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NAVAL PERSONNEL AND TRAINING RESEARCH LABORATORY

SAN DIEGO, CALIFORNIA 92152

RESEARCH REPORT SRR 71-11 OCTOBER 1970

PRINTED-CIRCUIT-BOARD SOLDERING TRAINING FOR GROUP IV PERSONNEL

E. A. Hooprich
E. W. Matlock

Group IVs on the soldering achievement test was compared with that of experienced technicians in the fleet. Tests designed to measure performance on soldering tasks similar to those taught in the course also were constructed and administered to selected classes.

Findings, Conclusions, Recommendations

The goals of this investigation were to determine whether or not Group IV personnel could be taught basic soldering skills and to compare several methods for accomplishing such training. Based on the research results, the following conclusions are presented: (1) Most Group IVs can learn the skills required for printed-circuit-board soldering. (2) However, preliminary evidence from a related study indicates that the Group IV personnel typically require nearly twice as long a training period to acquire these skills as do higher aptitude Navy personnel. (3) The soldering proficiency of Group IV trainees after completion of the TMDP course apparently equals or exceeds that of many experienced fleet technicians whose job duties occasionally involve soldering. (4) Group IV personnel can apply the skills learned in the TMDP soldering course to the replacement of components on printed circuit boards other than those used for training. (5) For learning soldering, the use of specially-developed viewer films is as effective a training method as that in which instructors individually explain proper techniques to each student. (6) The use of film viewers minimizes demands on instructors and should enable them to monitor larger classes of trainees. (7) Group IV trainees strongly prefer the viewer method to conventional methods for learning soldering techniques, and they experience little difficulty integrating the filmed lessons with simultaneous practice of soldering operations.

Two recommendations relevant to Navy training are proposed: (1) It is recommended that the film-viewer method described in this report be utilized for training both Group IVs and other Navy personnel in a variety of technical-mechanical skills. (page 10) (2) Another recommendation is that the content and general approach of the TMDP soldering course be considered for implementation into those Navy training courses that include printed-circuit-board soldering. (page 12)

Current and planned research projects relevant to the TMDP soldering course also are briefly described.

Naval Personnel and Training Research Laboratory
Printed-Circuit-Board Soldering Training for Group IV Personnel, SRR 71-11
October 1970, MMPB SD.03

SUMMARY AND CONCLUSIONS

Problem

One purpose of this research investigation was to determine whether or not Mental Group IV personnel can be taught, within an acceptable period of training, to perform adequately an exacting, technical Navy skill such as printed-circuit-board soldering. A related purpose was to compare two methods for accomplishing such training.

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Approach

During the period from January 1968 to March 1970, a total of 186 Group IV personnel in 13 TMDP classes received soldering training. Two different training approaches were implemented and evaluated. Research data were obtained from service records, questionnaires, and both paper-and-pencil and performance tests. Trainee achievement was measured by the pre- and posttraining administration of a soldering test previously developed for use with certain Navy advancement-in-rating examinations. The performance of the

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by

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Research Report SRR 71-11

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PRINTED-CIRCUIT-BOARD SOLDERING TRAINING FOR GROUP IV PERSONNEL

A. Introduction

All individuals considered for military service are required to take the Armed Forces Qualification Test (AFQT), a general measure of aptitude for military training. Those persons obtaining an AFQT percentile score from 10 through 30 are classified as being in Mental Group IV. The implementation of Project One Hundred Thousand by the Department of Defense involved modification of the qualification standards of the military services to admit specified numbers of Group IV personnel who would have failed to meet previous enlistment or induction criteria.

As part of the Navy's effort to maximize the utilization of its share of the input of Group IV personnel, the Navy Training Research Laboratory of the Naval Personnel and Training Research Laboratory, San Diego, has been conducting a series of experimental training courses, collectively called the Training Methods Development Program (TMDP). The experimental program was established in order to accomplish Group IV training research under conditions of greater experimental control than typically is possible in the ongoing Navy school situation. The major goals of TMDP are to determine what basic skills and job elements can be taught to Group IV personnel and to ascertain what training approaches and methods are most effective. Experimental courses developed thus far have involved training in hand tools, instrument reading, measuring techniques, practical mathematics, word skills, Seaman knowledge factors, basic graphics, electronic test equipment, and soldering. A more complete description of the objectives and implementation of TMDP is provided in a previous report by Steinemann (2).

The purposes of the research described in the present report were to determine whether or not Group IV personnel can be taught basic soldering skills within an acceptable period of time and to compare two methods for accomplishing such training. Although the requirement for soldering skills is common to a large number of Navy ratings, present assignment and utilization policies are such that it is not likely that the Navy job duties of most Group IVs will involve soldering. However, one of the objectives of TMDP is to establish the range of Navy skills and knowledges that can be learned by lower aptitude personnel. Soldering is considered to be representative of other moderately complex technical skills.

B. Procedures

1. Training Methods

A training course was developed to teach Group IV students the proper soldering techniques for removing and replacing various components--diodes, capacitors, resistors, wires--on a printed circuit

board. Correctness rather than speed of soldering performance was stressed, and students were expected to meet stringent standards in regard to the quality of the completed product. In addition to printed circuit boards and replacement parts, each student was furnished a tool box and a complete set of soldering tools, such as pliers, cutters, soldering irons, solder-removing devices, and heat sinks. A tool layout is shown in Figure 1.

Figure 1. Layout of tools used in soldering course.

The classroom procedures utilized for the initial classes were such that an instructor individually taught and helped each trainee. After establishing that the course objectives and content were appropriate for teaching soldering techniques to Group IV personnel, the use of rear-projection film viewers was introduced as an alternative

to individual guidance by an instructor. With either method--instructor or viewer--the course was designed to allow each trainee to progress at his own rate of learning.

The first step in the instructor-oriented method of training involved teaching the students to identify and use the various soldering tools and job aids. Next, the instructor demonstrated the techniques for removing and replacing a resistor on a printed circuit board. The Group IV students then began to practice replacing resistors. From this point onward in the training course, each student progressed at his own rate as he also learned to remove and replace capacitors, diodes, and wires. The student practiced the replacement of one component until this operation could be performed consistently with a high degree of skill; then, the instructor demonstrated to each individual student the procedures to be followed in regard to the next component. Thus, after the initial tool orientation and demonstration of resistor replacement, the instructor individually assisted and tutored the trainees rather than lecturing to the entire class.

Students were encouraged to decide for themselves whether or not the quality of their work met prescribed standards. This approach was used because it was believed that the effectiveness of an entirely self-study soldering course being developed would depend on the student being able to make reasonably accurate self-evaluations of his performance. However, in practice, there were instances in which students' soldering products obviously did not meet minimum standards and the instructor did suggest additional practice before progressing to the next component. Wall posters and models of correctly-soldered circuit boards were provided to enable the trainees to evaluate the quality of their soldering products. A large, lighted magnifying glass was available for use in examining soldered connections.

A series of filmed lessons was developed as an alternative to the instructor-dependent method of training described above. The most important aspects of the training course were condensed into 12 five-minute sound films, which can be shown on a cartridge loaded, eight millimeter, rear-projection viewer. The titles of the 12 films are listed in Appendix A. The Fairchild viewer used in this experiment can be stopped in the middle of a film, but it does not have either a still picture or reverse capability. The viewer screen measures 8 inches by 10½ inches. Students used earphones to listen to the film narration. Figure 2 shows a trainee viewing one of the soldering films at his workbench.

The sequence of the training films parallels that of the content of the course when taught by an instructor. The soldering films minimized but did not entirely eliminate the need for an instructor in the classroom. Students viewed each film as many times as necessary to learn the proper soldering techniques and to eliminate problems encountered during practice of the soldering skills. Although there was some variation, students typically viewed each film a minimum of three times. Instructors provided minimal assistance and typically

responded to questions by suggesting additional viewing of relevant film lessons. The film viewers were utilized under two different conditions: in one of them, two students shared a film viewer at their workbench; in the other, four viewers were located at a central location and were shared by an entire class varying in size from 11 to 15 students. Under the latter condition, the trainee could not simultaneously view the film and practice his soldering skills.

Figure 2. Student using film viewer to learn soldering techniques.

Regardless of which one of the two training methods was used, the length of the soldering course was approximately 15 hours, not including pre- and posttraining testing. Nearly all of the students were able to learn to replace all four components within this training period. Because of changes in the administration and scheduling of the total TMDP curriculum, of which the soldering course was only one of several taught to each class, the conditions under which the training was administered varied somewhat from class to class. The first six soldering classes were taught on a schedule that involved one hour of training each day; subsequent classes were on a more massed practice schedule of three hours per day. The students in some classes were split into two sections and those in the other classes were taught together in one group. Because of a varying input to TMDP and the splitting of some classes into different sections, the student-instructor ratio ranged from 16:1 to 6:1. Two former Navy personnel with considerable technical and soldering expertise and experience served as instructors.

2. Data Collection

In addition to selected information from the service records of the trainees, research data were obtained by means of questionnaires, aptitude tests, training course achievement tests, and transfer-of-training tests.

a. Service record data. Service record data included years of education, age, and scores on the following tests administered prior to or during recruit training: Armed Forces Qualification (AFQT), General Classification (GCT), Arithmetic (ARI), Mechanical (MECH), and Shop Practices (SP). Form 6 of the Navy Literacy Test was administered to the TMDP students just prior to the beginning of soldering training.

b. Questionnaires. A pretraining questionnaire was administered to all TMDP trainees to gather information about factors such as civilian school experiences, attitudes towards various training situations, and career intentions. A posttraining questionnaire was used to determine reactions to the entire TMDP curriculum and training procedures. A supplement to the posttraining questionnaire pertained specifically to the soldering training methods and was administered to the last four classes using the film viewers. Pre- and post-training questionnaire items are presented in Appendices B and C.

c. Soldering achievement test. The inclusion of soldering in the TMDP curriculum was facilitated by the fact that a soldering test for Navy advancement-in-rating purposes previously had been developed at the Navy Training Research Laboratory. It is a practical test of ability to solder on a printed circuit board and requires the replacement of three components (resistor, capacitor, diode) and a length of insulated wire. The replacement of these parts involves removing the old solder and then re-soldering the connections. A top view of the printed circuit board is shown in Figure 3.

The test is used to evaluate both the soldering procedures used and the quality of the finished product. Specific evaluation standards contained in a booklet and detailed scoring sheets facilitate objective and consistent test scoring. There are a total of 63 possible points, based on 24 performance items and 39 product items. Each item is scored either as satisfactory (one point) or unsatisfactory (no points). Copies of the scoring sheets for the two parts of the test are presented in Appendix D. Test administration and scoring procedures are described in more detail in a separate report (1).

The test was administered by a technician experienced in soldering procedures. Each individual being tested was furnished a correctly-assembled printed circuit board, replacement parts, solder, an instruction sheet with diagrams, and a tool box containing both appropriate and inappropriate soldering tools. The testee was told that the four parts were defective and must be removed and replaced by new ones. The

same form of the soldering test was administered before and after training. A 45-minute time limit was imposed for both the pre- and post-training administrations of the test; after training, nearly all of the students were able to complete the required soldering operations within this period of time.

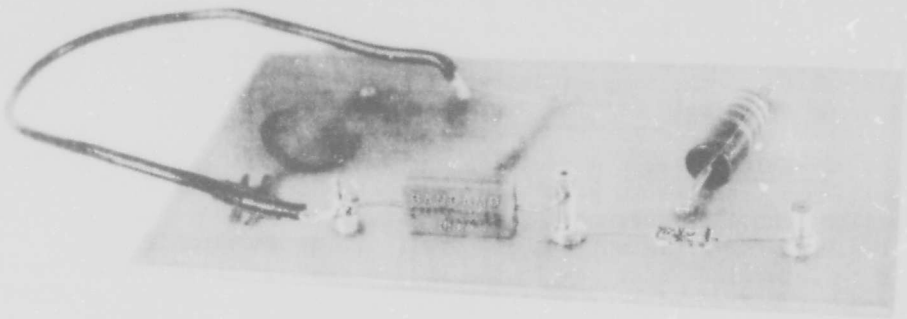


Figure 3. Printed circuit board used for soldering achievement test.

d. Transfer-of-training tests. The same type of printed circuit board was used for both the soldering training and the regular pre- and posttraining testing. However, in order to determine the extent to which the students could perform soldering tasks on circuit boards other than the specific ones on which they had been trained, transfer-of-training tests were developed and administered to four TMDP classes. The transfer tests typically were administered several days after the regular posttraining testing.

Two different transfer tests were utilized. Transfer Test I was similiar to the regular course achievement test in that it was necessary to replace a diode, a resistor, and a capacitor. However, the tasks actually were more demanding because there were more components on the board, the components were smaller, and the printed circuit board was more fragile. The maximum possible score was 63, and test scoring procedures were nearly identical to those used for the regular soldering achievement test. The printed circuit board used for Transfer Test I is shown in Figure 4.

The other transfer test also involved the replacement of a variety of components and was somewhat more difficult than the course achievement test administered before and after training. Before replacing the components, it was necessary to remove the printed circuit board from a radio receiver. The board was replaced in the radio receiver after the soldering tasks were completed and, if the soldering had

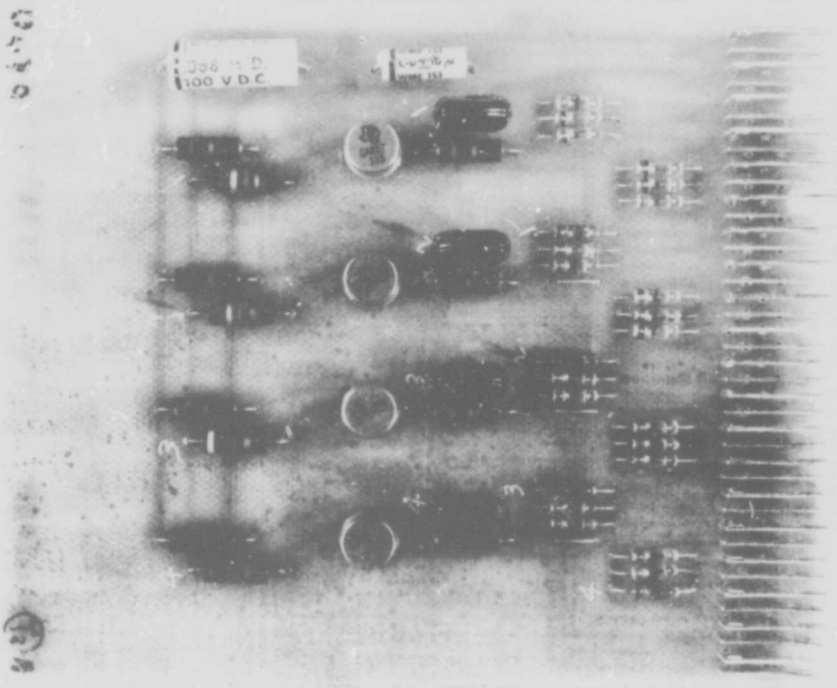


Figure 4. Printed circuit board used for Transfer Test I.

been done properly, the radio would then play. Soldering proficiency was evaluated on the basis of a total of 54 performance and product quality items. A top view of the printed circuit board used for Transfer Test II is shown in Figure 5.

3. Trainee Characteristics

During the period from January 1968 to March 1970, a total of 186 Group IV personnel in 13 classes completed the TMDP experimental soldering course. The Group IVs had just finished recruit training and were assigned to TMDP for temporary duty prior to reporting to their permanent duty stations. Requests for Group IV input to TMDP specified that the AFQT scores for each class be evenly distributed throughout the range of 10 through 30. Furthermore, it was requested that no student have a GCT score higher than 50 or an ARI score higher than 45. For several classes, it was necessary to exceed the GCT and ARI restrictions slightly in order to obtain an adequate sample of Group IV personnel.

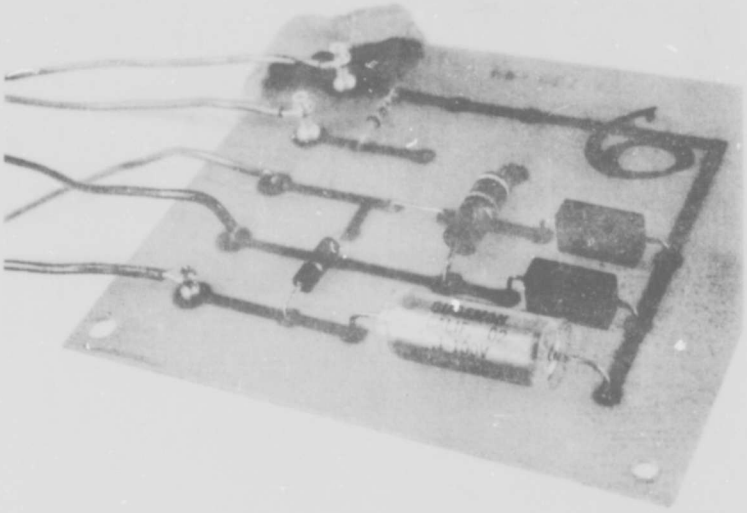


Figure 5. Printed circuit board used for Transfer Test II.

Presented in Table 1 are descriptive statistics pertaining to selected pretraining variables. It can be seen that the mean AFQT percentile score is approximately in the middle of the range defining the Mental Group IV category (10-30). The mean General Classification Test score is 39.3, with a score range from 22 to 54. The Group IVs' mean reading level, expressed as a grade-level equivalent, is 7.3, and the mean years of education is 11.5. Not shown in Table 1 is the fact that 133 (71 per cent) of the Group IV personnel had graduated from high school and 8 had completed at least one year of college.

The following is a summary of information obtained by means of a pretraining questionnaire: Although the students did not have a negative attitude toward school in general, they did indicate a dislike for academic courses such as English and mathematics. A shop course of some type was listed most frequently as the best-liked high school course. All but 18 of the Group IV trainees had taken at least one shop course, such as woodworking, metal, electric, or automotive. Furthermore, a majority of the students reported that they had done better in shop courses than in academic or commerical courses, and there was a strong preference for working with their hands (building, assembling, repairing) rather than with their head (reading, computing, analyzing). Of five different instructional or learning methods, shop practice was most frequently preferred by the trainees. Only 12 of the Group IVs indicated a definite intention to make the Navy their career. Over half of the responses to

a questionnaire item pertaining to post-Navy plans indicated intentions to attend some type of school. In regard to civilian job or occupational aspirations, those trades involving the use of manual skills--such as machinist, electrician, mechanic, carpenter--were most frequently mentioned. It can be inferred from the general pattern of responses to the pretraining questionnaire that both the educational background and occupational goals of the Group IV soldering trainees were oriented toward those tasks and jobs that require mechanical and shop skills rather than verbal or computational skills. A tabulation of responses to the pretraining questionnaire is presented in Appendix B.

TABLE 1

Descriptive Statistics for Selected Pretraining Variables (N=186)

Pretraining Variable	Mean	Standard Deviation	Range
Armed Forces Qualification Test	19.8	5.6	10-30
General Classification Test	39.3	6.6	22-54
Arithmetic Test	40.4	4.3	27-53
Mechanical Test	42.5	6.1	22-60
Shop Practices Test	44.0	6.2	25-61
Navy Literacy Test	7.3	1.2	3.8-10.2
Education (years)	11.5	1.1	8-14
Age (years)	19.0	1.0	17-23

Note.--

1. The AFQT score is a percentile score; the four Basic Test Battery scores (GCT, ARI, MECH, SP) are Navy Standard Scores; the Navy Literacy Test score is expressed as a school grade-level equivalent.

A brief questionnaire and informal interviews were used to determine the previous soldering experience of students in the first several classes receiving soldering training. Although many students indicated that they had previously learned to solder, close questioning revealed that the nature of the soldering tasks was much less demanding than that of the TMDP course. Virtually no relationship was found between the students' self-reports of soldering competence and their performance on the TMDP pretraining soldering test.

C. Research Results

1. Comparison of Training Methods

Presented in Table 2 are the mean soldering test scores of Group IV trainees taught by both the instructor method and the viewer method. It is evident that, under either training method, the Group IVs made substantial improvements in their ability to perform printed-circuit-board soldering.

There were no statistically significant (.01 level) differences between the instructor-taught and viewer-taught groups in regard to posttraining test scores and gain scores. Because of certain factors relevant to the training situation, the control of some experimental conditions was less precise than typically is desirable for an investigation of alternative training methods; these factors included practical considerations affecting overall TMDP administration and scheduling, availability of instructors, and variable input of Group IV students. However, data from a series of separate analyses suggest that these factors did not significantly influence achievement in the soldering course. There were no statistically significant (.01 level) differences in mean total posttraining test scores when the following comparisons were made: full classes--split classes; spaced practice (one hour a day)--massed practice (three hours a day); instructor taught, full class--instructor taught, split class; viewer taught, two students share one viewer--viewer taught, entire class share four viewers; and classes taught by one of the instructors versus those taught by the other instructor. Hence, there is reason to maintain confidence in the validity of the finding that, for practical purposes, there is no difference in the effectiveness of the two methods for teaching Group IVs to perform printed-circuit-board soldering.

Although there was no significant difference between the soldering performance of the Group IVs trained by the two different methods, some practical advantages of the viewers did become apparent. The student self-pacing feature of the TMDP instructor-oriented training method requires that, whenever a student has mastered one soldering operation and is ready to learn a new one, the instructor must individually explain and demonstrate the proper techniques. In large classes, this requirement kept the instructors quite busy. However, when the film viewers were used to supplant instructor demonstration and tutoring, instructors were then able to monitor more thoroughly the progress of

TABLE 2

Comparison of Mean Soldering Test Scores of Group IV Personnel
Trained by "Instructor" Method and Those Trained by "Viewer" Method

Soldering Achievement Test Score[a]	Instructor Method (N=139) Mean	SD	Range	Viewer Method (N=47) Mean	SD	Range	Difference Between Means	F-value
Performance								
Pretraining	4.3	2.7	0-13	3.2	2.1	0-11	1.1	6.93*
Posttraining	20.8	2.4	13-24	20.9	2.4	13-24	0.1	0.03
Gain	16.4	3.7	4-23	17.6	2.8	10-22	1.2	4.20
Product								
Pretraining	5.9	4.8	0-19	4.3	5.2	0-23	1.6	3.82
Posttraining	28.0	5.8	13-38	26.7	6.9	8-37	1.3	1.56
Gain	22.2	6.6	3-35	22.4	6.8	5-35	0.2	0.06
Total								
Pretraining	10.2	6.2	0-27	7.5	6.2	0-26	2.7	6.64
Posttraining	48.8	6.8	29-62	47.6	8.6	21-60	1.2	0.97
Gain	38.6	8.2	15-56	40.1	8.5	19-54	1.5	1.16

Notes.--

[a]Maximum possible scores: Performance - 24, Product - 39, Total - 63.
*Significant at .01 level.

all students. The instructors expressed the opinion that use of the filmed lessons should enable each instructor to teach larger numbers of students at one time than is possible with conventional methods involving individual demonstration and guidance. It is noted that the Group IV trainees did not experience any problems in learning to operate the film viewers.

2. Comparison of Soldering Test Performance of Group IV Trainees With That of Other Navy Personnel

Scores on the soldering test administered at the end of training leave no doubt that the Group IVs made substantial improvements in their ability to perform printed-circuit-board soldering. However, these scores alone do not indicate the soldering competency of the Group IVs relative to that of other Navy personnel. The conduct of other research projects by the Navy Training Research Laboratory has afforded opportunities to administer the soldering achievement test to samples of Navy personnel whose training or shipboard duties typically include some soldering. The total of 141 technical personnel who were given the soldering test consisted of graduates of various Navy Class "A" Schools--Data Systems Technician, Electronics Technician, Sonar Technician--and instructors at the Torpedoman's Mate School. Two separate samples of Electronics Technicians were tested. The non-Group IVs ranged from designated strikers to chief petty officers, and length of Navy service varied from 7 months to 25 years. There were, of course, wide differences in extent of soldering experience among the Navy technicians.

Shown in Table 3 are the mean soldering test scores for both the samples of Navy technical personnel and the total number of Group IVs receiving the TMDP soldering training. It can be seen that the mean posttraining scores of the Group IV students are substantially higher than the mean scores of the various groups of other Navy personnel, the job duties of many of which require proficiency in printed-circuit-board soldering. It should not be inferred from this finding that the non-Group IV personnel would not have done as well or much better on this particular soldering test if they also had just completed the TMDP training course. However, the data in Table 3 do provide some evidence that, at the time the Group IVs complete the TMDS course, their soldering competency may exceed that of many fleet technicians who are required only intermittently to demonstrate their soldering skills. It should be noted that the lower test scores of the Sonar Technicians undoubtedly are due to the fact they typically have considerably less soldering training and experience than do the other Navy ratings included.

A current study being conducted at the Navy Training Research Laboratory does provide some preliminary information in regard to the achievement of higher-aptitude Navy personnel receiving the TMDP soldering training. The participants in the experiment are 60 Navy personnel awaiting the beginning of classes at the Basic Electricity and Electronics School at the Naval Training Center, San Diego.

Although some of the personnel are in Mental Groups I or III, the majority of them are in the Mental Group II category. Two groups of 20 students each have received soldering training by either the instructor or viewer methods described in the present report. The initial findings indicate that the higher aptitude personnel attain mean posttraining scores (total) approximately seven points higher than those of the Group IV students while requiring only half as long a training period.

TABLE 3

Comparison of Soldering Test Performance of Group IV Trainees with That of Other Navy Personnel

Sample of Personnel Tested	N	Mean Test Score[a]			Range (Total Score)
		Performance	Product	Total	
Group IV (Posttraining test administration)	186	20.8	27.7	48.5	21-62
"A" School Graduates					
DS Rating	51	14.1	15.7	29.8	14-42
ET Rating	28	13.0	22.6	35.6	8-45
ET Rating	12	12.1	18.4	30.5	14-54
ST Rating (Pacific)	20	5.6	5.2	10.8	5-19
ST Rating (Atlantic)	19	8.0	4.8	12.8	2-25
School Instructors					
TM Rating	11	11.2	13.9	25.1	11-41

Note.--

[a]Maximum possible scores: Performance - 24, Product - 39, Total - 63.

3. Soldering Performance on Other Printed Circuit Boards

The type of printed circuit board used for the pre- and posttraining testing was the same as that used for soldering practice during training sessions. An implicit assumption of most training programs is that the skills and knowledges acquired in the specific learning situation will transfer, in a positive manner, to different job situations and tasks. In order to ascertain the extent to which the

TMDP students could perform soldering tasks on printed circuit boards with features somewhat different from those on which they had been trained, two transfer tests were developed. Transfer Test I was administered to TMDP Class 2, and Transfer Test II was attempted by students in three other classes. All Group IVs taking the transfer tests had been trained by the instructor method. It is the opinion of the technical experts who developed the transfer tests that they are more difficult than the regular course achievement test. In Table 4 are shown the mean soldering scores of the students on both the transfer test and the regular posttraining test. Performance on the transfer tests, expressed as a percentage of the maximum possible score, is generally lower than that achieved on the posttraining test. However, considering the fact that the transfer tests presumably are more difficult, it does appear that the skills learned in the course were effectively applied to soldering tasks involving somewhat different circuit boards.

4. Relationships between Aptitude Variables and Soldering Test Performance

Presented in Table 5 are product-moment correlations between selected pretraining aptitude test scores, plus years of education, and soldering test scores. It can be seen that only three aptitude test scores--Armed Forces Qualification, Mechanical, and Shop Practices --had statistically significant positive correlations with soldering performance. Not surprisingly, scores on the Mechanical Test correlated most highly with soldering achievement. The zero correlations between GCT and total test scores reflect the fact that the soldering performance and its evaluation are quite nonverbal. It is also noted that, within the very restricted range of AFQT scores, there still is a significant correlation between AFQT and soldering performance.

5. Posttraining Questionnaire Responses

Upon the completion of training, students in each TMDP class were administered a posttraining questionnaire. In addition, trainees taught soldering by the viewer method were asked to complete a special supplemental questionnaire. Appendix C is a breakdown of the responses to the questionnaire supplement and to items on the posttraining questionnaire that are pertinent to the soldering course.

Seventy-five per cent of the Group IVs indicated a belief that the TMDP soldering training would be useful for both Navy duties and later civilian life, and only seven per cent thought that it would not be very useful. When comparing the soldering course with other courses taken while attending TMDP, 35 per cent of the students reported that soldering was their best-liked course and 12 per cent selected it as the least-liked course. There was nearly unanimous agreement among the Group IV personnel that they liked the viewer method of soldering training, that they preferred it over conventional methods of soldering training, and that they would like to use viewer films to learn

TABLE 4

Mean Scores of Group IV Trainees on Tests Measuring Transfer-of-Training Performance on Printed Circuit Boards Other Than Those on Which Trained

TMDP Class Number	N	Test	Soldering Test Score: Performance Mean	Performance Max. Possible	Performance Per Cent Correct	Product Mean	Product Max. Possible	Product Per Cent Correct	Total Mean	Total Max. Possible	Total Per Cent Correct	Range (Total Score)
2	12	Posttraining	20.0	24	83%	29.1	39	75%	49.1	63	78%	36-58
2	12	Transfer-I	18.5	21	88%	28.3	42	67%	46.8	63	74%	28-58
3	16	Posttraining	18.4	24	77%	31.1	39	80%	49.4	63	78%	39-57
3	16	Transfer-II	18.5	23	80%	20.6	31	66%	39.1	54	72%	31-46
6	16	Posttraining	22.3	24	93%	27.1	39	69%	49.4	63	78%	42-62
6	16	Transfer-II	16.7	22	76%	20.1	31	65%	36.8	53	69%	24-48
8	11	Posttraining	20.5	24	85%	28.6	39	73%	49.1	63	78%	29-58
8	11	Transfer-II	16.5	22	75%	17.5	31	56%	34.1	53	64%	17-45

TABLE 5

Correlations between Aptitude Variables and Soldering Test Scores
(N=186)

Aptitude and Educational Variables	Soldering Test Score								
	Performance			Product			Total		
	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Armed Forces Qualification Test	.12	.19*	.04	.20*	.21*	.06	.19*	.24*	.06
General Classification Test	.06	.08	.00	-.04	-.03	.00	.00	.00	.00
Arithmetic Test	-.05	-.08	-.02	.09	.12	.04	.05	.07	.02
Mechanical Test	.25*	.10	-.12	.37*	.41*	.09	.41*	.38*	.02
Shop Practices Test	.24*	.06	-.14	.11	.20*	.09	.19*	.18	.02
Navy Literacy Test	.01	.12	.07	-.05	.03	.05	-.02	.06	.07
Years of Education	-.17	.02	.14	-.06	-.04	.00	-.11	-.02	.06

Note.--

*Significant at .01 level (correlation of .19 required)

other mechanical and technical skills. About two-thirds of the questionnaire respondents felt that they could learn soldering by using the films alone without an instructor present to answer questions. (However, it is the opinion of the instructors who monitored the progress of the viewer-taught classes that few of the Group IVs could learn soldering solely by use of the filmed lessons without at least minimal instructor guidance.) The most frequently reported criticism was that the viewer did not have either a reverse or a still-picture capability. Because the film could not be reversed, it was necessary for the students to rerun an entire film just to review one specific detail.

Responses to the pretraining questionnaire revealed that closed-circuit television was least preferred by the Group IV personnel as a method of instruction. In view of this, the Group IVs' strong endorsement of film viewers for training may seem somewhat contradictory. However, there are significant differences between the two modes of instruction, not the least of which is student control of the frequency and rate of visual presentation.

D. Conclusions and Recommendations

1. Conclusions

The major goals of this research investigation were to determine whether or not Group IV personnel could be taught basic soldering skills and to compare two methods for accomplishing such training. Based on performance on the posttraining soldering test, it is concluded that most Group IVs can learn the rather exacting operations involved in printed-circuit-board soldering. However, the Group IV personnel may require nearly twice as long a training period to acquire the soldering skills as do non-Group IV personnel taking the TMDP soldering course. The soldering proficiency of the Group IVs at the completion of training apparently equals or surpasses that of many experienced fleet technicians whose job duties occasionally involve soldering. With a minimal loss of proficiency, Group IV personnel can apply the skills learned in the soldering course to the replacement of components on printed circuit boards other than those used for the TMDP training.

Another research finding is that the use of specially-developed viewer films to demonstrate proper soldering techniques is as effective as the training method in which the instructor individually explains the proper techniques to each student. In other words, Group IV personnel can be taught the content of the self-paced TMDP soldering course by either personalized guidance by an instructor or by utilization of short films shown on a rear-projection viewer. Although the effectiveness of the two methods is comparable, the use of the film viewers minimizes the demands on the instructor and enables him to monitor larger classes of students. There is some doubt that Group IVs can learn soldering solely by the viewer method, as developed thus far, without at least minimum instructor

guidance or monitoring; one problem is the inability of some students to determine whether or not their soldering products meet minimum standards prescribed at various stages of the training course, even when standard models are available for comparison.

Group IVs trained by the viewer method strongly prefer this approach over conventional methods for learning soldering. Students in the soldering course do not have any problems operating the film viewers and experience little difficulty integrating the filmed lessons with simultaneous practice of soldering operations.

2. Recommendations

If formal training of Group IVs in Navy technical-mechanical skills is planned, it is strongly recommended that the film-viewer method described in this report be introduced and evaluated. The use of training films and film viewers certainly is not novel, but the integration of brief instructional films with the simultaneous practice of performance skills has not been sufficiently exploited. Besides having many of the features of standard training films and closed-circuit television, the film viewer approach has the special advantages of portability and individual self-pacing. It is recommended that, if possible, viewers have both still-picture and reverse capabilities.

The findings and recommendations derived from this study have potential application to Navy training in general rather than just to the training of Group IVs. For example, the use of film viewers should be an effective method for teaching performance skills to all Navy personnel. More specifically, it is recommended that the content and general approach of the TMDP soldering course be considered for implementation into those Navy training courses involving printed-circuit-board soldering.

3. Current and Future Research

Several current research projects being conducted by the Navy Training Research Laboratory pertain to the TMDP soldering course. In one project, the effectiveness of the viewer films is being compared with that of programmed booklets for teaching soldering to Group IV trainees. The booklets incorporate still photographs and essential content from the film lessons. Another current investigation involves an evaluation of three different methods--instructor, viewer, programmed booklet--for teaching the TMDP soldering course to Navy personnel with aptitude levels considerably higher than those of Group IVs.

Plans for future research include modifications in the use of the film viewers to teach soldering skills. If possible, viewers with improved features will be acquired and evaluated. An effort will be made to determine the maximum number of trainees that can share one viewer without a detrimental effect on learning.

Some additional planned research is not restricted to one particular training method. The effect of requiring Group IV trainees to learn to make fine discriminations between good and poor quality soldering products before receiving any training will be determined. If such discrimination training proves to be feasible, it may facilitate the development of a self-study soldering course that would require very minimal, if any, guidance and monitoring by an instructor. Other variables that will be considered for investigation are length of training, instructor-student ratio, and practice schedule.

The focus of the research described in this report is on the training of Group IV personnel to perform printed-circuit-board soldering. However, it should again be noted that soldering was selected primarily because it is considered to be representative of a certain class of Navy technical skills. Thus, it is expected that the aggregation of research findings--both present and future--will have relevance not only to the training of Group IVs in other skills but to Navy technical training in general.

REFERENCES

1. Matlock, E. W., and Standlee, L. S. Report on three skill measurement tests for advancement in rating. San Diego: U. S. Naval Personnel Research Activity, July 1967.

2. Steinemann, J. H. The development and evaluation of training methods for Group IV personnel: I. Orientation and implementation of the Training Methods Development School (TMDS). San Diego: U. S. Naval Personnel Research Activity, October 1968. (Research Report SRR 69-12)

APPENDIX A

List of Titles of Soldering Films

Film Number	Film Title
1	Introduction
2	Hand Tool Identification: Part A
3	Hand Tool Identification: Part B
4	Preparation for Soldering
5	Part Removal
6	Resistor Replacement
7	Capacitor Replacement: Part A
8	Capacitor Replacement: Part B
9	Diode Replacement
10	Wire Replacement: Part A
11	Wire Replacement: Part B
12	Wire Replacement: Part C

APPENDIX B

Pretraining Questionnaire Responses

Questionnaire Item	Response Frequency
1. In general, what has been your attitude toward school?	
Liked very much	25
Sort of liked	51
Sort of disliked	4
Disliked very much	1
2. Which school course did you like best?	
English	19
Mathematics	19
History	42
Science	11
Shop	82
Other	44
3. Which school course did you like least?	
English	64
Mathematics	71
History	20
Science	23
Shop	2
Other	30
4. Which of the following shop courses have you taken?	
Metal	83
Woodworking	138
Electric	31
Automotive	62
Other	12
5. In what kind of school course did you do best?	
Academic	27
Commercial	37
Shop	113

Note.--

1. The response frequencies do not always total 186 because of multiple responses, omitted responses, or the fact that some items had not yet been included in the questionnaire when it was administered to the earlier TMDP classes.

Questionnaire Item	Response Frequency
6. Would you rather work with your head (reading, computing, analyzing) or with your hands (building, assembling, repairing)?	
Head	38
Hands	97
No difference	49
7. Listed below are five instructional or learning methods used in schools. Indicate which one works best for you by putting the number 1 in the box in front of it. Put a 2 in the box in front of the next most effective one. Use the numbers 3, 4, and 5 in the same manner. Number 5 will indicate the method that is least effective for you.	
	Mean Rank (N=160)
Classroom lectures	2.9
Shop or laboratory practice	1.9
Reading textbooks or manuals	3.1
Programmed instruction (such as teaching machines or programmed booklets)	3.4
Closed-circuit television	3.7
8. Do you plan to make the Navy your career?	
Yes	12
No	83
Undecided	91
9. If you do not make the Navy your career, do you intend to return to school?	
Yes	44
No	15
Undecided	22
10. What do you expect will be your civilian job or occupation?	
Shop Trade (machinist, mechanic, welder)	52
Construction Trade (electrician, carpenter)	11

APPENDIX B (continued)

Questionnaire Item	Response Frequency
Manufacturing (factory assembly)	19
Clerical (clerk, data processing)	15
Personal Services (policeman, forest ranger)	11
Professional-technical (teacher, engineer)	8
Business (own business, manager)	7
Fine Arts (musician, artist)	5
Return to school (specific educational goal not indicated)	30
Undecided	28

APPENDIX C

Posttraining Questionnaire Responses

Questionnaire Item	Response Frequency
1. How useful do you consider the soldering training course to be?	
Expect to be useful both in Navy and in civilian life	138
Expect to be useful for performing Navy duties only	16
Expect to be useful in civilian jobs only	17
Do not expect to be very useful	13
(Questionnaire items 2 and 3 were administered to 147 TMDP students who had received soldering instruction along with a number of other training courses. Only the responses pertaining to the soldering course are reported here.)	
2. Which TMDP course did you like best?	
Soldering	52
3. Which TMDP course did you like least?	
Soldering	17
(The following questionnaire items were administered only to those students in four of the classes that were taught soldering by the viewer method.)	
A series of short films presented by a cartridge-loaded viewer were used to help you learn printed-circuit-board soldering. Your honest answers to the below questions will help us to decide how useful the films are and what are the best ways to use them.	
4. Did you like this method of learning soldering?	
Yes	38
No	1

APPENDIX C (continued)

Questionnaire Item	Response Frequency
5. Would you rather learn soldering by using the films or by the regular method involving lectures, demonstrations, and supervised practice?	
Prefer using films	33
Prefer regular method	2
Don't know which method I prefer	4
6. Do you believe you could learn to solder by just using the films without an instructor present to answer questions?	
Yes	24
No	15
7. Do you think you would like to use other short viewer films to learn other skills that involve using your hands to make or repair things?	
Yes	38
No	1
8. What problems did you have in using the films to learn soldering?	
Necessity of repeating entire film to review one specific detail	12
Forgetting much of what had just been viewed on a film	5
Details of demonstrations too small to be seen clearly on film	2
Instructional segments too condensed and fast paced	2
Films too brief	2

APPENDIX D

Forms Used for Scoring Soldering Test

NAME: _____ RATE _____ DATE _____

PERFORMANCE EVALUATION

JOB FACTOR	PROCEDURE			SCORE
Preparation	(1) ☐ Checked tool box & selected tools	(2) ☐ Arranged work area		
Care of tools during exam -	(3) ☐ Cleaned and tinned iron before starting	(4) ☐ Kept iron properly tinned during work	(5) ☐ Kept tools clean	
Part removal	(6) ☐ Clipped out old parts	(7) ☐ Removed solder with tool correctly	(8) ☐ Removed lead ends correctly	
Care of Printed Circuit Board	(9) ☐ Used Circuit Board Holder correctly	(10) ☐ Applied no strain or stress	(11) ☐ Did not use excess heat when removing leads	
Preparation for soldering new parts	(12) ☐ Removed excess solder from holes/terms	(13) ☐ Cleaned board with solvent	(14) ☐ Cleaned leads of new parts	
Fitting new parts to Printed Circuit Board	(15) ☐ Formed leads with correct tools (18) ☐ Fitted parts to PC Board without heat	(16) ☐ Cut & clinched leads to terms w/ correct tools (19) ☐ Stripped wire insulation with correct tool	(17) ☐ Cut & clinched leads to pads w/ correct tools (20) ☐ Tinned wire ends	
Soldering new parts	(21) ☐ Used correct solder size	(22) ☐ Used correct soldering iron	(23) ☐ Used heat sink where necessary	
Cleaning after soldering	(24) ☐ Cleaned with solvent			

Performance Score _____

APPENDIX D (Continued)

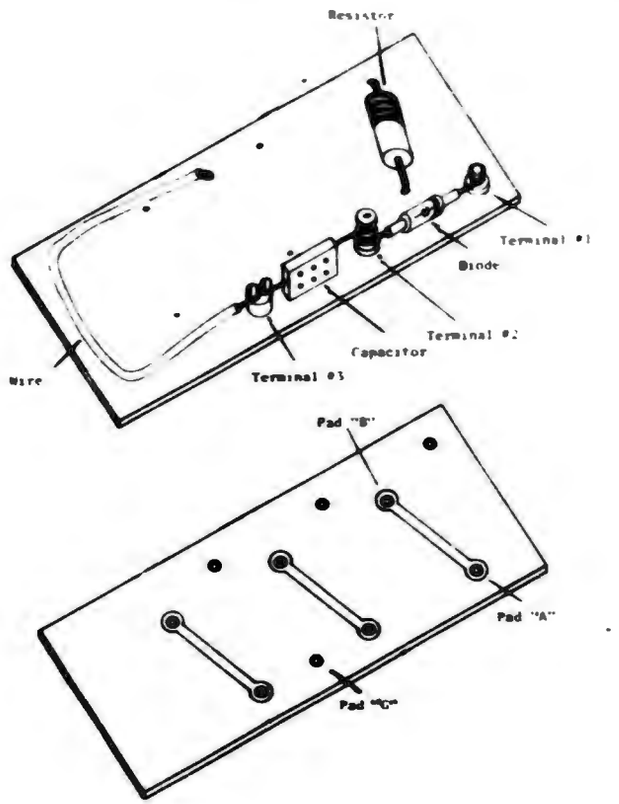
NAME _____ RATE _____ DATE _____

FINISHED PRODUCT EVALUATION

JOB FACTOR	ITEM										SCORE
	Pads				Terminals						
	A-B		C		1		2		3		
Lead length	1		2		3		4		5		
Lead bend	6		7		8		9		10		
Lead clinch	11		X		12		13		14		
Solder	15		16		17		18		19		
Area cleaned	20		21		22		23		24		
Heat	25		26		27		28		29		
	COMPONENTS										
	Resistor			Diode			Capacitor				
Position	30			31			32				
Lead dress	33			34			35				
	WIRE										
Wicking	36										
Strands	37										
Insulation	38										
Stripped length	39										

Product Score _____

SCORING: Write "1" in the block for each correct item, "0" for each incorrect or omitted item.



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13 ABSTRACT

As part of a larger program to determine which Navy skills can be learned by lower aptitude personnel and to ascertain what methods are most effective for accomplishing such training, an experimental course in printed-circuit-board soldering was administered to 186 Mental Group IV students in 13 classes. Two different training approaches--one stressing instructor guidance and the other featuring reliance on film viewers--were evaluated. Research data were obtained by means of questionnaires and both paper-and-pencil and performance tests. The soldering proficiency of the Group IVs was compared with that of experienced Navy technicians, and tests designed to measure transfer of the skills learned in the course also were constructed and administered to selected classes. The major research findings were (1) that Group IVs can learn the rather exacting skills required for a task such as printed-circuit-board soldering but require a considerably longer training period than other Navy personnel and (2) that the film-viewer method of training is an effective alternative to conventional methods of teaching soldering and was preferred by the Group IV personnel. Recommendations for implementing the research findings into Navy technical training are presented, and other current and planned research projects are briefly discussed. (U)

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