to how their deficiencies might be corrected.

Diagnostic Feedback + Training Group

Following the pretest, members of this group were given the same type of feedback as was given to those in the Diagnostic Feedback Group; that is, a list of individual weaknesses. In addition, they were assigned specific remedial training materials covering their individual weaknesses. For example, if the test results for an MT indicated that he was deficient in loading the tape canister and measuring frequency with an oscilloscope, he was assigned the self-instructional lessons that covered those areas. Members of this group were asked to complete their assigned training at times convenient for them during their subsequent patrol. Each MT was also supplied with a Progress Checklist, which was to be initialed by his supervisor when a lesson was completed. These Progress Checklists were similar to those that accompany the self-study workbooks available on a request basis from PTEP. A master list of training materials assigned to each MT was provided to the Training Officer, or the Leading Petty Officer, for the purposes of monitoring training and maintaining a record as each MT completed his assigned materials. A meeting was held with representatives of each crew assigned to this group, during which the experimental program was explained and the use of the training materials to supplement ongoing shipboard training was

encouraged. Just how and when the training was to be accomplished, however, was left up to the individual submarines.

Sample

Missile Technicians from 12 Atlantic Fleet FBM submarines participated in the program evaluation. Although four submarines were assigned to each group, the size of the MT crew varied from submarine to submarine. Therefore, the group sizes varied. A total of 77 MTs participated in the pretesting; 30 MTs were assigned to the Control Group; 24, to the Diagnostic Feedback Group; and 23, to the Diagnostic Feedback + Training Group. Fourteen MTs were unavailable for the posttesting due to discharge, transfer, or leave, thereby reducing the Control Group to 26; the Diagnostic Feedback Group, to 18; and the Diagnostic Feedback + Training Group, to 19. The distribution of pay grades and the percentage of the total sample each represents are shown in Table 3.

Table 3

Percentage Distribution of Pay Grades in the Experimental Groups

Pay Grades	Diagnostic Feedback + Training Group (N = 19)	Diagnostic Feedback Group (N = 18)	Control Group (N = 26)	Total Sample (N = 63)
E-4	53	28	35	38
E-5	37	56	46	46
E-6	10	5	8	8
E-7/E-8	0	11	11	8

Procedures

Fleet testing was conducted by the staffs of the Personnel and Training Evaluation Program (PTEP) Central Test Site Detachments located at Charleston and New London. The PTEP team members were trained as test proctors by members of the research staff during pilot evaluation of the tests. The specially developed MTRE performance tests, the test equipment test, and the DMS test were administered in place of the usual testing carried out by PTEP. The time to carry out PTEP testing was increased from 1 to 2 days because individually administered performance tests require more time than the group written tests normally administered by PTEP.

A testing schedule for each MT was arranged at the start of the 2-day testing period. The testing usually started out with a group administration of three DMS problems followed by the hands-on performance tests. Only those MTs who

had responsibility for MTRE operation and maintenance on their last patrol were given the MTRE Corrective Maintenance Test. The remaining MTs were given the MTRE Preventive Maintenance Test. All MTs were given the Test Equipment Test. Each MT was told that the testing program was experimental in nature and would take the place of the usual PTEP testing.

The MTs were not informed that there were three different groups involved in the experimental program. They were told, however, that everyone would be retested following their next patrol. At posttest, the MTs completed a short biographical questionnaire. The MTRE performance tests and the test equipment test administered at posttest were the same as those administered at pretest. Of the three DMS problems administered at posttest, one was exactly the same as that administered at pretest so that a rough estimate of reliability could be obtained. The other two problems were different to eliminate the possibility of remembering the problem solution, which is always provided by the nature of the test. All of the PPP items covered in the DMS pretest problems were covered in the posttest problems, and the total number of questions was the same at pretest and posttest.

RESULTS

MTRE Performance Tests

Objectivity, Reliability, and Validity

It is important that a performance test yield similar results when used by different raters. Consequently, during the pretesting of 27 MTs, the objectivity of the MTRE performance tests was evaluated by using two raters from the research staff individually paired with PTEP raters. A total of 79 problems was observed and separately recorded by the different pairs of raters. Those steps that an MT did not attempt to complete were not included in the evaluation since this would have resulted in an inflated amount of agreement between raters. For the 25 MTs observed on the three preventive maintenance problems, the percentage of agreement between the different pairs of raters was 92, 99, and 94 percent for the tape fault, digital multimeter, and tape reader problems, respectively. Only 2 of the 27 MTs were given the corrective maintenance test, and there was 96 percent agreement on the diagnostic steps observed in these problems.

When test performance is related to whether or not a cut-off score is met, it is classified as a criterion-referenced test, and most standard measures of reliability and validity cannot be used (Popham & Husek, 1969). In the present program, where the purpose is to diagnose deficiencies and assign training to remedy those deficiencies, test reliability can be viewed in terms of the consistency of the diagnostic decisions that would be made at two different points in time. In this program, the Control Group received no special treatment (i.e., no specific feedback and/or training materials). Thus, although up to 5 months passed between pretesting and posttesting, this group provided data to estimate test-retest reliability. For the three preventive maintenance problems, there was agreement in diagnostic decisions from pretest to posttest of 83 percent for the tape fault problem, 74 percent for the digital multimeter problem, and 74 percent for the tape reader problem. For the two corrective maintenance problems, there was 75 percent agreement.

The MTRE performance tests have high face validity because the MTs have to operate MTRE. The purpose of the MTRE performance tests was to determine if preventive maintenance procedures and basic troubleshooting techniques could be performed properly. The tests have high content validity since the performance steps are replicates of procedural steps found in maintenance documents for this equipment.

Preventive Maintenance

For the three preventive maintenance problems, all groups performed poorly on the pretest and all improved on the posttest. However, there was little difference between the groups. This is shown in Figures 1, 2, and 3, in terms of the percent of performance steps completed. Analyses of variance with repeated measures on the pretest/posttest variable indicated that the average improvement of 19 percent on the tape splicing and reloading procedure, 10 percent on the Digital Multimeter Electrical Adjustment Check, and 15 percent on the Tape Reader Electrical Adjustment Check were statistically significant ($F(1, 51) = 25.36, p < .01$; $F(1, 47) = 17.64, p < .01$; $F(1, 49) = 19.34, p < .01$; respectively).

No other effects were found to be significant in these analyses. An additional set of analyses was performed to see if the average improvement from pretest to posttest was due to those MTs in the sample who did not attempt one or more of the problems at pretest but did try the same problem, or problems, at posttest. Removal of these individuals did not change the results.

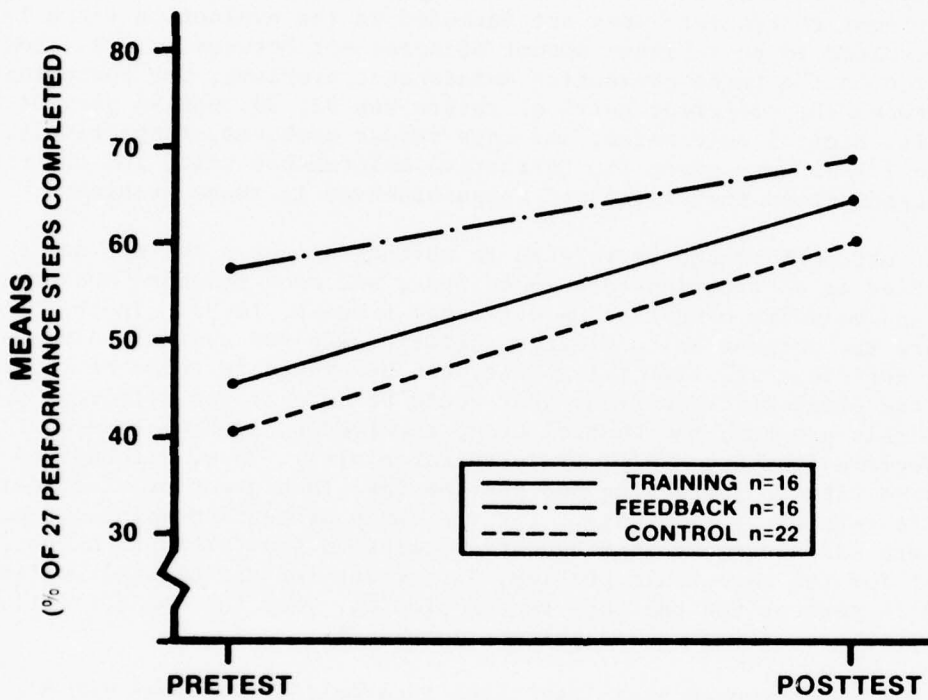


Figure 1. Performance on Tape Splicing/Canister Reloading Procedure.

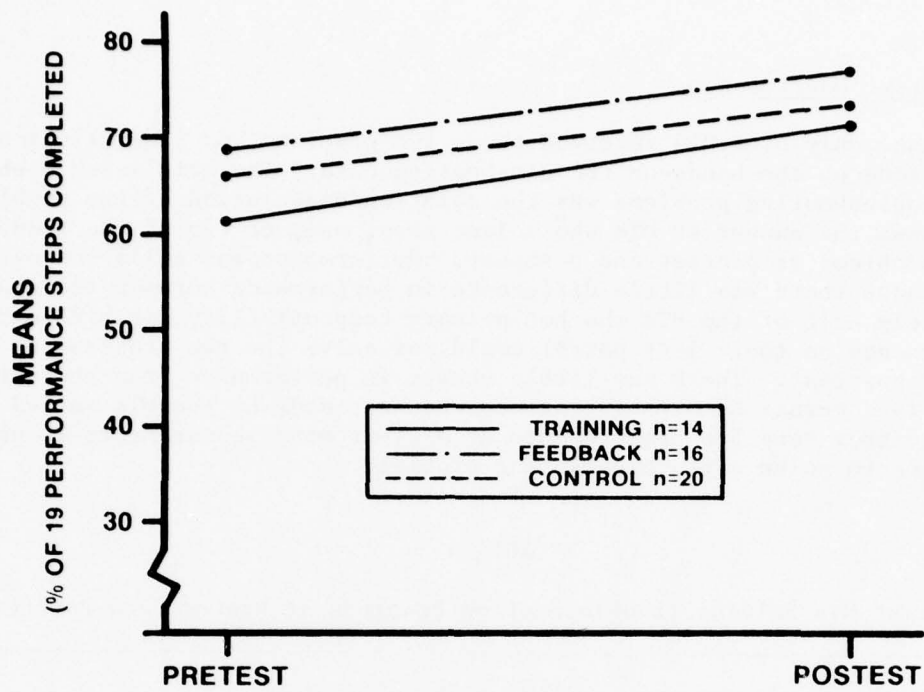


Figure 2. Performance on Digital Multimeter Electrical Adjustment Check.

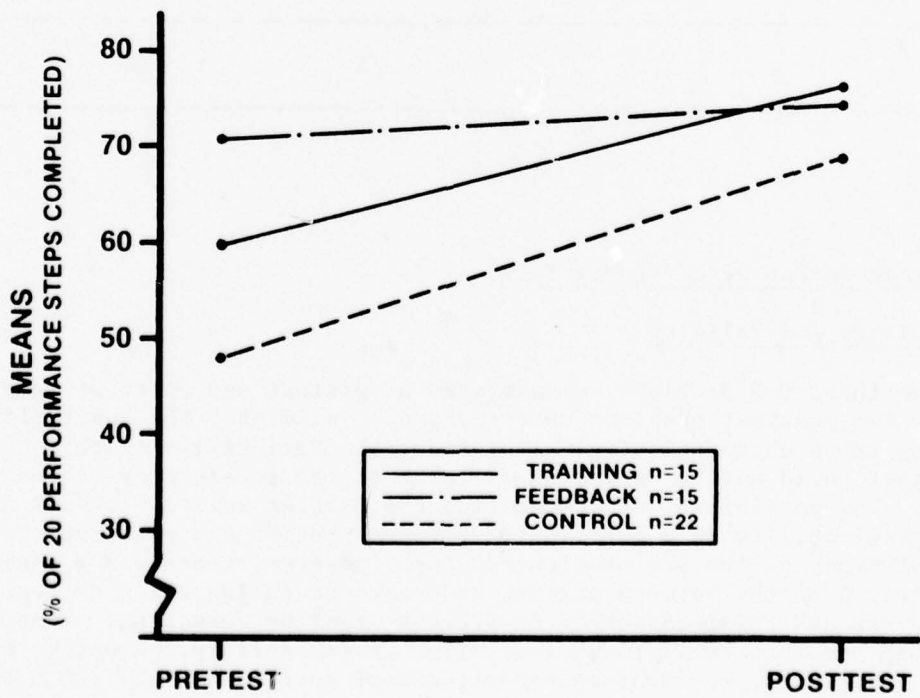


Figure 3. Performance on Tape Reader Electrical Check and Adjustment.

Corrective Maintenance

Since only nine MTs received these two problems, no statistical analyses were performed on the hands-on troubleshooting data. The main measure obtained in the troubleshooting problems was the solution/nonsolution of the problem. Table 4 shows the number of MTs who solved zero, one, or two of the troubleshooting problems at pretest and posttest. Performance was collapsed over groups because there was little difference in performance between the groups. Approximately half of the MTs who had primary responsibility for MTRE operation and maintenance on their last patrol could not solve the two problems at either pretest or posttest. There was little change in performance from pretest to posttest. The average number of test measurements made by the MTs varied greatly. They made either very few measurements or a great many measurements in unsuccessful attempts to solve a troubleshooting problem.

Table 4

Number of MTs Solving Troubleshooting Problems at Pretest and Posttest

Condition	Problems Solved		
	None	One	Two
Pretest	4	3	2
Posttest	5	1	3

Decision Measurement System (DMS) Test

Reliability and Validity

The three DMS problems administered at pretest and posttest were not all the same: two posttest problems were changed to eliminate the possibility of remembering the problem solution. Therefore, the reliability of this troubleshooting test could not be estimated in terms of the consistency of the diagnostic decisions. The possibility of remembering the problem solution argues against estimating reliability as a correlation between pretest and posttest scores for the Control Group on the one problem repeated; however, there was a period of approximately 5 months between pretest and posttest during which correct selections discovered through trial-and-error at pretest might be forgotten. Thus, a correlation may provide a very rough indication of reliability. Keeping the above reservations in mind, the Pearson product-moment correlation was .40 between pretest and posttest scores on the one repeated problem.

The validity of the DMS test is based on the fact that the paper-and-pencil problems were developed by inserting faults in MTRE, following accepted troubleshooting procedures to isolate the faults, and noting the conditions at each major step throughout the troubleshooting procedure. The extensive use of display pictorials, machine printouts, and waveform photographs gave the MTRE troubleshooting problems both high face and content validity. It should be noted, however, that performance on the paper-and-pencil DMS problems has not been compared with hands-on performance on MTRE. Therefore, the relationship between simulated troubleshooting performance and actual troubleshooting is not known.

Troubleshooting Problems

There were no significant effects found for any of the variables when the total DMS score over all three problems was analyzed. Table 5 shows that there was little change from pretest to posttest and no differences between the three groups in terms of the total points attained over the three problems.

Table 5

Mean Total Points Attained on the Three DMS Problems
at Pretest and Posttest for Three Groups

Condition	Groups		
	Diagnostic Feedback + Training Group	Diagnostic Feedback Group	Control Group
Pretest	201	207	195
Posttest	198	210	204

Note.--Maximum score = 252.

Test Equipment Test

Objectivity, Reliability, and Validity

Objectivity of the Test Equipment Test was evaluated in the same way as the MTRE performance tests; that is, two raters from the research staff were individually paired with PTEP raters during the pretesting of 20 MTs. A total of 160 problems were observed and separately recorded by the different pairs of raters. If, in any of the three scoring areas (e.g., initial procedures, control settings, or problem solution), an MT did not attempt to complete the steps, that area was not included in the evaluation since this would have resulted in an inflated amount of agreement between raters. The area of safety was included in the evaluation only if one or more of the other three scoring areas were attempted. For the three problems using the oscilloscope, there was 81 percent

agreement between raters; for the three problems using the differential voltmeter, 81 percent agreement; for the two problems using the volt-ohm-microammeter, 67 percent agreement.

Using the same procedure followed with the MTRE Preventive Maintenance Test, the reliability of the Test Equipment Test was estimated in terms of the consistency of the diagnostic decisions. For the oscilloscope, there was 81 percent agreement in the diagnostic decisions from pretest to posttest; for the differential voltmeter, 60 percent agreement; for the volt-ohm-microammeter, 77 percent agreement. For observing safety precautions over all test equipment problems, there was 96 percent agreement in the diagnostic decisions from pretest to posttest.

The Test Equipment Test has high face validity because, during the test, the MTs have to make calibration adjustments and measurements using the equipments in the same manner as on the job. The test has high content validity since the steps covered by the scoring areas are taken from the equipment technical manuals. The validity of the individual problems was further assured by having several experienced MTs at the two MTRE equipment facilities "walk through" the test problems. (One of the original oscilloscope problems was eliminated after this test tryout when it was found that MTs do not usually make the measurement it required.)

Test Equipment Use

For all test equipments, all groups performed poorly on the pretest, and all improved on the posttest. Thus, there was little difference between the groups. This is shown in Figures 4, 5, and 6, in terms of the percent of possible points that could have been attained over the scoring areas of initial procedures, control settings, and problem solution. Analyses of variance with repeated measures on the pretest/posttest variable indicated that the average improvement of 11 percent on the oscilloscope, 19 percent on the differential voltmeter, and 16 percent on the volt-ohm-microammeter, were statistically significant ($F(1, 60) = 12.48, p < .01$; $F(1, 60) = 19.22, p < .01$; $F(1, 60) = 17.83, p < .01$; respectively). The average improvement of 15 percent on observing safety precautions over all problems was also statistically significant ($F(1, 60) = 17.83, p < .01$). No other effects were found to be significant in any of these analyses. As with the MTRE performance tests, an additional set of analyses was performed to see if the average improvement from pretest to posttest was due to those MTs in the sample who did not attempt one or more of the problems at pretest but did try the same problem, or problems, at posttest. Removal of these individuals did not change the results.

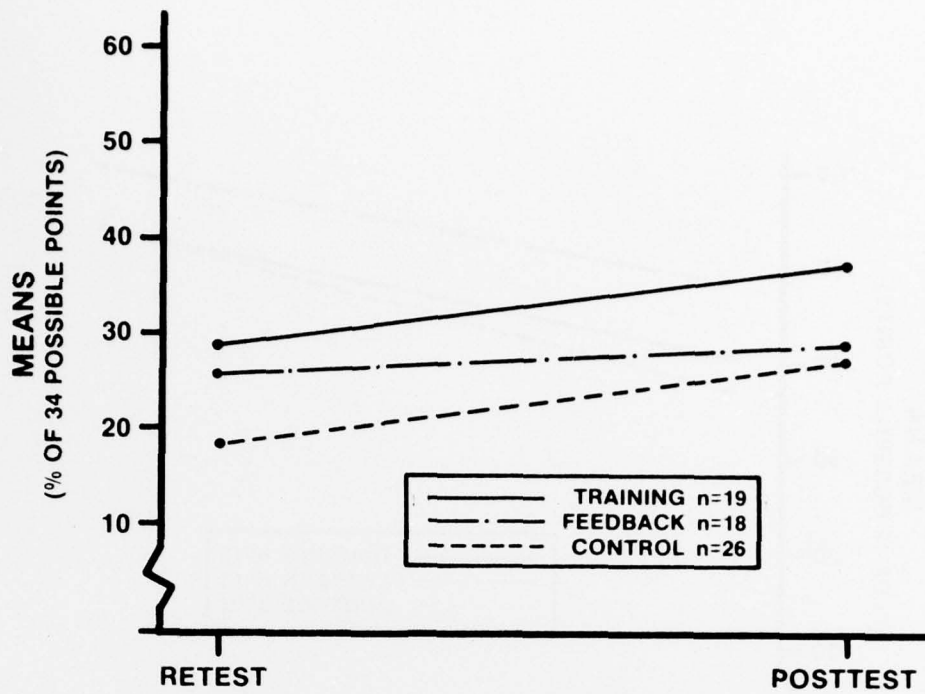


Figure 4. Performance Using the AN/USM-281A Oscilloscope.

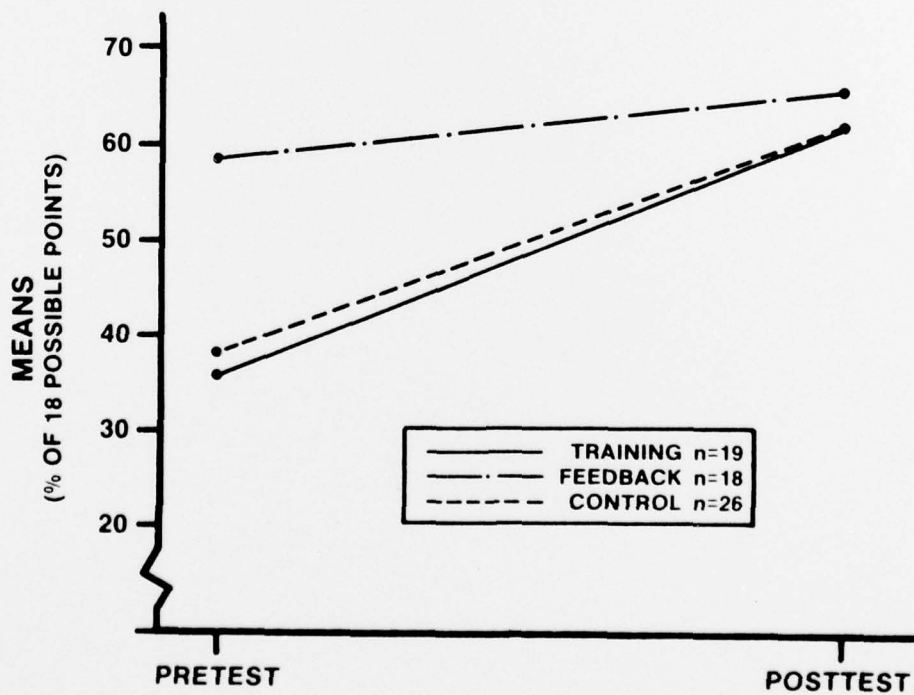


Figure 5. Performance Using the John Fluke 803D/AC Differential Voltmeter.

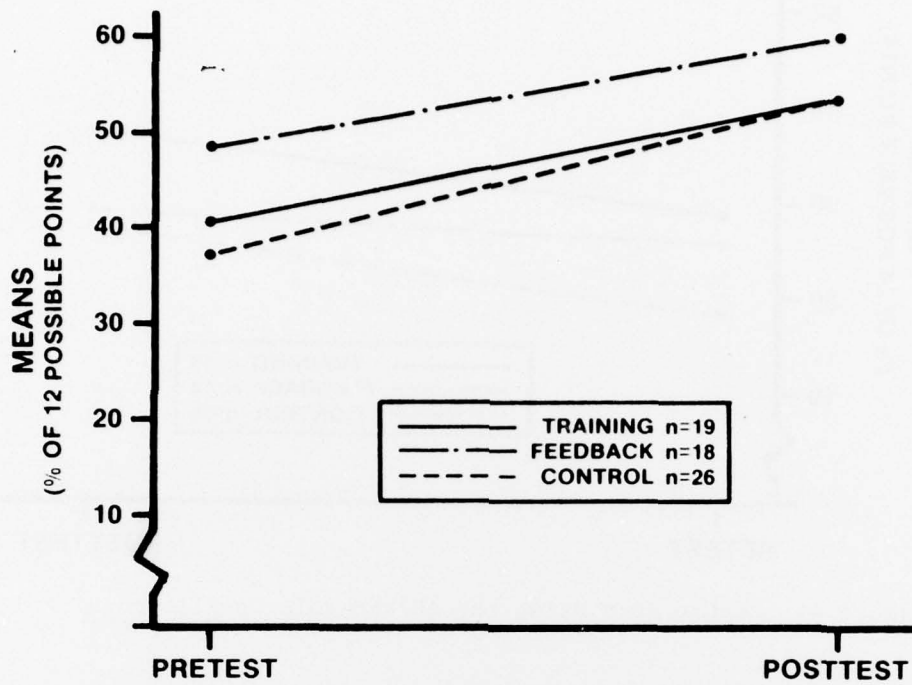


Figure 6. Performance Using the Simpson Model 269, Series II, Volt-ohm-Microammeter.

DISCUSSION

Performance Deficiencies

The pretest results showed that there were serious deficiencies in tasks related to the maintenance of the MTRE. In fact, the initial performance levels were so low that almost all MTs were assigned the entire remedial training package. Prior to testing, it had been anticipated that a considerable number of MTs would require little or no remedial training. On preventive maintenance tasks, the overall percentage of steps completed correctly was only 57 percent (Figures 1, 2, and 3). This level of performance is especially low when it is considered that the appropriate maintenance documentation was in the hands of the MT during testing. An examination of the effect of previous school experience on the performance of these tasks revealed that a significantly greater percentage of steps were completed (80 percent) by the 19 MTs who had attended the MTRE Maintenance Course than by the 35 MTs who had not (48 percent) ($t(52) = 3.76, p < .01$). The largest contribution to the poor performance of the MTs without MTRE classroom experience was made by newly rated MTs, several of whom could not even find the applicable procedures in the documentation available during the testing. Perfect performance was a rare event, even among those who had classroom training on MTRE. It should be noted that the time between completion of the MTRE Maintenance Course and testing ranged from 4 to 29 months. The maintenance skills of the MTs given the MTRE Preventive Maintenance Test might be expected to decrease during this period because they had not had recent responsibility for MTRE and, therefore, had no opportunity to practice these skills.

As indicated previously, the few MTs who had responsibility for MTRE on the patrol previous to the testing were given the MTRE Corrective Maintenance Test. Their troubleshooting performance showed serious deficiencies. Performance on the troubleshooting problem of medium difficulty is of most interest because it uses a prefaulted module and is very similar to the problems given to students in the MTRE Maintenance Course. Four out of the nine MTs who had responsibility for MTRE on their last patrol could not solve this problem at pretest. Surprisingly, three of these nine MTs had not attended the MTRE Maintenance Course. Yet, one of these three MTs was able to solve the problem at pretest, while three out of six MTs who had attended the course could not solve the problem. This seems to suggest that classroom training on MTRE may not be strongly related to troubleshooting performance. Performance on the simulated troubleshooting problems, given to all of the MTs, lends support to this suggestion. There was little difference in the mean total number of points attained on this pretest between MTs who had MTRE classroom training (210) and those who had not (198). Although the MTRE Maintenance Course may be fundamental to performing preventive maintenance, it appears that other factors may be of equal importance in developing troubleshooting skills. It is probably safe to conclude that one of these factors is practice in performing corrective maintenance, which does not occur frequently on MTRE because of its exceptional reliability.

Serious performance deficiencies were also found in the use of test equipment. While the deficiencies encountered in the use of the differential voltmeter and the volt-ohm-microammeter were less serious than those encountered in the use of the oscilloscope, performance was still not adequate to support maintenance. Previous school experience was related to more proficient test equipment use, just as it was related to better performance on MTRE preventive maintenance tasks. Over all three pieces of test equipment, a significantly greater percentage of

points was attained (46 percent) by MTs who had attended a test equipment course than by those who had not (31 percent) ($t(61) = 1.81, p < .05$). Only 10 of the 63 MTs tested had the advantage of classroom experience devoted solely to test equipment use. For those 10, the time since completion of the course ranged from 1 to 96 months. Proficiency might be expected to decrease over at least the longer time periods because of intermittent practice opportunities, especially in the case of the most complicated piece of test equipment, the oscilloscope.

In regard to the oscilloscope, not only did the MTs have difficulty in making calibration adjustments and measurements, but a majority of them had trouble with the basic turn-on procedures. In fact, many MTs could not even setup the equipment. A comment made by many MTs during testing was that the oscilloscope is usually already setup and calibrated, and, if it is not, an Electronic Technician (ET) can be asked to do it. However, the poor performance exhibited by the MTs on use of test equipment prompted PTEP to examine a selected sample of Sonar Technicians and Electronic Technicians using an adaptation of the Test Equipment Test. The results for these two samples were similar to those for the MTs (PTEP Evaluation 5-76, Note 6) and are in line with previous research (e.g., Abrams & Pickering, 1962; Steadman & Harrigan, 1971; Steinemann, Coady, Harrigan, Matlock, & Steadman, 1969), which has repeatedly shown serious problems in the use of test equipment. The MT's notion that he can rely on the ET for help in using the oscilloscope is not borne out by this data.

The results from the 12 MT crews tested showed that all groups improved significantly. Neither feedback on individual weaknesses nor feedback plus specifically assigned remedial training improved job performance over that shown by the Control Group. Therefore, the improvement that did take place for the three groups was probably due to experience gained in the testing situation.

Absence of Training and Feedback Effects

There was no training effect because most of the 19 MTs in the Training Group did not complete their assigned lessons. This was confirmed from both self-reports during posttesting and from the Progress Checklists. These checklists were returned by only two of the four submarines in the Training Group. Of the two sets of Progress Checklists returned, only one contained supervisors' initials verifying the completion of lessons and was accompanied by a signed "Training Attendance and Critique Record," which usually accompanies the completion of self-study workbooks obtained from PTEP. As a consequence, only five MTs could be identified as having completed their assigned lessons.

To get an idea of whether or not the training materials might have improved hands-on performance if they had been more widely used, the five MTs who completed their lessons were singled out for examination. The performance of each of these MTs was compared to that of similar MTs from the other two groups; that is, members of the Control Group and Feedback Group who would have been assigned, at the minimum, the same lessons as each of the five MTs were selected to form a yoked subsample. It should be noted that the five Diagnostic Feedback + Training Group MTs who had completed their lessons had not been assigned training in all areas. Table 6 shows the yoked subsample compared in terms of the percentage of the points or steps that were missed at pretest but were attained at posttest. For example, if at pretest five steps of the Digital Multimeter Electrical Adjustment Check were either incorrect or not completed, and four of these steps were completed correctly, at posttest, then

the "percent improvement" was 80 percent. The Training Group showed more improvement than the other groups in all but one case. While these comparisons are based on extremely small subsamples, they do suggest that, had training been completed, it would have improved performance. An independent study, in which 10 enlisted personnel of a variety of electronic ratings were tested ashore and then given the test equipment training, confirmed the trend found in the yoked subsample. The results for the independent study are summarized in Table 7. There was highly significant improvement in performance after completion of training on the three pieces of test equipment--at posttest, 6 out of 10 attained over 90 percent of the possible points on the oscilloscope; 6 out of 10, over 90 percent on the differential voltmeter; and 9 out of 10, over 90 percent on the volt-ohm-microammeter ($F(1, 18) = 278.0, 50.5, \text{ and } 58.2$, respectively, all $p < .001$).

Table 6

Percent of Possible Improvement in Hands-on Performance for a Yoked Subsample

Test	Experimental Groups		
	Diagnostic Feedback + Training Group	Diagnostic Feedback Group	Control Group
Oscilloscope ^a	80	60	28
Test Equipment	Differential Voltmeter ^a	86	37
	Volt-Ohm-Microammeter ^b	100	0
MTRE	Tape Splice/Canister Load ^b	91	0
	Digital Multimeter Check ^c	33	50

Note.--No training was assigned to this subsample as a result of the MTRE problem involving the tape reader check.

^aN = 5 for all three groups.

^bN = 3 for all three groups.

^cN = 2 for all three groups.

Table 7

Performance of Ten Navy Technicians on the Test Equipment Test
Before and After Training

	Percent Correct		
	Oscilloscope	Differential Voltmeter	Volt-Ohm Microammeter
Before Training	5	22	29
After Training	90	91	94

Although the Feedback + Training Group was given feedback and specifically assigned remedial material, they still did not improve in performance--mainly because the training was not completed. Given this fact, it is not surprising to find that feedback alone had no effect. The Sonar Technician application (Winchell, Panell & Pickering, 1976) also found that feedback alone had no effect. It was suggested that it may have been too difficult for the Sonar Technicians to extract the needed information from the available documents. While this could possibly be true in the present application for the test equipment information, it is obviously not the case for the MTRE information, since detailed step-by-step procedures are listed in the official documents. The reasons for not using feedback are probably the same as those for not using training.

Comments on the Nonuse of Training

There may be a number of reasons why the assigned training was not used by a majority of MTs in the Training Group to supplement their ongoing shipboard training. First of all, there may have been some features of the training materials that contributed to their nonuse. For example, the individual lessons of a training package, which ranged from approximately 1 to 2 hours, were much longer than the ½-hour lessons of the Sonar Technician application in which training was found to be used (Winchell, Panell & Pickering, 1976). In addition, testing took place on several different pieces of equipment rather than just one piece, as in the Sonar Technician application. When deficiencies were found, these features resulted in the assignment of lengthy training packages covering many different areas.

Personnel assignment practices, peculiar to the operation and maintenance of MTRE, probably had a stronger influence on the nonuse of training materials than lesson length or training package size. In particular, only one MT is assigned the responsibility for MTRE on a given patrol. That MT is not only the only one who has the opportunity to practice his maintenance skills, but he is also the only one who is likely to feel that those skills are necessary to his job. Moreover, a given MT usually has responsibility for MTRE only once during

his tour on an FBM submarine. This probably serves to reduce the perceived importance and relevance of the training for those MTs not currently assigned responsibility for MTRE.

Another important reason for nonuse of training materials is that MTRE is an exceptionally reliable piece of equipment. Because MTRE operates without failure for extended periods of time, studying material related to MTRE is likely to appear to be unprofitable. Unfortunately, the exceptional reliability of MTRE results in little opportunity to practice maintenance skills, and this sets the stage for the deterioration of these skills.

Implementation Costs

The estimated cost of reproducing one complete set of training materials, less the test signal generator, is \$196.85. The amount of \$195.74 is a one-time cost because all of the materials are reuseable, with the exception of the first self-study workbook. The prototype test signal generators cost \$1350.00 each in an eight-item lot, which includes one-time developmental costs. The price of this equipment can be expected to decrease with additional orders, especially if the lot sizes are larger. A breakdown of the estimated costs by training package are shown in Table 8. Since only a limited number of MTs would be tested under the recommendations that follow, the time requirements for MTRE equipment, test equipment, and a test proctor are minimal. The hands-on performance tests can be completed in less than 2½ hours, and testing could be easily conducted by PTEP during the routine PTEP testing.

Table 8

Estimated Cost of Training Materials

Self-Study Workbook	Components	Estimated Cost
Review of Safety Precautions	19 Printed Pages	\$1.10
Troubleshooting MTRE Faults	60 Printed Pages	\$2.75
	Simulated Troubleshooting Exercises	\$0.00 ^a
MTRE Maintenance Procedures	42 Printed Pages	\$2.00
	238 Slides	\$75.00
	8 Audio Cassettes	\$84.00
	1 Tape Player	\$26.00
Test Equipment Measurements	233 Printed Pages	\$6.00
	1 Test Signal Generator	\$1350.00

^a Available through PTEP

CONCLUSIONS

It is clear from the present application of a diagnostic testing and shipboard training program that there are serious deficiencies in tasks related to the maintenance of MTRE. It is also clear that the MT and those responsible for his training must be convinced that a problem exists that can be helped by training. The existing MTRE Maintenance Course may be all that is needed to produce an MT who can accomplish MTRE preventive maintenance tasks. However, MTRE classroom training is not likely to be helpful unless received in the off-crew period just prior to assignment of MTRE responsibility. The same probably holds true for the test equipment courses.

It is recognized that not all MTs will be sent to the appropriate schools just prior to being assigned MTRE responsibility. Some will already have attended these schools. The present testing-and-training program can play an important role in identifying performance deficiencies in those who have received school training in the past. By testing those MTs at the beginning of the off-crew period just prior to their assignment of MTRE responsibility, any performance deficiencies can be revealed. These deficiencies can then be corrected through the use of the self-study workbooks of the present program.

RECOMMENDATIONS

To improve the proficiency level of the MT designated to have responsibility for operating and maintaining MTRE, it is recommended that:

1. If the designated MT has not already attended the MTRE maintenance and test equipment courses, he should attend these courses during the off-crew period immediately preceding the patrol on which he will assume MTRE responsibility.

2. If the designated MT has attended the MTRE maintenance and test equipment courses, he should be given the MTRE diagnostic test at the beginning of the off-crew period immediately preceding the patrol on which he will assume MTRE responsibility. He should then be assigned the appropriate remedial training package and be retested at the completion of training.

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