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ABSTRACT

The objective of this research was to develop and evaluate methods for producing training programs and job supports for Signal Corps Electronic Repairmen. The rationale for this study was: (1) identification of specific tasks is vital to effective training, (2) the decision-making function is critical, (3) it is possible to construct job aids and training which will allow the repairman to rely primarily on the decision-making mechanism of identification, and (4) troubleshooting information can be separated for storage in a job aid or in the individual. An analysis of existing electronic communication equipment was conducted, then the information was placed in job aids and used to develop a training program. The course was developed for 420 academic hours as compared to the standard of 856 hours for the conventional course. After 22 hours of testing over a 6-day period, it was concluded that there was no significant difference between the two groups and that the training and job aids provide an effective program method. (GEB)

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Technical Report 70-19

Development of a Training Program and Job Aids for Maintenance of Electronic Communication Equipment

by

Richard M. Gebhard

HumRRO Division No. 1 (System Operations)

AD ________

December 1970

Prepared for:

Office, Chief of
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Contract DAHC 19-70-C-0012

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HumRRO Division No. 1 (System Operations)
Alexandria, Virginia
HUMAN RESOURCES RESEARCH ORGANIZATION

Technical Report 70-19
Work Unit JOBTRAIN
Sub-Unit IV

The Human Resources Research Organization (HumRRO) is a nonprofit corporation established in 1969 to conduct research in the field of training and education. It is a continuation of The George Washington University Human Resources Research Office. HumRRO's general purpose is to improve human performance, particularly in organizational settings, through behavioral and social science research, development, and consultation. HumRRO's mission in work performed under contract with the Department of the Army is to conduct research in the fields of training, motivation, and leadership.

The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

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FOREWORD

The objective of the research described in this report was to develop and test a method for building training programs and their job supports for Signal Corps Electronics Repairmen. The work was done under JOBTRAIN IV, the final sub-unit of HumRRO Work Unit JOBTRAIN, in which an experimental training program for the 294.1 Carrier Equipment Repairman was developed, conducted, and tested. Other publications of JOBTRAIN are a series of Research Memoranda on *The Development of Training Programs for First Enlistment Personnel in Electronics Maintenance MOS's.* These memoranda are *I. How to Define Training Objectives*, July 1960; *II. How to Analyze Performance Objectives to Determine Training Content*, January 1960; *III. How to Design the Handbook Materials*, February 1960; and *IV. How to Design Training Methods and Materials*, February 1960.

The JOBTRAIN research IV was conducted in 1962 by HumRRO Division No. 1 (System Operations). A summary reporting of JOBTRAIN research was included in HumRRO Technical Report 66-23, *A Description and Analytic Discussion of Ten New Concepts for Electronic Maintenance*, by Edgar L. Shriver and Robert C. Trexler. Because electronics maintenance continues to be an important problem area, the present report, *Development of a Training Program and Job Aids for Maintenance of Electronic Communication Equipment*, is being published to document the research on the JOBTRAIN concept of maintenance training and job aids.

JOBTRAIN research was initiated by Dr. Arthur J. Hoehn while Dr. William A. McClelland was the Director of Division No. 1. Succeeding Work Unit Leaders were Mr. Richard Gebhard, Dr. Robert Vineberg, and Dr. Edgar L. Shriver. Dr. Hoehn succeeded Dr. McClelland as Director of the Division and Dr. J. Daniel Lyons was Director during the later phases of the research.

The research was performed and most of the report preparation completed while HumRRO was part of The George Washington University.

Cooperation and assistance were provided by the U.S. Army Southeastern Signal School during the period of research, and their personnel were primarily responsible for translating the methods of development into a practical training program that could be economically implemented. Mr. Leon Helmly supervised this activity, and was assisted by Mr. Peter Fransham in the preparation of the experimental lesson plans. Military personnel who provided technical assistance included M/Sgt George Fellmy, SFC Kenneth Skinner, Sgt. George W. VanDeventer, Sgt. Vincent Broderick, SFC Raymond E. Hovendick, SFC Nathaniel Spotser, SP/4 Joseph T. Douponce, S/Sgt Hobert E. Peters, S/Sgt James F. Craig, SFC James B. Stites, and S/Sgt Matthew J. Degutes. Other military personnel who helped conduct the testing were under the direct supervision of Mr. Robert Thompson, Chief Instructor of the 294.1 Carrier Equipment Repair Course.

Special acknowledgment is due Mr. Norman B. Carr, Educational Advisor to the Commandant, who provided cooperation and assistance in selecting personnel and in arranging, coordinating, and marshaling the efforts of the Southeastern Signal School in support of this research.

HumRRO research for the Department of the Army is conducted under Contract DAHC 19-70-C-0012. Training, Motivation, Leadership Research is conducted under Army Project 2Q062107A712.

Meredith P. Crawford
President
Human Resources Research Organization

SUMMARY AND CONCLUSIONS

OBJECTIVE

This study was designed to develop and evaluate methods for producing a combination of training and job aids (manuals) for maintenance of electronic communication equipment that would require less training time than the standard course and manuals.

APPROACH

The specific training program subjected to study was that for the MOS 294.1 Carrier Equipment Repairman at the U.S. Army Southeastern Signal Corps School, Fort Gordon, Georgia.

The basic rationale of the JOBTRAIN approach is:

(1) That efficient and effective training can be designed and evaluated only if the specific tasks required by the job are identified.

(2) That the decision-making function is critical to many electronics maintenance tasks.

(3) That it is possible to construct job aids and training which will allow the repairman to rely primarily on that decision mechanism which human beings perform best, that is, identification.

(4) That it is feasible to separate troubleshooting information into information (equipment-specific) best stored in a job aid and information (general) best stored in the individual through training.

The objective was approached through an analysis of existing electronic communication equipment. This analysis produced a standard strategy for troubleshooting the equipment and the specific information (meter readings and other indications) for supporting and executing that strategy.

The information developed from the equipment analysis was placed in job aids and was used to develop content for a training program. The information, produced by expert repairmen using the guidelines prescribed in this report, capitalizes on the aptitudes and experiences characteristic of the typical repairman. In turn, the amount of abstract electronics theory given in the training course can be reduced and more attention can be devoted to those theories which facilitate performance. This approach also makes it possible to provide more practice on real equipment (using the job aids).

The method of analysis developed in this project was applied to the 10 items of equipment maintained by the 294.1 MOS by experienced MOS 294 repairmen operating under the guidance of JOBTRAIN personnel. Job aids and a course of instruction were prepared by the same personnel. The course was 420 academic hours, as opposed to the standard 856-hour course for the same MOS. The equipment was in use no more hours than in the standard course. The JOBTRAIN course was conducted in the main, by the same personnel who made the analysis.

Graduates of the JOBTRAIN course were required to troubleshoot 18 malfunctions placed in the various items of equipment during a six-day period. They were also tested on their ability to align, remove, replace, name, locate, and make final tests on the equipment. In Sub-Unit JOBTRAIN I, a field survey in Europe had indicated that men in the field should be able to perform at a certain level on a test of this type in order to meet minimum field requirements.

Graduates of the conventional course, matched to the JOBTRAIN students in background and aptitude factors, were tested on the same test at the same time. Testing was administered by a special group of school instructors. No judgments on quality of student troubleshooting performance were required of the administrators; all troubleshooting was merely recorded as correct or incorrect, depending on whether the student correctly identified the malfunctioning part. The other tests of student ability required some judgment on the part of administrators but there was not much latitude.

RESULTS AND CONCLUSIONS

The results of 22 hours of individual testing during a six-day period showed no significant difference between the two groups in any area. It is concluded that the combination of JOBTRAIN training and job aids is as effective for the 294.1 MOS as conventional school training and manuals and that a 50% reduction in academic hours can be achieved by this combination.

CONTENTS

Development of a
Training Program and
Job Aids for Maintenance of
Electronic Communication Equipment

INTRODUCTION

There are three major aspects of the Work Unit JOBTRAIN approach to electronics maintenance:

(1) The Field Survey (JOBTRAIN I)
(2) Functional Context Training
(3) Job Aids (special manuals) based on Equipment Malfunction Analysis.

The field survey was used to structure the end-of-course performance test, and did not directly affect the training to any significant degree. It provides information for making equipment failures in the JOBTRAIN IV performance test like the failures in the field, and an estimate of how well a person should perform on the test in order to fulfill field performance requirements.

Functional context training is a way of introducing theoretical knowledge in the context of practical troubleshooting—as the knowledge is needed for execution. Functional context training was developed and used in previous research for the Signal Corps and has had varying degrees of influence on electronics courses at both Signal Corps schools. This training approach is appropriate for use with conventional content as well as the content of the JOBTRAIN course. It is of particular note that the major reductions in JOBTRAIN training time are *not* attributable to this aspect of the approach. Implementation of some degree of functional context training, although it has some value in its own right, would not constitute implementation of JOBTRAIN.

Job aids, or special manuals, used in the course are derived from an equipment analysis which determines a troubleshooting strategy for the equipment analyzed and generates the specific information needed to support that strategy. The strategy and the information to support it are incorporated in the special manuals (job aids). It is this aspect of the JOBTRAIN concept which accounts for the major reductions in training time obtained in the study. This is the result of deleting most of the circuit theory from the course which the conventionally trained man is expected to use to generate both his own troubleshooting strategy and the specific information to support his strategy.

The equipment analysis is similar to the analyses developed in other research by HumRRO, the National Bureau of Standards, and private industry. All of these concepts require changes in technical manuals. The JOBTRAIN IV study represents an experimental implementation of the approach common to all these concepts.

This is a report of the type of equipment analysis developed in JOBTRAIN IV, and describes the type of functional context training used with the job aids, or special manuals. The report also gives the results of tests conducted on graduates of the JOBTRAIN IV program and the standard training program for Military Occupational Specialty (MOS) 294.1, Carrier Equipment Repairman.[1]

[1] Now MOS 101-31L20, Radio Relay and Carrier Repair.

Chapter 1

WHAT THE ELECTRONICS REPAIRMAN DOES

Electronics maintenance repair is characterized by a wealth of job-oriented behaviors, most of which can be treated within one of three major classes: (a) *mechanical behaviors*, such as the disassembly and/or assembly of components, the removal and replacement of piece parts, and soldering; (b) *operator behaviors*, such as energizing the system, energizing components apart from the system, switching and monitoring; (c) *decision-function behaviors* upon which each choice of action is based. The selection of a particular test, or a decision to replace a particular part are examples of job-oriented behaviors within the third classification.

THE DECISION-MAKING FUNCTION

Among maintenance behaviors, those relating to the decision function stand out as primary contributors to system maintainability. This is true even though the mechanical skills necessary to effect a repair, once the malfunctioning piece-part is identified, must always be present. For electronic systems, it is usually the diagnosis rather than the part replacement that accounts for the largest portion of the system "down time" for which the repairman bears responsibility.

Decision making has both an active and a passive aspect. Information, stored and recalled as needed, comprises the passive aspect. Sensing, recognizing, and interpreting events comprise the active aspect. Although the active aspect always implies a man, the passive need not. Information can be stored separately from the man in job aids such as books, charts, tables, and written formulations.

The information stored inside the man himself is referred to as experience. The formation and modification of experience is the province of training. Training must take into account the nature and amount of information available in job aids, because this will always determine the nature and amount of experience which must be provided.

Job aids well-mated to experience can simplify training and keep the performer operating at a level of complexity where error is not excessive. Job aids and experience that are mismatched can make performance very costly in terms of both error rate and the time required to train. Because of this effect, a closer examination of the experience and actions demanded of the decision maker is in order.

COMPONENTS OF THE DECISION PROCESS

In Gagne's (1) treatment of the relationship between human information processing and action, the active aspect of decision making is represented by the sensing, filtering, identifying, interpreting, and inventing mechanisms, while the passive aspect is represented by the long and short term memory.

Among the active components, not all mechanisms are performed equally well. In general, human beings are very good at *sensing* and *filtering* events even though machines capable of sensing and filtering some types of events much more finely than human beings have been constructed.

With respect to the *identification mechanism*, however, man still shines. The brain has a high tolerance for input variations within a class. It also has rapid access to comparative data whereas a machine programmed to identify has to sort through its entire memory in serial order. The machine may also reject or misclassify events that are only slightly different.

When the human *interpretation mechanism* is utilized, performance costs in terms of increased error rate can be considerable. When required to make interpretations, human performers tend to jump to conclusions based on an inadequate number of observations, tend to overlook data and possible interpretations even when these are available in the long term memory, and tend to make mistakes even when the necessary inferences are prescribed by a set of rigidly defined rules.

The term "inventing" stands for a highly regarded function in our society but, in practice, the employment of the *inventing mechanism* is quite inefficient. To be characterized within this class, the formulation of rules, approaches, or "short cuts" need only be novel with respect to the person concerned. To more sophisticated persons, these rules and approaches may be trite or inefficient. In almost every case, the inventing function is essentially a trial-and-error process.

The decision-making process can be illustrated further by examining the way in which it is called into play in troubleshooting electronic equipment. For example, at some point in the repair process, it may be necessary to examine the output, displayed on an oscilloscope, of a small collection of parts. The decision function commences when the repairman directs his attention toward or *senses* the oscilloscope display. *Filtering* is employed when some instruction, such as "ignore the envelope and look for the synchronization pulse," is called from the *short term memory*. At this point, comparative information is extracted from the *long term memory* in the form of synchronization pulse characteristics. Using this comparative information, the sensed and filtered event is *identified* as a good synchronization pulse, or as a distorted or missing pulse.

The next step in the process requires an *interpretation* of the event by applying a set of rules to the class of events identified. If he has been conventionally trained, and if he is using conventional job aids, a set of rules for making an interpretation will not be directly available. Instead, the job aid will provide the repairman with a description, in the form of a schematic, of the way in which the equipment is constructed. On the basis of this information, the repairman must, using his experience, formulate his own set of rules for treating the event he has identified.

Note that the traditionally trained repairman must, in effect, reconstitute circuits in his mind, working backward from the symptom he identified to the altered circuit characteristic that could result in this symptom. This is human functioning of the highest order and is equivalent to, in some cases, the inventing mechanism originally required to design the circuit. It is also expensive, since training time as well as error rates become excessive when the more complex decision-making mechanisms are the rule.

Human beings perform the identification mechanism well. If job aids and training could be so constructed that the greatest burden of decision making during troubleshooting falls on the identification mechanism rather than upon the interpretation and inventing mechanisms, it seems reasonable to expect that training efficiency and effectiveness could be enhanced. An investigation of this possibility represents the part of the problem studied in JOBTRAIN research.

The behavior of repairmen in the field suggests that the identification mechanism is being employed on a more or less haphazard basis. An experienced maintenance supervisor, when assisting a novice, is likely to provide cues to the type of information he himself uses to solve troubleshooting problems. He tends to say things like, "Didn't you notice that the alarm unit is not functioning properly?" or "Didn't you notice that the manual regulator control has no effect?" Apparently he has learned, over the years, to recognize certain "diagnostic" consequences that are characteristically associated with certain classes of failure. This may be how repairmen have improved their performance as they gained experience on the job. Perhaps they have been reprogramming their long term memories with an array of symptom-part relationships, and are then choosing the part to be investigated through the application of the identification mechanism.

The experienced technician, once a defect has been repaired, can always produce a theoretical rationale to suit the situation. The multiplicity of competing analyses (often defended at great length and with a good deal of heat) produced by three or four technicians who are jointly considering an as-yet-unsolved problem suggests that the solution may lead to the rationale rather than vice versa.

WHERE TROUBLESHOOTING INFORMATION SHOULD BE STORED

In electronic systems, the task of spelling out and inserting into a job aid a specific solution for each contingency would expand geometrically as each choice point was examined, proceeding from the over-all system down to the specific piece-part. The tremendous cost of job aid storage for this amount of information would include the increased error rate that undoubtedly would result from the difficulty of navigating such an elaborate and voluminous job aid.

Fortunately, it is possible to separate information about electronic failures into that which is true of only one equipment or subequipment and that which is true of any equipment. This makes a very convenient basis for dividing the information to be stored. Thus, job aids might be used to store items such as:

> For system B, if the scope tracing is distorted and the amplitude level is low even though the system alarm lamp does not light, part X or Y or . . . Z may be at fault.

Long term memory storage, on the other hand, might be used for items such as:

> For any amplifier at all, if it has no output, check the B+ parts, coupling capacitor, etc; whereas, if it puts out a distorted wave shape check the grid leak, cathode resistor, etc; whereas, if it has low amplitude . . . etc.

The job aid need not reveal how System B functions, nor is the long term memory concerned with how amplifiers function. Each deals, respectively, with the ways in which System B does *not* function or the ways in which amplifiers do *not* function.

Job aids that reduce job complexity often meet with a great deal of resistance from practitioners schooled in older techniques. The motivation underlying resistance seems to lie in the notion that a job aid de-values the contribution of the human being.

In the case of electronics maintenance, even the engineer who has designed a circuit will refer to schematics and notes in addition to technical source books when troubleshooting that circuit (unless the circuit is small and simple, in which case troubleshooting is not much of a problem). The aim of job simplification through the use of job aids is not to reduce the man to the status of an automaton. The repairman can and should be taught highly theoretical material *if this material will help him recognize general classes of part failure.*

SUMMARY OF RATIONALE

The rationale of this study is:

(1) That efficient and effective training can be designed and evaluated only if the specific tasks required by the job are identified.

(2) That the decision-making function is critical to many electronics maintenance tasks.

(3) That it is possible to construct job aids and training which will support the repairman in that decision mechanism which human beings perform best, that is, identification.

(4) That it is feasible to separate troubleshooting information into information (equipment-specific) best stored in a job aid and information (general) best stored in the individual through training.

Chapter 2

THE CONSEQUENCES OF MALFUNCTION

ANALYSIS OF FAILURE EFFECTS

In Work Unit JOBTRAIN a method of analyzing existing items of electronic communication equipment was developed. When applied by appropriate personnel (experienced 294.1 technicians were used in the research), this method produces a troubleshooting strategy for the analyzed equipment and the specific information (e.g., indications, voltage readings) to support the strategy. This strategy and the specific information are placed in a job aid (manual) to guide the maintenance man on the job. The man on the job does not "invent" strategies or reconstitute circuits in his mind, but follows the guidance already worked out by experts. His job involves more recognition, filtering, sensing, and especially identifying, rather than interpreting and inventing.

The JOBTRAIN analysis requires the consideration of certain effects of failed parts. The effects which are considered are those that (a) produce a discriminable effect without special test equipment (e.g., failure of a buzzer to sound), and (b) changes at built-in checkpoints in the equipment. Senior electronics maintenance men, who are familiar with the subject equipment, must consider each piece part in turn and record the effects that the part produces when it fails (shorts or opens).

A matrix can be formed with the piece parts on one dimension and the effects produced on the others.[2] Some effects will be produced by any one of 100 parts, others by 50 parts, still others by fewer parts. The objective of the collation is first to select main effects which divide the equipment into mutually exclusive major groups of parts and, second, to find effects which subdivide these groups. Judgment is required in deciding which effects to use. There will be redundancy, in the sense that there will be an overlap in the parts that produce the two effects.

When the process is completed a network of effects is produced. The effects are then collated and organized in a hierarchy. The hierarchy of failure-effect relations is shown in Figure 1.

SYMPTOM PATTERNS

The symptoms illustrated in the example have been organized into non-redundant pattern groupings. Total configurations (with certain symptoms present or absent) can be just as diagnostic as a completely new symptom.

The symptom "low B+," for example, might very easily group with "60 cycle hum." If the equipment has both a meter to indicate B+ level, and an audio output, these two symptoms can be obtained almost simultaneously. It is possible that these two symptoms can divide suspect piece parts into not two but three separate collections. One collection might give rise to "low B+." Another collection might have satisfactory B+ but "60 cycle hum." The third class would be those parts resulting in both "low B+" and "60 cycle

[2] See Appendix A, Generating a Failure Effect Analysis, and Appendices B and C for a full description of how to turn the failure effect analysis into a checkout procedure.

hum." As other easily obtained symptoms are added to this pattern, it is possible for suspect piece parts to be divided into a number of separate collections. The more collections, the fewer will be the piece parts in any single collection.

In practice, it is seldom true that all possible configurations lead to separate collections of suspect parts. Usually, however, enough configurations can be obtained to result in at least twice as many collections as there are symptoms observed.[3]

The groups of parts which are identified in this process do not necessarily have any functional relation to each other, such as all in the same stage. This research task abandoned a form of analysis in terms of functional entities at an early date.[4] Two or more elements of a complex equipment having vastly different functions may form a malfunctional entity because they have common consequences, while elements in a common functional entity may have quite different malfunctional consequences.

This means that it is the *failed* rather than the functional equipment with which the repairman must deal. The collection of malfunction-consequence lore must therefore be preceded by an identification of malfunctional entities. To do this, it is necessary to work forward from the actual or hypothesized part failure to the system consequences, rather than backward from a function to the parts which determine that function.

There is another reason for proceeding in this fashion. Standing between the person doing an equipment analysis and the identification of a truly comprehensive set of failure effects is the set of notions about function which he carries with him into the analysis. Such notions can close his mind to the wealth of symptoms which malfunctions generate. Thus, instead of speculating on the parts which could result in a given consequence, the analyst determines what the consequences of each particular part failure would be.

The various effects identified in the analysis are organized in a manual for the repairman on the job, which lists the effects to be observed in a checkout sequence as they would be produced during the checkout procedure. The manual is made up of numbered paragraphs rather than the hierarchy shown above. Depending on the effects found in accordance with each paragraph, the troubleshooter is referred to another paragraph. If a bad effect is detected, the reference is to a subtest to further narrow the locus of the bad part; if the effect is good, the troubleshooter goes to the next paragraph in the main (turn on) sequence. The paragraphs are in terms of "main tests," "subtests," and "sub-subtests."[5] The JOBTRAIN manual is in words rather than diagrams, color blocks, or charts. The words refer to effects to be observed or measured. The repairman must learn the techniques for measurement and the nature of the things to be observed.

When the troubleshooter does complete the listed tests and observations, *all* the parts which can cause these effects are listed. The effects in the last box in the hierarchy are common to only one small group of parts, that is, two to 30 on the average. Parts in the last box were ordered on the basis of their likelihood of failure. To provide tests that identify the individual piece part in the same manner the list of parts is identified, would increase the bulk of the job aid many times over.

[3] Care must be taken to ensure patterns are not emphasized to the point where observations which could really only be obtained in a temporal sequence are gathered into a "pseudo" pattern. The general rule for including observations within a single pattern is—group together those symptoms which can be obtained at one time (with relative ease).

[4] For an approach based on functional entities, see BAMAGAT® Manual by Field Service and Support Division, Hughes Aircraft Co., Los Angeles.

[5] This type of hierarchy of effects is presented in four different formats under the HumRRO Work Units JOBTRAIN, FORECAST, and MAINTRAIN, and in the BAMAGAT® manual. Each format has its own characteristics, which are described in HumRRO Technical Report 66-23, *A Description and Analytic Discussion of Ten New Concepts for Electronics Maintenance* (2).

Hierarchy of Failure Effect Relations

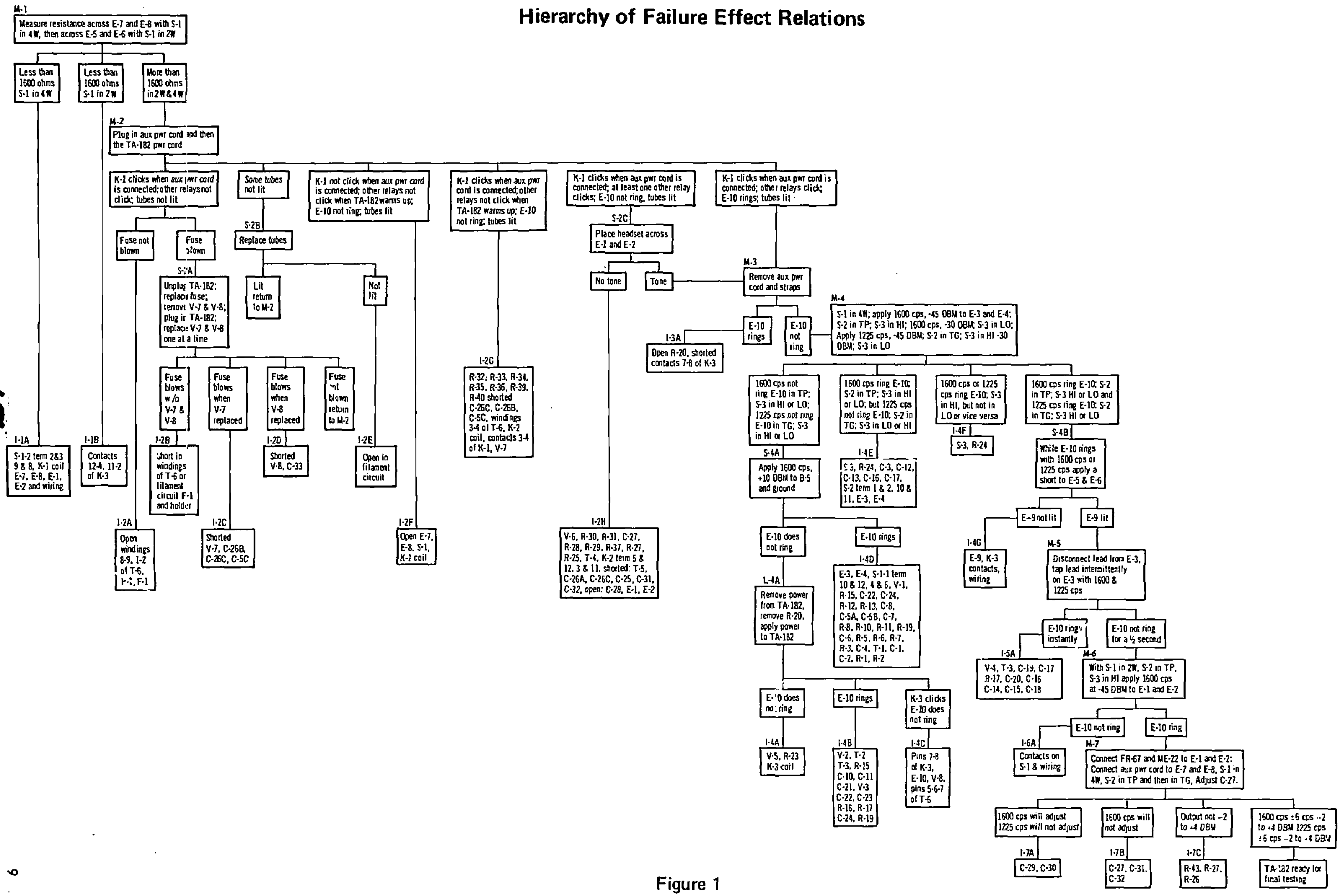

Figure 1

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Two types of failure effects can be defined: (a) *system-specific* symptoms (to be put in job aids), and (b) *system-independent* symptoms (to be covered in training). It is desirable to generate as many system-specific symptoms as possible because, in general, the more such symptoms employed the fewer suspect parts remain. System-specific symptoms are of especial value in the case of electronics troubleshooting because system-independent troubleshooting frequently requires the attachment of special test gear, disassembly of the system and sub-units, or substitution of suspected parts.

DESIGNING A CHECKOUT PROCEDURE

The job aid derived from the failure effect analysis is meant to support the recognition of system-specific symptoms without the aid of parallel training. It must, therefore, be clear, concise, easy to follow, and complete as far as system-specific symptoms are concerned.

An observation-consequence checkout such as the one illustrated cannot be small in bulk and still outline a separate procedure for troubleshooting down to each possible malfunctioning part. The number of such troubleshooting procedures tends to increase geometrically as one progresses from the most global to the most specific type of symptom. For this reason, the illustrated job aid does not attempt to present more than the first four or five troubleshooting steps. If enough system-level symptoms have been generated by the failure effect analysis and if these symptoms have been organized into an efficient pattern, four or five steps should be sufficient to carry job aid support well beyond the system-specific level to individual piece-parts or groups of parts. To insure completeness, all those parts which could—by even the most remote possibility—result in a specified symptom pattern are listed in the observation-consequence checkout.

Chapter 3

PROGRAMMING THE LONG AND SHORT TERM MEMORY

ORGANIZING TRAINING CONTENT

The derivation of job-oriented objectives employed in this research has been described in Chapters 1 and 2. These objectives may be grouped in the following categories:

CONCEPTS—For this purpose, a concept is defined as the designation of a class of events to which a common response is required. An example of a concept is the statement, "If an amplifier has a distorted wave shape, check the input capacitor, grid lead resistor, etc." Another lower-level example is the symbolic use of color to designate digits (black stands for zero, brown stands for one, red stands for two, etc.).

PROCEDURES—A procedure is a sequence of prescribed operations. The steps involved in setting up an oscilloscope are an example.

DISCRIMINATIONS—A discrimination is the separation of a group of similar events into two or more subclasses. The recognition of a distorted, as contrasted with a normal, sine wave on an oscilloscope is an example of a discrimination.

MOTOR SKILLS—Motor skills are the eye-hand coordinated activities required by the job. Soldering, aligning, and tuning fall into this category.

The analysis of training objectives into the above four categories was followed by the construction of an outline which assigned to each lesson mastery of a portion of these training objectives. This outline was planned to ensure that the objectives of each portion of training were clearly defined and that they were attainable. Appropriate training techniques were then selected for achieving them.

Lesson sequences ordered on the basis of the way in which tasks are performed in the field seem to be more efficient than other sequences. In particular, the structuring of training to proceed from the whole to the part rather than vice versa (given the name "functional context") has shown promise (3). Functional context sequences differ from conventional electronics maintenance training sequences, which require the learning of abstract principles before instances of their application have been provided and which do not introduce the trainee to the total system until training is well advanced.

Use of "functional context" dictates that the trainee first learn how the system functions, how to set up preliminary checks and actions, and how to identify abnormal function. Such activities are high level in terms of the system, but low level in terms of the skills involved. They are routinely performed by the experienced repairman. In addition to requiring little skill, such activities tend to be the first troubleshooting tasks required on the job. Thus, functional context permits the trainee to work on the system at a very early stage of training, acquiring more sophisticated skills as time goes on.

SPECIFIC TRAINING TECHNIQUES

The following are additional techniques that were employed in developing the training program:

(1) Obtain a response—When a skill level rather than mere familiarization is the objective, learning is greatly enhanced if at least one appropriate response is obtained.

(2) Associate the response with the work setting--A response is most likely to occur within a setting similar to the one in which it was learned. Therefore, a work setting context should be provided for those responses which the graduate will be required to make in the field.

(3) Introduce background content within the context of the appropriate work settings—Those features of the job situation which require specific solutions provide an ideal work context for obtaining responses which provide solutions. Thus, the cues necessary for remembering the correct response will be associated at the appropriate time and place with the job.

(4) Teach the whole before the part—Motivation to learn is greater when immediate application is possible. Although an electronic system becomes more complex as one progresses from the part to the whole, the amount of information required to understand it becomes less complex. "What the whole system does" tends to be simpler and easier to understand than "the way in which it does it." Thus, whole to part training can proceed from the simple to the complex. Finally, proceeding from whole to part makes it easier to provide a work context for new training.

(5) Repeat important responses—If skill levels do not approach required levels, more practice is needed. A good way to provide this practice is to present the trainee with additional "functional context" situations which require the desired response.

(6) Provide for over learning—Human performance capability deteriorates over time unless practice is maintained. In order to compensate for this effect, it is necessary to raise skill levels to a slightly higher level than that required by the job so that forgetting will not cause performance deficiency.

Worth mentioning are some further principles observed in the construction of the experimental lessons. For instance, learning tends to be enhanced if practice units are of such scope and difficulty and are so sequenced that trainee errors are kept at a low level during the training process. It is also advantageous to have each learning or practice unit sufficiently extensive in scope so that its completion will represent and can be perceived by the trainee as a meaningful subgoal. If content is artificially fragmented for purposes of training, practice should be provided consolidating the fragments into the whole performance. Training and practice should also be structured so that it is possible for the average trainee to complete them. Very little is accomplished by material which is so difficult that only a small portion of the class can successfully complete it.

EXAMPLES OF COURSE MATERIALS

Appendix D contains a prototype conference lesson plan constructed for this research. It illustrates the way in which some of the training techniques listed above can be employed, especially for system-independent information. The format employed promotes instructor spontaneity and initiative, by providing a set of questions to be asked and answered. Instructors may augment this material in any way they see fit as long as each of the questions is asked and answered (either by the class or by the instructor if the class cannot answer it).

Controlled labs and practical exercises provide another major training vehicle. Practical exercises are especially important because a major portion of the theoretical material taught is to be presented within the context of carefully selected practical exercises. Appendix E illustrates a controlled lab lesson as well as a practical exercise critique.

Trainees begin their first controlled lab by checking out the system (whole to part). After practice on this checkout, troubleshooting is performed down to easily located defects such as burned-out lamps and blown fuses. This practice is continued until a problem is presented which requires more skill than the trainee has acquired. At this point, the instructor, using the controlled lab technique, introduces new theoretical material, to enable the trainee to complete the problem successfully.

After a controlled lab session, trainees work a number of practice exercises requiring recently acquired theoretical material (repetition). Practical exercises are selected to illustrate variations of general principles. After each practical exercise, trainees are required to fill out a sheet stating what has been done. If the problem has not been correctly solved, the trainee is told to keep working. If successfully completed, four specific questions about the problem are asked. Each trainee either answers the same four questions correctly or is told the correct answer.

The controlled lab together with the practical exercise critique constitute a major means for storing troubleshooting information in the long and short term memory.

To facilitate administration, practical exercises are distributed at random throughout the entire training program. Thus, no trainee attempts all of the practical exercises associated with a particular controlled lab immediately after that controlled lab is completed. Instead, each trainee does one or two exercises (not necessarily identical). Remaining exercises are presented in subsequent lab sessions. This ensures that the trainee will continue to rehearse skills previously learned. It also prevents him from concentrating only on those types of troubles which have been covered in the immediately preceding controlled lab.

Chapter 4

TECHNIQUES FOR EVALUATING THE EFFECTS OF TRAINING

EVALUATION TECHNIQUES

A number of techniques have been used for estimating the impact on field performance of a given training program. At one time it was felt that nothing was better than a field follow-up that evaluated men in the job setting. In recent years, however, it has become evident that a field follow-up has some major disadvantages, at least for use in military systems.

It is difficult to get the graduates of an experimental training program assigned to a specific job. Even when assignments to particular units by name are requested, experience has shown that a significant proportion of the men will be lost in the pipeline Those experimental trainees who arrive at an appropriate unit are subject to the unit commander's prerogative to assign a man to duties other than those related to his MOS. If the man is assigned to a job related to his MOS, he may act only as an assistant, helper, or supply runner. Finally, a man performing the duties of his MOS may still have a very selective experience on the job because the unit to which he is assigned uses only a portion of the equipment on which he has been trained. Field follow-ups, for these reasons, are not very useful and they are difficult and expensive to administer.

Another means for estimating field performance is the end-of-course test administered within the school setting. This also has some serious drawbacks, one of the most important being lack of evidence supporting a relationship between the test and the performance of the graduate in the field. Another drawback is a tendency for end-of-course tests to be based on what is taught rather than on what the man must do on the job.

Ratings by supervisors, instructors, or peers; questionnaires administered to supervisors, instructors, trainees, or peers; direct observation within the normal work setting; written tests; performance tests, work samples (a special case of performance tests)—all have been used to estimate job performance with varying success.

One of the primary objections to ratings is that they do not measure reliably (4). The problem is not that judgments are poor but that they are not consistent. Without consistency it is impossible to separate ratings which are good judgments from those which are not. In addition, it has been shown that supervisor and instructor ratings of capabilities tend to be strongly influenced by other kinds of factors such as the trainee's personal appearance, demeanor, tardiness, or absence from the job.

Questionnaires have been proposed as a means for overcoming the influence of non-job-related factors on ratings. Unfortunately, different persons tend to interpret the same question in different ways; even for a single individual, interpretations differ over time depending on the particular framework within which the question is approached. Also, questionnaires are never all returned from the field, and it is impossible to estimate the significance of those not returned.

A long period of direct observation would be necessary to get a representative sample, since some things occur in the field often and others infrequently. For this reason, direct observation tends to be expensive, and the work sample observed may be biased.

Written tests tend to be more reliable than almost any other measure. Unfortunately, it has been shown that they do not tend to be strongly related to performance on the job (5, 6). Persons with high verbal ability tend to score higher on written tests than do persons with low verbal ability, even though they are equal in terms of job performance. Even when the verbal component is disregarded, written tests often seem to reflect what is taught more than what a man can do.

Performance (as opposed to written) tests sometimes reflect performance in the field more strongly than do other tests. They tend to be long and expensive because of the amount of time necessary to administer each item. However, even though the cost is high, it can be afforded for use in testing experimental programs. Previous experience has shown that shorter, less expensive tests can be drawn from a long test for operational use.

THE SAMPLING PROBLEM

Performance tests are sometimes unreliable because of the small number of items that can be administered within given time limits. One solution is to part score (by grading segments of the total job). But part-scoring or part-task items which are independent of the kind of training are hard to come by. To part-score an item, it is necessary to score the specific procedure or steps through which the repair is made. This is usually not appropriate because there may be many ways of approaching the problem, thus penalizing a man for choosing one way rather than another. Even when it is appropriate to penalize a particular route, it is difficult to know how much of a penalty to apply. The problem of appropriately "weighting" the various parts of the job is difficult and subject to considerable unreliability itself.

Since in the case of electronics maintenance jobs it is not possible to test a man on every situation which can possibly arise, a small group of items must be used to represent all. How should this small group mirror the frequency with which item types occur on the job and how should it mirror the *types* of items which occur?

If frequency is represented, the time limitation will restrict the range of content sampled. A few items occurring frequently can result in exclusion of critical though rarely occurring items. An item occurring only 2% of the time on the job would not be represented among 30 or 40 work sample items selected for frequency of occurrence.

If content is represented, special problems arise which are independent of the error resulting from obscuring frequency. An item which represents a class of job tasks for one training program may represent, for another training program, a completely different class of job tasks. The way in which the job is divided can very easily bias the test in favor of only a portion of all possible training approaches. In most cases this will also result, for certain training programs, in a gap in job coverage in the test. Under such circumstances the test designer should make every effort to demonstrate that test categories exhaustively represent job categories, that is, items should intercorrelate highly within categories and minimally across categories, and every job task should be represented by a test category.[6] Even under these conditions, the test should be used only with the reservation that it may not, for certain training programs, sample the overall proficiency of the trainee.

[6] For examples of tests of electronic maintenance which individually measure men on a large job sample see 7, 8, 9, 10.

ERIC

A JOB-RELATED TEST FOR EVALUATING CARRIER EQUIPMENT REPAIRMEN

For this research, the decision was made to construct a job-related test that would sample as many different aspects of the total job as possible in a six-day period. Accordingly, content was represented at the expense of frequency. Inasmuch as carrier equipment repairmen (MOS 294.1) work on a number of equipments, however, it was possible to represent frequency, to a certain extent, by assigning work sample problems to equipments on the basis of the frequency with which these equipments are encountered in the field.

The major job categories represented by the job-related test were based on an extensive survey of the activities of carrier equipment repairmen in Europe conducted by Hoehn and McClure (11). Four major job categories were represented in the work sample: (a) troubleshooting, (b) maintenance, (c) removal and replacement, and (d) final test and alignment. These categories were further subdivided.

(1) Eighteen *troubleshooting* problem sub-categories (Figure 2) were selected to be administered to each person tested. Three problems were selected within each sub-category to provide three alternative versions (A, B, and C).

Carrier Equipment Repairman Training Program Criterion Measure

Carrier Equipment Troubleshooting Items for Alternate Forms A, B, and C

(1) Shorted Modulator Varistor
(2) Open in Coupling Transformer
(3) Shorted Tuning Capacitor in Oscillator Circuit
(4) Open Plate Supply Resistor in Amplifier Circuit
(5) Open Relay in Power Supply Switching Circuit
(6) Mistuned Filter in Transmit Circuit

(7) Open Plate Supply Resistor in Limited Amplifier Circuit
(8) Open Transformer in Demodulator Circuit
(9) Grid to Plate Short in Variable Resistance Control Tube
(10) Missing Pin in Inter-Panel Cable Connector (Transmit Circuit)
(11) Short Decoupling Plate Capacitor in Signal Rectifier Circuit
(12) Open Modulator Varistor

(13) Open Resistor in Impedance Pad
(14) Detuned Capacitor in RF LC Circuit
(15) Open Filter Choke in Power Supply
(16) Shorted Secondary Tuned Coupling Transformer
(17) Open Power Switch
(18) Low Emission in Signal Detector Diode

Figure 2

In order to increase the number of troubleshooting items which could be given, the troubleshooting process for 16 of these sub-categories was carried only to identification of the bad part replacement. Two of the 18 items were administered as "solder" problems (replacement was required). For these problems, the trainee was given additional time, but he was required to make a repair and return the equipment to operating condition before being scored correct on the problem.

Many carrier equipments are composed of a number of interconnecting chassis or "panels." To evaluate whether repairmen are handicapped by not knowing in which panel the defect lies, each problem was administered "blind" a certain portion of the time. For the "blind" administrations, a problem was presented within a complete equipment without identifying the defective panel.[7]

(2) Five additional sub-categories of *maintenance* items were used:
 (a) Installation and hook-up.
 (b) Equipment check out.
 (c) Equipment test and adjustment following hook-up.
 (d) Preventive maintenance.
 (e) Alignments.

Three installation and hook-up items, two equipment checkout items, three equipment test and adjustment following hook-up items, two preventive maintenance items, and one alignment item were included in this section of the test. Even though listed as single test items, some of them, such as equipment test and adjustment following hook-up, represent a number of procedural steps.

(3) Removal and replacement items in the order of increasing difficulty and/or number of steps required to complete were:
 (a) Crystals; electron tubes; lamps plug in assembly; protector block.
 (b) Binding posts; capacitor, small, fixed, two lead; coil, small, 2-leads; fuse holder; lamp holder; resistor, 2-lead.
 (c) Capacitor, large can type 2 or more leads; coil, large, 3 or more leads; connector, 3 to 5 terminals; equalizer; filter; potentiometer.
 (d) Connector, 6 to 10 terminals; relay, 6 to 10 terminals; switch, rotary or toggle, 6 to 10 terminals; transformer, 6 to 10 terminals.
 (e) Connector, 11 to 40 terminals; wafer switch, 11 to 40 terminals.

(4) Final test items[8] were selected at random from the *final test and alignment* section of Carrier Equipment technical manuals. Five items were selected for administration to each person tested. Each final test item required the successful completion of a number of procedural steps.

PERFORMANCE STANDARDS

The following things were done to develop a set of standards based on the tasks required by the job.

(1) A comprehensive list of job tasks derived from the terminology in various technical manuals was compiled in three sections: troubleshooting tasks; removal and replacement tasks; and remaining tasks such as preventive maintenance, final tests, and alignment.

(2) This list was then submitted to experienced repairmen for review. The reviewers were asked to add any tasks which had been omitted but which they believed to be relevant, remove any tasks which men in the MOS would not be required to do, and—in the case of non-troubleshooting tasks—substitute the name of a single task for two or more tasks which were similar enough to be considered one.

[7] Only equipments which were composed of two or more panels could be used for "blind" administrations. Specifically, the AN/TCC-7 telephone carrier terminal, the AN/TCC-4 telegraph carrier terminal, the AN/TCC-3 telephone carrier terminal, and the AN/TCC-8 telephone carrier repeater were used for "blind" administrations.

[8] The term "final test" is one used in the standard equipment manuals to describe a certain type of equipment test. It should not be confused with the total job-related test constructed for this study.

(3) The revised lists were then submitted to repairmen and supervisors in the field to determine which of the tasks a newly graduated repairman should be able to perform, and which tasks graduates should be expected to perform only after acquiring field experience. They also assigned maximum allowable performance times for each job task.
(4) The material gathered from the repairman and supervisors in the field was analyzed and a set of tentative standards for these various tasks was proposed.
(5) The tentative standards proposed on the basis of the survey were reviewed by responsible Signal Corps agencies.

A tentative set of standards was proposed as the training program target. For maintenance activities the proficiency standard of complete performance of 80% of the specified tasks in the allotted time was suggested. This same standard was also used for final tests and alignment tasks, and for removal and replacement tasks.

With respect to troubleshooting, however, the time required to complete a task in the field differs widely. At the same time, the important thing is to reach correct solution and, in most cases, the time required to achieve it is secondary. To take this into account and still administer the test within reasonable time limits, it was decided to establish a standard of successful completion of 50% of the specified tasks within a 60-minute time limit per item (malfunction).

DIAGNOSIS OF TRAINING STRENGTH AND WEAKNESS

Evaluating the product of training evaluates the training program itself. A test which reflects the ability of the trained graduate to perform the job-related behaviors required by the job will, thereby, reflect the quality of the training program. Moreover, if the means for attaining each job-related behavior have been carefully specified in terms of training content, the training program can be refined until 75%, 80%, 90%, or any specified proportion of graduates, achieve the required performance level. When job-related behaviors have been specified and specific training content has been designed to raise skill levels on those behaviors, the product of training can, in a real sense, be engineered to meet any specific standard if means exist for measuring the success of the program.

Training programs can be refined until their strengths and weaknesses are known if the performance test does more than simply provide a "go - no go" judgment. It should also diagnose—in terms of "terminal behaviors"—the strength and weakness of training.

Three part-scored tests were added to the test battery to improve the diagnostic capability of the work sample. Two of these were set up to diagnose troubleshooting performance, and the third to diagnose final testing and alignment performance.

The first test added to diagnose troubleshooting deficiency was a "Name and Location" test, in which the examinee was required to identify a number of equipment parts. In each case an actual equipment item was displayed, and the examinee was told to touch the called-for part. The test included gross system features such as switches and controls as well as small piece-parts such as capacitors, resistors, and varistors.

The second troubleshooting diagnostic test was concerned with the set-up and use of test equipment. As in the first test, actual equipment was used. For some test items, the examinee was required to set up and adjust test instruments; for others he obtained readings on test equipment that was already set up and adjusted. In either case, the item was scored on the basis of the state of the equipment after the examinee had completed the item.

The final test and alignment items were very similar to the test equipment items. All the needed tools and equipment were available. Some of the equipment was properly connected and warmed up. Other equipment had to be connected before the appropriate readings could be obtained and adjustments made on the system being tested in order to bring readings within specified tolerances.

As is the case with many electronic maintenance problems, final tests and alignments for carrier equipment are complicated by inadequate, and in some cases inaccurate, technical data specifications. Some final tests and alignments cannot be performed in the way the technical manual specifies because the manual is in error. The diagnostic test was designed to reflect the examinee's ability to find the appropriate paragraph in the technical manual, and to correctly interpret instructions. When the subject did not perform a procedure correctly, simplified instructions were read to him and he was told to try again. This two-phased approach permitted an evaluation of the degree to which faulty performance was due to confusing instructions.

TRIAL ADMINISTRATION OF THE TEST

The test was given two preliminary trials by administering it twice to conventionally trained personnel. The test took approximately six days to administer per sample of 20 to 30 subjects. Each man was being tested for about 18 hours on troubleshooting and four hours on other aspects of maintenance. The remainder of the time was administrative. It was therefore desirable to provide practice for test administrators to ensure a smooth presentation of test items, so that no subject would be handicapped by administrative mistakes. It was necessary also to practice inserting test problems into the hardware to ensure a problem of uniform difficulty in all administrations of the test.

For trial purposes the test was administered two times in 1962 to recently graduated carrier equipment repairmen.[9] One of the results of these first two testings was a marked difference in troubleshooting success achieved by the two groups tested, the second group's average scores being much higher than those of the first group.

Nothing in the background of the two groups could be found to account for such a gross discrepancy in troubleshooting ability. Nor was there evidence of any peculiarity in test administration or in test security measures that would have made the test easier for the second group than for the first. Nevertheless, in consideration of the possibility that the second testing might have been scored more leniently or that information about troubleshooting items had leaked out, the testing procedure for the experimental group was changed.

Since any information about the general or specific location of the defective piece-part would help the student find the bad part, the procedure for the troubleshooting items was modified. For the first and second administrations, the particular version of a problem being tested had been left on location until every subject assigned to that version had completed it. This meant that a problem could be identified, for some individuals, by its location in the room.

To further reduce the possibility of information about a test problem being leaked, it was decided to change the test problem on each location after each subject had completed it. In some cases the same problem was reinserted into the location; however, this was something that no subject could predict, so information obtained from the man who had just completed working on a station was not of value.

[9] The general approach to testing procedures follows that used in HumRRO Work Units FORECAST (7) and NICORD (10).

Chapter 5

THE EXPERIMENTAL COMPARISON

To evaluate the concept of electronics maintenance discussed in this report, the test described in Chapter 4 was given to two groups of trainees at the same time and under the same conditions. One group had been trained using experimental training materials. The other group had received the standard training given to Carrier Equipment Repairmen (MOS 294.1) at the Southeastern Signal School, Fort Gordon, Georgia. During training, the experimental group became familiar with the use of experimental job aids just as the standard group became familiar with standard technical manuals.

A testing schedule was devised which provided for one experimental and one standard trainee to be given exactly the same problem, during the same hour, on the same day, and by the same test administrator. Experimental and standard pairs were matched, as nearly as possible, in terms of their background and aptitude. Matching was achieved by selecting trainees on the basis of certain items in the Enlisted Qualification Record (Form 20) including: civilian education, high school subjects, civilian occupation, electronic aptitude (EL) score (from the Army Classification Battery (ACB)), citizenship, psychiatric record, and Posture and Eyes (P&E) from the physical profile scale.

The standard group (22 men) was selected, with respect to the Form 20 items, to conform to the normal input to the 294.1 course. The characteristics of the normal input were established by examining the Form 20 of every 10th man to attend the 294.1 course during 1959. Since the standard course was longer than the experimental course, the standard group was selected first. The experimental group was then formed by finding one man who was similar, in terms of the items on his Form 20, to each standard trainee. The matching attained is shown in Appendix F. The matches obtained were considered to be good.

TEST ADMINISTRATION

The experimental training program was 11 weeks long, whereas the standard training program is normally 25 weeks in length. The beginning of training for the experimentals was delayed 14 weeks in order for them to graduate and be tested at the same time and under the same conditions as the standard group.[10]

The standard group and their experimental counterparts were tested at the Southeastern Signal School in July 1962.

[10] Due to an administrative error, 16 of the trainees in the standard group began training two weeks earlier than had been originally scheduled. Accordingly, training for their experimental counterparts was also begun two weeks early. Since it was only possible to administer one experimental course, however, the six counterparts of the standard trainees who began training as originally scheduled also had to be started two weeks early.

The six experimental trainees who were the counterparts of the later-starting standard trainees were held over for two weeks so that they could be tested with their standard counterparts. During these two weeks, the six experimental trainees worked only on practice exercises. This arrangement, although not originally planned, made possible an evaluation of the effect of two weeks' extra practice for the experimental group.

Three of the standard trainees were dropped during training for administrative or scholastic reasons. Only one student in the experimental course failed to complete it.[11] The counterparts of these trainees were tested, however, so that the following comparisons are based on 19 standard and 21 experimental trainees.

The test plan was available to test supervisory personnel only. The test administrators were instructors chosen from another course. They were not informed of the correct answers to problems nor were they informed that the same problem was being given at the same time to another student. The test administrators could not identify which students were in the standard group or experimental group.

TEST RESULTS

Maintenance Tasks

Among standard trainees, 62% of the maintenance tasks were successfully completed; among the experimental trainees, 58% of the maintenance tasks were successfully completed. This difference is not statistically significant.[12]

Removal and Replacement Tasks

Among standard trainees, 98% of the removal and replacement tasks were successfully completed; among experimental trainees, 97% of the removal and replacement tasks were successfully completed. This difference is not statistically significant.

Final Test and Alignment Tasks

The average number of final test and alignment tasks successfully completed (out of eight administered) was 2.8 for standard trainees and 2.0 for experimental trainees. This difference is not statistically significant.

Troubleshooting Tasks

The standard trainees achieved 29% success on the troubleshooting problems; this is equivalent to between 5 and 6 out of 18 troubleshooting problems. The experimental trainees achieved 37% success, or between 6 and 7 out of 18 problems. This difference is not statistically significant.

Other Relationships

Since troubleshooting problems had been constructed to represent differing classes of failure, it was expected that the problems would not be equivalent in terms of difficulty. There was also the possibility that either the standard trainees, the experimental trainees, or both might find certain equipments (AN/TCC-3, AN/TCC-4, AN/TCC-7, etc.) easier to work on than others. Similarly, solder problems (those problems which require the trainee to complete a repair down to and including the replacement of a defective part) might be more difficult even though extra time was allotted for completion of the problems. The same held true for the known versus blind (single panel versus entire equipment) problems. Finally, it was not unreasonable to expect that either or both groups might exhibit improvement as testing continued; this would appear as a difference in performance over testing days.

[11] Hardship discharge.

[12] All analyses are by analysis of variance technique controlled on subject pairs.

The results of a statistical analysis using the least squares technique for determining answers to all these questions are shown in Table 1. The only significant differences were in "problems" and "equipments." For both groups some problems were significantly harder and some easier than others. For the experimental group some equipments were significantly harder and some easier than others. An examination of the data indicates that, for the experimentals, the AN/TCC-7 and the AN/TCC-11 were easier and the AN/TCC-4 was harder than others.

Table 1

Effect of Variations Among Problem Versions, Equipment Types, Completeness of Repair, Amount of Prior Information, and Experience[a]

Reduction Due to:	Group	Mean Squares	Error Mean Squares	*F*	*P*
Problem Versions	Standard	.74	.17	4.28	.01
	Experimental	.55	.19	2.82	.01
Equipment Types	Standard	.27	.19	1.41	NS
	Experimental	.72	.19	3.81	.01
Completeness of Repair	Standard	.00	.21	–	NS
(Solder Problems)	Experimental	.00	.19	–	NS
Amount of Prior Information	Standard	.20	.21	<1	NS
(Known-Blind)	Experimental	.32	.18	1.75	NS
Experience	Standard	.13	.17	<1	NS
(Across testing days)	Experimental	.29	.19	1.53	NS

[a]Least squares analysis.

Another question subjected to test by least squares analysis concerned the performance of the experimentals who had received two extra weeks of practice. The results of the analysis showed that the five individuals (the experimental who was dropped came from this group) receiving the extra training did not perform at a significantly different level, on the troubleshooting test, than did the 16 individuals who had received 11 weeks of training.

Data reflecting on the following relationships appear in Table 2.

(1) The written grades received by trainees in the standard course and troubleshooting success, final test success, maintenance success, and removal and replacement success.
(2) Time to complete a troubleshooting problem and troubleshooting success.
(3) Maintenance task scores and removal and replacement time scores.
(4) Section III of the Name and Location test (identification of specific piece parts) and the written grades of the standard students.

Written grades of the standard students did not correlate with troubleshooting success, final test success, maintenance success, removal and replacement success, or the piece-part section of the Name and Location test. For both experimental and standard trainees, a negative correlation was obtained between troubleshooting success and troubleshooting time. Since this correlation may be due to an artifact (i.e., failed problems are automatically scored as a 60-minute effort), correlations were also computed between troubleshooting success and average time to solution *for those problems which were* *solved.* (This correlation also appears in Table 2). This second computation substantially reduced the size of the negative correlation for both experimental and standard trainees, and the correlations do not reach statistical significance.

Table 2

Correlations Between Variables Suggested by Previous Testing of Standard Trainees

Variable 1	Variable 2	Group	Correlation	*P*
Written test grade	Troubleshooting success	Standard	.13	NS
	Final test success	Standard	.00	NS
	Maintenance success	Standard	.01	NS
	Removal and replacement success	Standard	.01	NS
	Name and Location (Section III)	Standard	–.12	NS
Time to complete troubleshooting problems	Troubleshooting success	Standard	–.92	.001
		Experimental	–.89	.001
Time to complete troubleshooting problems successfully solved	Troubleshooting success	Standard	–.44	NS
		Experimental	–.18	NS
Removal and replacement time	Maintenance success	Standard	–.17	NS
		Experimental	–.04	NS

Final Test and Alignment Diagnostic Test

Table 3 shows the percentage of "successes without assistance" on the final test and alignment diagnostic items, the percentage of "successes after being given simplified instructions," and the percentage of failures after being given "simplified instructions." These figures are summed and averaged across all of the diagnostic final test items. The differences are not statistically significant. An examination of each item revealed a very similar pattern of success and failure for both groups. Those items which were difficult for the standard trainees to solve without simplified instructions were also difficult for the experimental trainees to solve without simplified instructions, and those which were difficult even after simplified instruction were difficult for both groups.

Table 3

Average Success With and Without Assistance on Final Test and Alignment Tasks
(Percent)

Group	Average Success Across Items With and Without Assistance	Average Success Across Items Without Assistance	Average Failure Across Items
Standard	88	65	12
Experimental	81	58	19

DISCUSSION

Maintenance Tasks

The experimental and standard trainees performed at approximately the same level on the maintenance portion of the work sample test. The level of performance for both groups falls below the tentative standard set (80%). This may reflect an unrealistic target estimate or it may pinpoint an area wherein all trainees are still deficient.

Removal and Replacement Tasks

Neither the experimental nor the standard trainees appear to have had much difficulty with these items.

Final Test and Alignment Tasks

The low level of performance of both experimental and standard groups on the final test and alignment tasks is probably due, in large part, to the ambiguity with which existing final test instructions are written. In the course of selecting items for the final test and alignment diagnostic test, consulting technicians found several instances of ambiguous instructions, or, in some cases, instructions that could not be executed as given.

Another reason for the poor performance of both groups may lie in the number of subroutines which must be completed correctly, for each final test or alignment, before a pass-fail score is assigned to the last step in the series. Some trainees may have correctly performed a substantial number of these subroutines and still failed the total task.

Troubleshooting Tasks

It is very difficult to administer a test of the work sample type in such a way that every subject is tested under the same conditions. When more than one version of a troubleshooting problem has to be constructed, variations in the success with which the "bugged" component is made undetectable results in differing test conditions—even for those subject pairs who have been administered the same problem, on the same day, at the same hour, by the same test administrator.

Another problem is the susceptibility of equipments to unforeseen malfunctions which are not part of the problem being tested. Maintaining relatively constant testing conditions required ingenuity and perseverance on the part of the Southeastern Signal School instructors who checked out the equipment before each subject began a problem and who inserted the "bugs" into the equipment. Whatever variations existed in testing conditions were a reflection of the intrinsic difficulty of the problem.

CONCLUSIONS

(1) The results clearly indicate that the experimental and standard trainees performed at substantially the same level on a work sample test. In view of the training time required for the experimental group, 11 weeks, this is an important finding. The time actually spent in training for the experimental trainees was approximately half that spent in training by the standard trainees—normally 25 weeks. This supports the proposition that the curriculum design principles employed on this research can lead to substantial training savings.

(2) The fact that five experimental trainees who received two extra weeks of training did not perform at a significantly different level on the troubleshooting work

sample than did the 16 trainees who received only 11 weeks of training may be ignored due to the small number of cases. When one takes into account, however, the fact that neither the standard nor the experimental trainees tended to improve from day to day during testing, coupled with the fact that no new material was given during the extra two weeks, it seems possible that the practice portions of the training program might be reduced even further without appreciably affecting troubleshooting performance.

(3) The lack of relationship between written tests is currently given to Carrier Equipment Repairmen and their performance on the work sample supports the general finding, obtained by other researchers, that course grades and course tests tend to be very little related to work sample tests.

(4) The distribution of success without and with clarification of instructions in manuals, for both experimental and standard trainees, suggests that performance on final test and alignment tasks can be improved with better presentation of the technical materials for this MOS.

LITERATURE CITED
AND
APPENDICES

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Appendix A

GENERATING A FAILURE EFFECT ANALYSIS

A good failure effect analysis should produce as many statements as time and resources will permit about the ways in which a system fails. These statements may be put in the form: "If part X fails in such and such a way then consequence Y will occur." Statements in this form can be represented on a Failure Effect chart. Figure A-1 is an example of such a chart using the simple gasoline engine fuel system, diagrammed in Figure A-2, as an illustration.

This format (Figure A-1) is particularly useful when a computer is used to go from the failure effect analysis to a check out program. When a computer is used, data can be entered with the appropriate row number and column number each time an "X" appears in the chart.

When constructing a failure effect chart, it is extremely important to make sure that each symptom is independent of every other symptom. This means that a row by column entry (X or the absence of an X) cannot be allowed to change value on the basis of some other row by column entry. Note, for instance, that each symptom in Figure A-1 remains distinct. Thus, "engine stops after one or two minutes" is kept separate from "engine dies when idling." Not maintaining such distinction reduces the efficiency of diagnosis.

Another thing to remember when generating a failure effect analysis is that parts can fail in more than one way. Not only can they short or open (each of which may result in a different set of symptoms), but they can also change in value without producing either a dead short or an open. For example, the fuel line can fail by freezing, forming a vapor lock, or developing a leak. The consequences which result from these separate types of failure, however, are not the same.

Separate types of fuel line failure can be handled by entering the fuel line in three separate rows. This solution emphasizes the fact that the rows in Figure A-1 represent malfunctions rather than parts. If the rows represented parts, it would be necessary to introduce other rows designating the type of failure, resulting in the lack of independence and the inability to use a computer, or else the other ways in which a part can fail would have to be ignored. Neither is acceptable. A part which can fail in more than one way, therefore, must be handled by listing it in a separate row for each separate way in which it can fail. Only when two different ways of failing produce exactly the same pattern of consequences can this be ignored.

Just as it is important to represent a part on the chart as many times as that part has different consequences, it is also important that all of the statements which are true of a part, as revealed by the analysis, should be represented on the chart. The most striking feature of a failure effect analysis constructed by working up from the malfunction to the part is the way in which the number and quality of symptoms are constantly being enriched. Most malfunctions are so rich in consequences that it is not possible for an engineer or technician to forecast the categories within which symptoms will fall. Because this is so, there is always a great danger that some of the statements which are true of a part will be omitted from the chart. This can happen in many ways.

One reason why symptoms which are true for a particular part can accidentally be omitted is because the part in question renders inoperable some remote parts when it

Correct Failure Effects Chart

	Engine starts—runs 2 minutes—stops	It is summer	It is winter	Engine dies when idling	Engine can be restarted w/out advancing choke	Engine stops on the road after coughing once or twice	Engine can be made to keep running by advancing choke
1. Fuel line frozen	X		X				
2. Fuel line vapor lock	X	X					
3. Fuel line leak						X	
4. Gas tank empty						X	
5. Fuel pump weak						X	X
6. Carburetor needle valve						X	X
7. Carburetor mixture				X	X		

Figure A-1

Diagram of a Fuel System

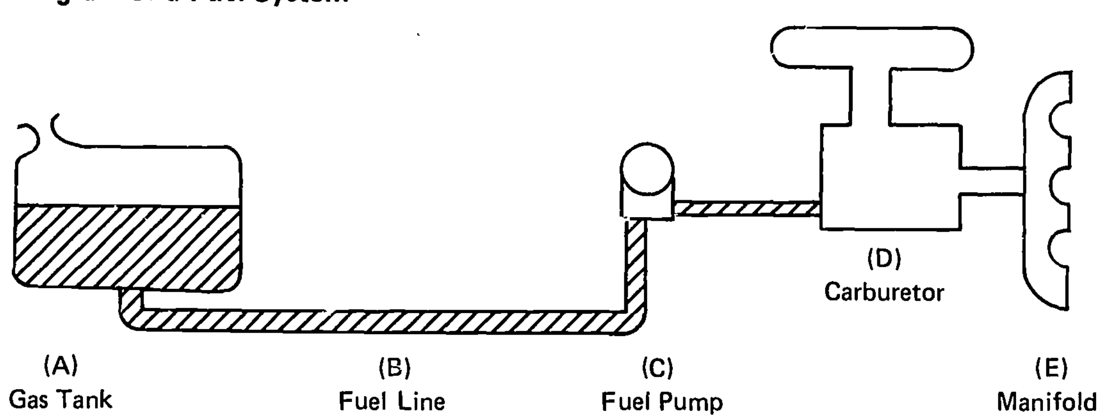

Figure A-2

fails and thereby produces the symptoms of malfunction in those parts. Symptoms may also be omitted because certain consequences are discovered after a related part has been plotted. B+ parts are good examples of the first category. When B+ parts fail, they not only have immediate consequences in terms of altered B+ readings, but they also have as consequences many of the symptoms of parts served by the B+ line.

Omissions due to related but remote consequences can be held down by working upward from the power supply and backward from the final outputs of the system. First, the B+ system can be analyzed up to the point where operating voltages are distributed to other parts of the system. Then, as B+ related symptoms develop, these symptoms can be added to those B+ symptoms already noted. After generating the consequences which arise prior to the point where the B+ is distributed throughout the system, an analysis can be begun working backwards from output stages. Working backward from the output stages is desirable because, although output stages can reflect certain troubles back through the system, bad output signals usually do not result in bad output signals from previous stages.

Part-symptom relationships which are overlooked because a symptom is discovered after a related part has been plotted are serious because it is often the new or previously undiscovered symptoms which contribute most to an efficient checkout. Such omissions often occur because some new way of energizing or taking observations from the system has been developed. The example in Appendix C contains some novel symptoms of this type.

Appendix C is composed of a malfunction diagram, a checkout diagram and a checkout program for the telegraph-telephone signal converter TA-182/U. A normal input to this converter is a 90 volt, 20 CPS ringing signal. The failure effect analysis for this equipment disclosed that if the output of the converter was strapped to the input and if 110 volts, 60 CPS were applied to the input terminals before the converter was energized, certain relays would click or not click depending on whether or not certain malfunctions existed in the system. (This relationship was not discovered until the question was asked, "How can the failure of each particular part be made to display its consequences—even by unconventional operations?") Once the relationship had been discovered, however, it was necessary to re-examine parts which had previously been analyzed since they had some additional consequences within this new framework.

There is no easy way to ensure that part-symptom relationships, for previously analyzed parts, will not be overlooked when a new consequence or new way of obtaining a consequence is discovered. Time spent checking for such errors is well spent, however, because of the efficiency which often results when unsuspected symptoms and symptom patterns are discovered. Any approach to this problem of overlooked symptoms must rely on a check of previous parts every time a new symptom is added. Similarly, each new part must be checked against all previously determined symptoms.

Since a failure effect chart for large systems can become extensive, it is worthwhile to divide the chart into a number of sub-charts. If this division is based on classes of symptoms such as B+ effects, signal processing effects, control signal effects, and so forth, the job of checking previous parts for subsequent symptoms and previous symptoms for subsequent parts can be greatly simplified. Thus, each time a new symptom develops, it is entered into a sub-chart containing similar symptoms. It may then be that only the parts on that sub-chart need be checked against that symptom. When analyzing a part, on the other hand, one need only look through a subset of symptoms in order to determine whether a symptom has been previously listed, and, if it has, with which parts it is associated. Since the computer will construct elements only on the basis of symptom and part number when the intersection of row and column is marked with an "X," the number of times a part or symptom designation is repeated (on sub-charts) will have no effect.

The sub-chart technique is also useful for keeping general troubleshooting information separate from detailed information. This tends to eliminate from the collection of system-specific symptoms all those which are obtained through the use of vacuum tube voltmeters, oscilloscopes, signal generators, and so forth. As pointed out in Chapter 2, symptoms which require such equipment should be considered in terms of developing training materials.

It is probably impossible to generate *all* malfunction symptom relationships for even small systems. For example, the symptoms for either position of a two-position switch can be listed. As other switches are added, however, the number of symptoms noted will approach 2^N (where N is the number of such two-position switches). Most systems have switches with more than just two positions. It can readily be seen that as switches and positions increase, the number of symptoms will expand geometrically. Fortunately, however, many such symptoms are easily seen to be redundant. In any case, the experience of this research suggests that it is worthwhile to analyze the system as though it were possible to generate all relationships. The number of relationships obtained will then depend only on the time and effort expended. Under such circumstances, extremely fruitful but hitherto unsuspected malfunction-symptom relationships have ample opportunity to be discovered.

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Appendix B

HOW TO DERIVE CHECKOUT PROCEDURES FROM FAILURE EFFECT ANALYSES

A good failure effect analysis should contain information about the consequences of the failure of *any* part within the system. In addition, this information should be extensive enough to allow diagnosis of any disturbance down to a relatively small collection of parts. Unfortunately, however, a failure effect analysis is "knowledge in the raw," and it is not, in the form in which it is generated, usable.

Even for extremely simple electronic systems, a good failure effect analysis will probably generate a greater number of part-consequence relations than can be simultaneously attended to by even a gifted maintenance technician. In order, therefore, to make use of the spelled-out consequences of part failure within equipment, there still remains the problem of organizing these consequences into some format which will be useful to the maintenance technician.

Since no new information is added, the organization of a failure effect analysis into a useful format is, essentially, a clerical task, but one which can assume (in the case of very large systems) monumental proportions. Nevertheless, since it is clerical in form, a good share of the drudgery of doing it can be assumed by an appropriately programmed electronic digital computer.

In the following paragraphs, such a system—using IBM 1620 card computer equipment[1]—is presented. As in the case of the technique for performing a failure effect analysis, outlined in Appendix A, the system which follows will not necessarily generate the optimum or most efficient of all possible troubleshooting sequences. The system presented does the job better than any alternative system we were able to devise and may be regarded as a model for present or future systems.

Before an efficient troubleshooting sequence can be developed, some definition of troubleshooting efficiency must be established so that decisions can be made regarding alternative operations. For this research, the definition of efficiency was derived from an examination of the troubleshooting task itself. On the basis of this examination it was posited that maintenance technicians normally obtain two types of observation, which might simply be labeled "primary observations" and "secondary observations." A "primary observation" is one which is made of the entire system—or a portion of the entire system—to determine whether or not any malfunctioning part lies within the portion observed. A "secondary observation" is one which is made to reduce to as small as possible the collection of suspect parts once the existence of a malfunction is established by a primary observation.

Given the above definitions for primary and secondary observations, it is relatively easy to define troubleshooting efficiency as follows:

> An efficient *primary* observation is one which is the consequence, when they fail, of a great many individual parts within the system. An efficient *sequence of primary observations* is one which will, at an early step, pick up, if they should fail, most of the parts within the system.

[1] Identification of this equipment does not constitute, nor should it be considered, an endorsement or approval either by HumRRO or by the Department of Defense.

An efficient *secondary observation* is one which eliminates one-half of the suspect parts, and an efficent *pattern of secondary observations* is one for which the average number of observations is the minimum required to get down to the smallest (using available data) possible collection of parts.

Secondary observations should be selected solely on the basis of the way in which they differentiate among suspected parts. However, since primary observations usually function also as secondary observations, these should be selected first on the basis of the number of parts they pick up and secondly on the basis of the way in which they differentiate, assuming that a malfunction is detected, among suspected parts. For example, an observation of the operating voltages within a system can frequently limit possible malfunctions to only a portion of each stage which the operating voltages serve.

There are certain secondary criteria of the efficiency of a given observation, such as the ease with which the observation can be obtained, the similarity or dissimilarity of an observation to the last previous observation, and so forth. If, in general, primary observations are selected and sequenced on the basis of scope, and secondary observations are selected and sequenced on the basis of differentiation, a troubleshooting procedure will evolve that ensures a high probability of detecting any possible malfunction on the first or second primary observation, and, once a defect is found, a minimum of secondary observations will be required to identify any given failure. In constructing the steps which follow, these criteria of efficiency have formed the basis for decision whenever alternative steps were considered.

Step 1—Information from the failure effect analysis is conceived in units composed of one part and one symptom.

Step 2—A symptom frequency count should be obtained by the computer. This frequency count will be used in the selection of primary observations since the symptom with the greatest frequency count is the one which will pick up more parts than any other.

Step 3—Certain parts within the system—which result in symptoms regardless of the way in which the equipment is energized—must be identified. For example, the lack of a power lamp or the lack of any scope tracing will often occur on the first primary observation regardless of switch setting, special hookup features, and so forth. Since these symptoms are bound to occur on the very first observation, regardless of any other observation that is made, they may be called "free" symptoms since no decision has to be made whether they should be included. These "free" symptoms have to be designated by the engineers or technicians who do the failure effect analysis.

Step 4—Those parts which will be identified by free symptoms must be removed from the total collection.

Step 5—A symptom frequency count should be obtained from the computer on the subset of units (all part-symptom units for parts which result in free symptoms) obtained under Step 4. This frequency count may subsequently be compared with the frequency count obtained under Step 2, to determine what proportion of the parts identified by a given non-free symptom overlap with parts picked up by free symptoms. This information will be useful for selecting both primary observations and secondary observations, since a symptom which overlaps one-half of those parts picked up by the free symptoms is a good candidate for a secondary observation.

Step 6—One or more primary observations such as meter readings or scope tracings (obtained for certain specified switch settings) can now be selected to be lumped with the free symptoms to compose the first pattern of primary observations. Possible candidates for such additional observations will come from the largest counts remaining after the frequency counts obtained under Step 5 have been subtracted from the frequency counts obtained under Step 2. Other things being equal, the overlap between such observations and the free symptoms (their value as secondary observations), the ease with which they may be obtained, the nature of the last previous observation, and so forth, may determine this selection.

Additional observations often fall out as clusters rather than as isolated symptoms. For example, in the case of field carrier equipments, it was found, that it was desirable for the technician to operate a butterfly switch on a telephone handset while observing a lamp and buzzer. Before operating the butterfly switch, however, it would be possible, if certain parts failed, to hear a 60 cycle hum in the handset. A different grouping of parts causes the same hum *after* operating the butterfly switch. Accordingly, these observations fall naturally into a cluster which can be observed almost simultaneously.

Step 7—Once a homogeneous set of additional symptoms has been generated, it is necessary to perform Step 4 again to separate from the part-symptom file those data for any part which has one or more of the additional symptoms (including those part-symptom data where the symptom is neither a "free" nor an "additional" symptom but the part has at least one of the additional symptoms associated with it).

Step 8—All of the part-symptom data for parts associated with one or more additional symptoms can now be combined with part-symptom data for parts associated with one or more free symptoms to form the first pattern of primary observations. This combined data file will contain all of the symptom data for the parts involved. Some of these symptoms will be neither "free" nor "additional" symptoms. It is from these remaining symptoms that the pattern of secondary observations will be selected. To make this selection, the data contained in the combined data file must be displayed. A program was written to permute the symptoms in such a way that all of the primary symptoms can be printed in adjacent columns, the first few columns from the left. The columns associated with those symptoms which are good candidates for secondary observations were then permuted to the left while poor candidates were permuted towards the right. This grouped the primary observations and probable candidates for secondary observations in one portion of the display. It also seemed desirable to permute the parts (rows) in such a way that parts associated with the most frequently occurring, or the most easily observed, symptom would appear at the top.

It is possible to permute the rows and columns in such a part-symptom matrix by employing certain properties of the powers of two. One way to do this is to assign an index number to the first, second, and so forth columns. A computer was then programmed to examine each part-symptom unit and to raise two to the power corresponding to the index number assigned to the symptom. This resulted in a value corresponding to the association of that part with the symptom represented by the index number. Sorting this value on the basis of magnitude permuted the rows in the desired fashion.

Step 9—A simple examination of the listing of results (printout) obtained under Step 8 reveals those parts which are associated with a unique configuration of primary observations since similar patterns are grouped together by the permutation. Parts with identical total symptom configurations were also revealed. The only remaining judgment involved the selection of efficient secondary observations to distinguish among those parts which had non-unique patterns of primary observations but differing patterns among the "remaining" symptoms. This judgment was facilitated by the permutation which moved the most likely candidates for secondary observations into the columns immediately adjacent to the columns corresponding to the primary observations. It is conceivable, for very large matrices, that the judgment might require two or more intermediate steps involving a re-permutation of the columns using new sets of index numbers which eliminated those symptoms which were obviously unsuitable.

Step 10—The judgment obtained under Step 9 results in a unique configuration of symptoms for each part grouping which does not have an identical pattern of symptoms in common with some other part grouping, but for some part groupings there may be superfluous symptoms. It is desirable to eliminate these superfluous part-symptom units from the combined data file of "free" plus "additional" symptom.

Step 11—Short (30 spaces or less) symptom statements were composed for each symptom to be used, and these symptom statements were associated with the appropriate part-symptom units.

Step 12—At this point, the data file consists of a unique configuration of part-symptoms for each unique part. It is desirable to display this information by preparing a printout.

Step 13—The printout obtained under Step 12 constitutes a sort of dictionary of the unique symptom configurations for each part which demonstrates one or more of the primary observations ("free" or "additional" symptoms). This dictionary is ordered in the same way as the permuted row and column matrix. To complete this dictionary for *all* parts, it is necessary to take the remaining part-symptom data obtained under Step 7 (those part-symptom cards corresponding to those parts which are associated with neither a "free" nor an "additional" symptom), and iterate Steps 6 through 12 (except that there will be no "free" symptoms). The process will then have to be reiterated until the part-symptom units are exhausted.

In the preceding program, Steps 3, 6, 8, and 9 are not strictly clerical inasmuch as they require judgments from engineers or technicians. Notice, however, that no new information about the system is added at these points. The non-judgmental portions of the preceding program can, therefore, be viewed as the clerical tasks which support the judgments which are made. As indicated, the final printout supplies a "dictionary", or description, of the unique configuration of consequences—associated with any particular part—which ensues from a relatively efficient pattern of primary and secondary observations.

Appendix C

A SAMPLE MALFUNCTION DIAGRAM, CHECKOUT DIAGRAM, AND CHECKOUT PROCEDURE FOR AN ACTUAL SYSTEM COMPONENT

Figure C-1 is the schematic diagram for the telegraph-telephone signal converter TA-182/U (one of the standard pieces of Signal Corps carrier equipment used in this study). It is used in conjunction with other carrier equipments, but is self contained, has its own power supply and carrying case. In normal use, it processes signals coming from and going to a telephone user. Specifically, when a telephone user turns the crank on his telephone unit, he generates a 20 cycle per second ringing signal which is received by a telegraph-telephone signal converter. The converter, after delaying for a short time to make sure that the ringing signal is not just static, will then impress a higher frequency (1225 or 1600 cycles per second) on the line linking the user with a remote user. Conversely, when a 1600 or 1225 cycle per second signal is received by the signal converter, it will, after delaying a short time, impress a 20 cycle per second signal onto the line leading back to the user. Thus, the signal converter processes signals in both directions. On the way out, it raises the frequency, and on the way in, it lowers the frequency.

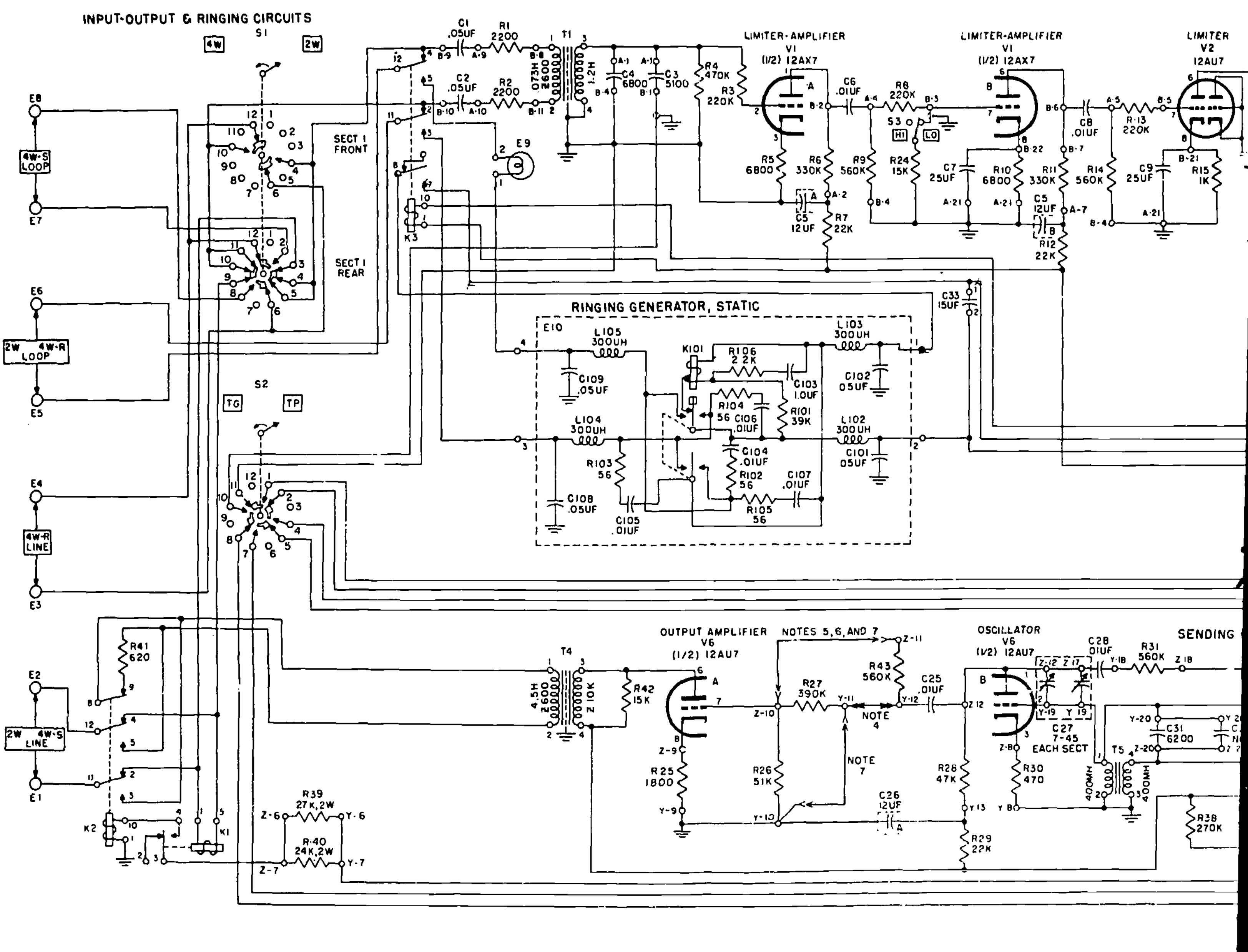
Figure C-2 is a malfunction diagram constructed as part of the research for the telegraph-telephone signal converter. It illustrates many of the principles pointed out in Chapter 2, but it is not usable as it stands because of the multiplicity of symptoms and relationships and the lack of a clearly structured method for proceeding.

Figure C-3 is a checkout diagram also constructed as part of the research for the telegraph-telephone signal converter. It is based on the malfunction diagram illustrated in Figure C-2. By following this simple checkout, it is possible for a repairman to either checkout or repair the telegraph-telephone signal converter.

To use the checkout diagram, the repairman begins in the upper left hand corner, and performs the preliminary observations listed in the box labeled "P." Thus, he will strap E-1 to E-3, E-2 to E-4, and he will apply the auxiliary power cord to E-7 and E-8. He also must be certain that switch (S-1) is turned to the 4-wire position, and that switch (S-2) is turned to the TP position. Switch S-3 must also be in the "high" position.

After completing the preliminary operations, the repairman performs the operations listed in the box labeled M-1. He must measure the resistance across E-7 and E-8 and then across E-5 and E-6 with switch (S-1) turned to the 2-wire position. Notice that the checkout diagram lists three possible observations. Two of these observations lead to part collections. These are listed under I-1a and I-1b. The other observation leads to the second main test (M-2). One of the possible observations from main test 2 then leads to main test 3 (M-3). This process continues until one of the observations from main test 7 leads to the conclusion that the TA-182 is ready for final testing.

Final testing consists of alignment and calibration procedures which are outlined in existing technical manuals. Experience has proven that for many of the Signal Corps carrier equipments studied, the final tests become more or less superfluous once an efficient checkout has been designed.



Telegraph-Telephone Signal Converter TA-182/U, schematic diagram (see note 8).

Figure C-1

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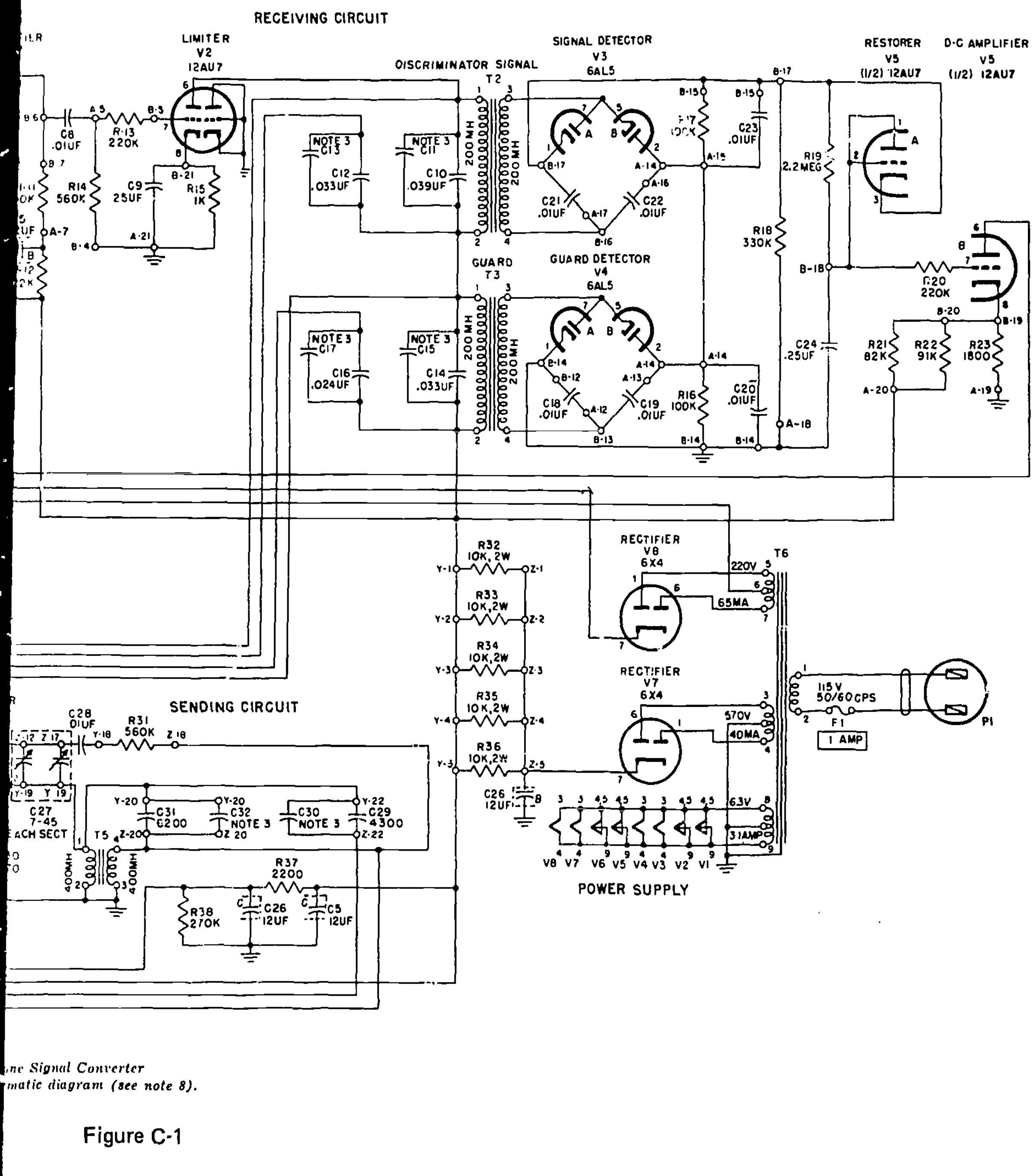

NOTES:

1. UNLESS OTHERWISE SHOWN, RESISTORS ARE IN OHMS, CAPACITORS ARE IN UUF.
2. ROTARY SWITCHES ARE VIEWED FROM END FARTHER FROM CONTROL KNOB. SECTION I IS THE SECTION CLOSER TO THE KNOB.
3. CAPACITORS C11, C13, C15, C17, C30, AND C32 DO NOT HAVE SPECIFIC VALUES. FOR REPLACEMENT SEE OSCILLATOR AND DISCRIMINATOR ALINEMENT PROCEDURES.
4. THE CIRCUIT ARRANGEMENT SHOWN (TERMINALS Y-11 AND Y-12 STRAPPED) WILL USUALLY PROVIDE AN OUTPUT LEVEL OF 0 dbm ± 2 db.
5. FOR OUTPUT LEVELS LESS THAN −2 dbm, CONNECT A STRAP BETWEEN TERMINALS Z-10 AND Z-11. OUTPUT LEVELS WILL BE INCREASED BY APPROXIMATELY +4 db.
6. FOR OUTPUT LEVELS GREATER THAN +2 dbm, BUT LESS THAN +4 dbm, DISCONNECT THE STRAP BETWEEN TERMINALS Y-11 AND Y-12. CONNECT A STRAP BETWEEN TERMINALS Z-10 AND Z-11. OUTPUT LEVELS WILL BE REDUCED BY APPROXIMATELY 3db.
7. FOR OUTPUT LEVELS GREATER THAN +4 dbm, DISCONNECT THE STRAP BETWEEN TERMINALS Y-11 AND Y-12. CONNECT A STRAP BETWEEN TERMINALS Y-10 AND Y-11. CONNECT ANOTHER STRAP BETWEEN TERMINALS Z-10 AND Z-11. OUTPUT LEVELS WILL BE REDUCED BY APPROXIMATELY 4 db.
8. THIS ILLUSTRATION IS APPLICABLE TO CONVERTERS BEARING THE ORDER NUMBERS AND SERIAL NUMBERS LISTED BELOW.

ORDER NO.	SERIAL NUMBER
3289-PHILA-51	701 THROUGH 900
3291-PHILA-52	911 THROUGH 1153
3366-PHILA-52	2000 THROUGH 9448
4697-PHILA-52	2901 THROUGH 11539
6438-PHILA-51	10027 THROUGH [illegible]
30005-PHILA-51	1 THROUGH 1100

...ne Signal Converter
...matic diagram (see note 8).

Figure C-1

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TA-182 Malfunction Diagram

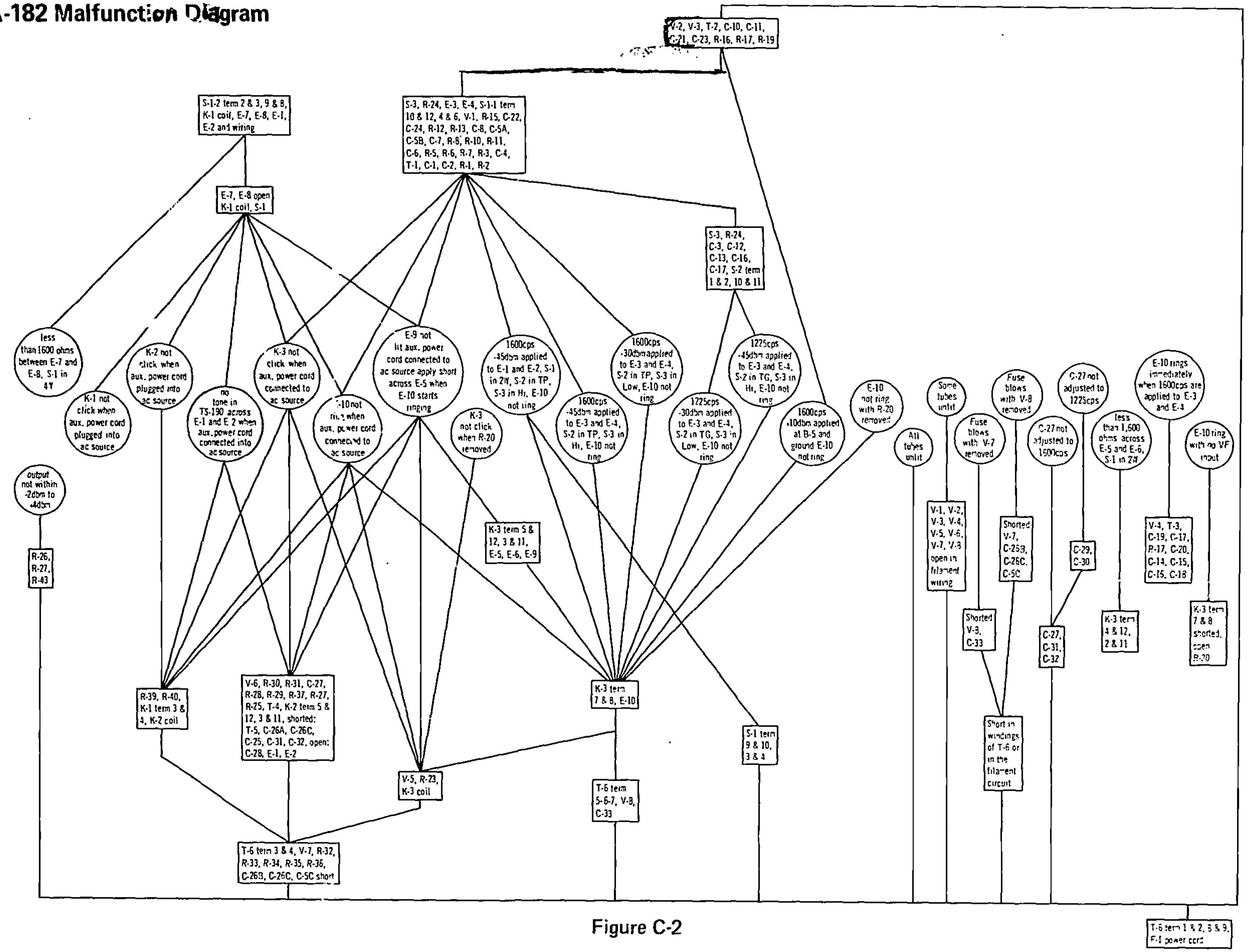

Figure C-2

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TA-182 Checkout Diagram

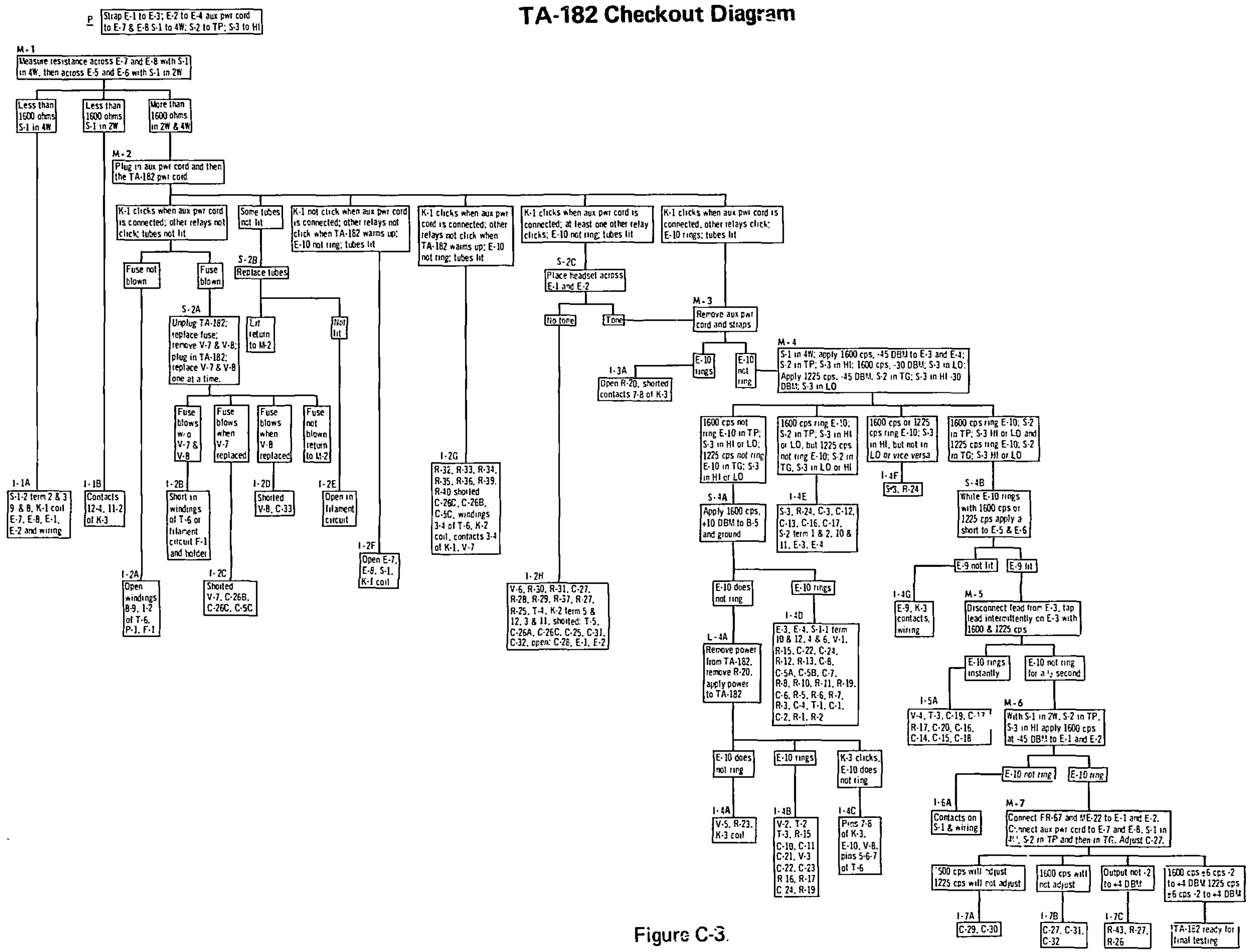

Figure C-3.

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The observations associated with main test 2 (M-2) illustrate the usefulness of an efficiently organized pattern of observations. Notice that "K-1 clicks" appears in many patterns. The presence or absence of other observations such as "E-10 not ring," "tubes not lit," and so forth, serve to identify many differing part collections all of which are associated with "K-1 clicks."

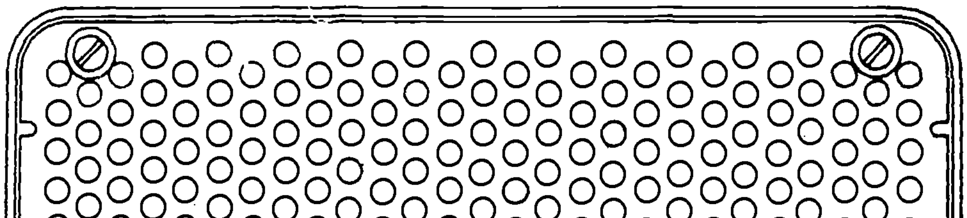
The observations which appear in main test 2 (M-2) have been gathered together because they can be observed almost simultaneously and because they form complex patterns of consequences. This gathering together of symptoms to form a pattern which can be easily observed is in accordance with the principles of checkout construction cited previously.

Figure C-4 is a more explicit version of the checkout diagram, and is in booklet form. It spells out, in more detail, the various operations, observations, and consequences listed in the checkout diagram. Nothing new, however, in terms of additional observations or part listings appears. The repairman has the option of using either the checkout diagram or the booklet.

Control Panel, Telegraph-Telephone Signal Converter TA-182/U

Preliminary Actions

1. Put the TP-TG switch in the TP position.
2. Put the 2W-4W switch in the 4W position.
3. Put the SENSITIVITY switch in the HI position.
4. Strap E1 to E3 and E2 to E4.
5. Connect the auxiliary power cord to E7 and E8.



Telegraph-Telephone Signal Converter 182/U, control panel.

Figure C-4

There are two features of the checkout diagram which recommend its use for the storage of job-aid information in military settings. First, the checkout diagram is extremely concise making it possible for large systems to be represented on two or three pages only slightly larger than the one illustrated. This is an important consideration for those settings which require the repairman to carry with him to the job only a minimum of printed information. The checkout diagrams together with the schematic of the equipment in question would be sufficient to support the performance of any repair appropriate to the echelon of maintenance under consideration.

Second, the checkout diagram can be easily amended. When modified equipment is sent to the field, or when modification work orders are sent to the field, the job aid can be amended simply by generating the symptom, and consequent changes resulting from the modifications, blocking out the inappropriate portions of the checkout diagram, superimposing the new material, printing the changed checkout diagram and distributing it to the field.

For systems which become operational during or shortly after the test and development phase, the ease with which changes in technical information can be made is extremely important. In many cases, such equipment is modified daily. Thus, the integrated approach to the design of the repair "information matrix", that is, job aid storage complementing memory storage can solve the indirectly related problem of keeping technical information up to date.

MAIN TESTS

Test	Procedure	Obtained Results	Next Test or Source of Trouble
M-1	Measure resistance across E7 and E8 with S1 in 4W, then across E5 and E6 with S1 in 2W.	Less than 1600 ohms, S1 in 4W.	Go to I-1A.
		Less than 1600 ohms, S1 in 2W.	Go to I-1B.
		More than 1600 ohms, S1 in 2W and 4W.	Go to M-2.
M-2	Plug in auxiliary power cord and TA-182/U power cord.	K1 clicks when auxiliary power cord is connected, other relays not click, tubes do not light.	Go to S-2A.
		Some tubes do not light.	Go to S-2B.
		K1 does not click when the auxiliary power cord is connected, other relays do not click when TA-182/U warms up, E10 does not ring, tubes light.	Go to I-2F.
		K1 clicks when the auxiliary power cord is connected, other relays do not click when the TA-182/U warms up, E10 does not ring, tubes light.	Go to I-2G.
		K1 clicks when the auxiliary power cord is connected, at least one other relay clicks, E10 does not ring, tubes light.	Go to S-2C.
		K-1 clicks when the auxiliary power cord is connected, other relays click and E10 rings, tubes light.	Go to M-3.

Test	Procedure	Obtained Results	Next Test or Source of Trouble
M-3	Remove auxiliary power cord and straps.	E-10 rings.	Go to I-3A.
		E-10 does not ring.	Go to M-4.
M-4	S1 in 4W, apply 1600 cps at a -45 dbm to E3 and E4; S2 in TP; S3 in HI. Apply 1600 cps at a -30 dbm; S3 in LO; S2 in TG. Apply 1225 cps at a -45 dbm, S3 in HI; then 1225 cps at a -30 dbm, S3 in LO.	1600 cps not ring E10 in TP, S3 in HI or LO. 1225 cps not ring E10 in TG, S3 in HI or LO.	Go to S-4A
		1600 cps ring E10, S2 in TP, S3 in HI or LO. But 1225 cps not ring E10, S2 in TG, S3 in HI or LO.	Go to I-4E.
		1600 cps or 1225 cps ring E10, S3 in HI but not in LO or vice versa.	Go to I-4F.
		1600 cps ring E10, S2 in TP, S3 HI or LO and 1225 cps ring E10, S2 in TG, S3 in HI or LO.	Go to S-4B.
M-5	Disconnect lead from E3 and tap lead intermittently on E3 with 1600 cps and 1225 cps.	E10 rings instantly.	Go to I-5A.
		E10 not ring for a ½ second.	Go to M-6.
M-6	With S1 in 2W, S2 in TP, S3 in HI apply a 1600 cps at a -45 dbm to E1 and E2.	E10 does not ring.	Go to I-6A.
		E10 rings.	Go to M-7.
M-7	Connect FR-67 and ME-22 to E1 and E2. Connect the auxiliary power cord to E7 and E8, S1 in 4W, S2 in TP and then in TG. Adjust C27 for the proper frequency.	1600 cps will adjust. 1225 cps will not adjust.	Go to I-7A.
		1600 cps will not adjust.	Go to I-7B.
		Output not between -2 and +4 dbm.	Go to I-7C.
		1600 cps at ±6 cps, -2 to +4 dbm; 1225 cps at ±6 cps, -2 to +4 dbm.	TA-182/U is now ready for final testing.

SUB TESTS

Test	Procedure	Obtained Results	Next Test or Source of Trouble
S-2A	Unplug the power cord and check the fuse. If the fuse is not blown go to I-2A, if it is blown replace and remove V7 and V8. Plug power cord back into the AC source and replace V7 and V8 one at a time.	Fuse blows with V7 and V8 removed.	Go to I-2B.
		Fuse blows when V7 is replaced.	Go to I-2C.
		Fuse blows when V8 is replaced.	Go to I-2D.
		Fuse doesn't blow when V7 and V8 are replaced.	Return to M-2.
S-2B	Replace tubes that are not lighted.	Tube lights.	Return to M-2.
		Tube does not light.	Go to I-2E.
S-2C	Put headset (TS-190) across E1 and E2.	Tone is heard.	Go to M-3.
		Tone is not heard.	Go to I-2H.
S-4A	Apply 1600 cps at +10 dbm to B5 and ground.	E10 does not ring.	Go to L-4A.
		E10 rings.	Go to I-4D.
S-4B	While E10 rings with 1600 cps or 1225 cps apply a short across E5 and E6.	E9 does not light.	Go to I-4G.
		E9 lights.	Go to M-5.

LOCALIZATION TEST

Test	Procedure	Obtained Results	Next Test or Source of Trouble
L-4A	Remove power from the TA-182/U unsolder R20, apply power to the TS-182/U.	E10 does not ring.	Go to I-4A.
		E10 rings.	Go to I-4B.
		K3 clicks, E10 does not ring.	Go to I-4C.

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ISOLATION INFORMATION

I-1A

IF:

K1, short.
Wiring from S1 contacts to E7 and E8 to K1 to E1 and E2, shorted.

THEN:

The resistance will be less than 1600 ohms across E7 and E8.

I-1B

IF:

K1 contacts 12 to 4 and 11 to 2, open.

THEN:

The resistance will be less than 1600 ohms across E5 and E6.

I-2A

IF:

Winding 8-9, 1-2 of T6, open.
Power cord, open.
Power plug, open.
Fuse holder, open.

THEN:

Tubes will not light nor will relays K2 or K3 click.

I-2B

IF:

Any windings (5-7, 3-4, 8-9, 1-2) of T6, shorted.
Filament circuit, shorted.

THEN:

Fuse F1 will blow.

I-2C

IF:

V7, short.
C26B, short.
C26C, short.
C5C, short.

THEN:

Fuse F1 will blow when tube V7 is placed in the tube socket.

I-2D

IF:

V8, short.
C33, short.

THEN:

Fuse F1 will blow when tube V8 is placed in the tube socket.

I-2E

IF:

The filament wiring is open between any two tubes.

Then:

Tubes beyond the open circuit will not light.

I-2F

IF:

K1 coil, open.
Wiring E7 - E8 to S1, open.
Contacts of S1, open.
Wiring from S1 to K1, open.

THEN:

Relay K1 will not click.

I-2G

IF:

R32, 33, 34, 35, 36, defective.
C26C, leaky.
V7, low.
T6 term 3 and 4, open.
K2 coil, open.
Low voltages coming through T6.

THEN:

B+ reads low (300 normal).

IF:

R39, 40, open.
K2 coil, defective.
Contact 3, 4, of K1, open.

THEN:

Other relays not click even if B+ normal.

I-2H

IF:

TS-190/U is connected between ground and the following points.

THEN:

No tone at Z12 indicates oscillator not functioning.

I-2H *(Continued)*

IF:

R30, open.
V6, defective.

THEN:

No tone at Z12 but full B+ (as measured at pin 4 of T4) will appear at pin 1 of V6.

IF:

R31, open.
C27, short.
T5, short or open.
C31, short.
C32, short.
C28, open.

THEN:

No tone at Z12 and at least 41 VDC but less than full B+ (as measured at pin 4 of T4 will appear at pin 1 of V6).

IF:

V7, open.
R28, open.
R29, open.
C26, short.
R37, open.

THEN:

No tone at Z12 and less than 41 VDC at pin 1 of V6.

THEN:

Open C25 will yield tone at Z13 but not at Y12.

THEN:

Open R27 or wiring (see note on schematic) will yield at Z12 and Y12 but not V6 pin 7.

THEN:

Open R25 or wiring will yield tone at Z12, Y12, and V6 pin 7 but not at V6 pin 8.

THEN:

Open V6, open T4, open wiring, open or short contacts of K2 will yield tone at Z12, Y12, V6 pin 7, and V6 pin 8 but not at K2 pin 3 or K2 pin 5.

I-3A

IF:

R20, open.
Contacts, 7-8 of K3, short.

THEN:

E-10 will vibrate continuously *without* a signal being applied to the receive circuit.

I-4A

IF:

V5, defective.
R23, open.
K3 coil, open or short.

THEN:

E10 will not ring when R20 is removed because K3 cannot click and apply power to the static ringing generator E10.

I-4B

IF:

V2, defective.
T2, primary or secondary, open or short.
C10, open or short.
C11, short.
R15, open.
C21, short or open.
C22, open or short.
V3, defective.
C23, open or short.
R16, open.
R17, open.
T3 primary, open.
C24, short.
R19, open.

THEN:

E10 will ring when R20 is removed.

I-4C

IF:

Contacts 7 and 8 of K3, open.
E10, defective.
V8, defective.
Pins 5, 6, 7 of T6, open.

THEN:

K3 will click but E10 will not ring when R20 is removed.

I-4D

IF:

You insert 1600 cps at points listed and ground.

THEN:

At A5 with a signal level of +10 dbm and E10 doesn't ring, the probable trouble is R13.

THEN:

At B6 with a signal level of +10 dbm and E10 doesn't ring, the probable trouble is C8.

I-4D *(Continued)*

THEN:

At B3 with a signal level of -20 dbm and E10 doesn't ring, the probable trouble is V1, C5, R12, R11, C7, R10.

THEN:

At A4 with a signal level of -25 dbm and E10 doesn't ring, the probable trouble is R8.

THEN:

At B2 with a signal level of -25 dbm and E10 doesn't ring, the probable trouble is C6 of R19.

THEN:

At A1 with a signal level of -45 dbm and E10 doesn't ring, the probable trouble is R5, R6, R7, C5, R3, C4, or T1.

THEN:

From A9 to A10 with a signal level of -45 dbm and E10 doesn't ring, the probable trouble is R1 or T1.

THEN:

From B9 to A10 with a signal level of -45 dbm and E10 doesn't ring, the probable trouble is C1.

THEN:

From B9 to B10 with a signal level of -45 dbm and E10 doesn't ring, the probable trouble is C2.

I-4E

IF:

C3, short.
C12, short or open.
C13, short.
C16, short.
C17, short.
S2 contacts, open.

THEN:

1225 cps will not ring E10 in TC position, while 1600 cps will ring E10 in the TP position when signals are applied to E4 and E4.

I-4F

IF:

S3 contacts, open or shorted.
R24, open.

THEN:

A -45 dbm may not ring E10 in HI positions of S3 or -30 dbm may not ring E10 in LO position of S3.

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I-4G

IF:

E9, defective.
K3 contacts 12-5 or 11-3, dirty or open.
Wiring from E10 to E9 to K3 or E5 or from E6 to K3 to E10, open.

THEN:

Lamp E9 cannot light when the circuit is completed by shorting E5 and E6.

I-5A

IF:

V4, defective.
T3, open or short.
C18, open or short.
C19, open or short.
R17, open.
C20, short.
C14, open or short.
C15, short.
C16, short.
C17, short.

THEN:

K3 will energize instantly and E10 will ring when 1600 cps is applied in TP or 1225 is applied in TG positions of switch S2.

I-6A

IF:

Contacts 3-4-5, rear section, open or dirty.
Contacts 9-10-11, rear section, open or dirty.
Contacts 10-12, front section, open or dirty.
An open in the associated wiring.

THEN:

E10 will not ring when 1600 cps is applied to E1 and E2.

I-7A

IF:

C29, open.
C30, open.

THEN:

These defective tuning capacitors will cause the oscillator to produce a frequency other than the required 1225 cps.

I-7B

IF:

C27, open.
C31, open.
C32, open.

THEN:

These defective tuning capacitors will cause the oscillator to produce a frequency other than the required 1600 cps.

I-7C

IF:

A level of -2 to +4 dbm is not obtained.

THEN:

R43, R27, R26 must be strapped to obtain this correct reading.

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Appendix D

AN EXAMPLE OF A CONFERENCE TYPE LESSON PLAN

The next pages contain one of the conference hour lesson plans constructed for the experimental training program. Notice, in particular, that the lesson is structured in such a way as to elicit responses from the students on pertinent points. Information is given about the background of the students, the objectives of the lesson and the concept to be treated. Background information acquaints the instructor with the topics and experiences covered by previous training. The objectives state quite clearly what it is that the trainee is to be able to do upon the completion of the training session. The concepts to be learned are also listed. The special instructions provide information about training aids or special presentation techniques.

U.S. ARMY SOUTHEASTERN SIGNAL SCHOOL
FORT GORDON, GEORGIA

LESSON PLAN

TITLE:	COMPONENT IDENTIFICATION
ANNEX:	MOS 294.1 EXPERIMENTAL TRAINING PROGRAM
OBJECTIVES:	TO PROVIDE STUDENTS WITH THE ABILITY TO IDENTIFY SCHEMATIC SYMBOLS, COLOR CODES, AND WIRING DIAGRAM SYMBOLS.
TRAINING AIDS:	TRA-8
REFERENCES:	TM 11-681, APPENDIX III
METHOD OF INSTRUCTION:	CONFERENCE, DEMONSTRATION
TIME:	1 HOUR
MAIN POINTS:	I. SCHEMATIC SYMBOLS. II. COLOR CODE. III. PRACTICE EXERCISE. IV. SUMMARY
MAIN POINT I:	SCHEMATIC SYMBOLS.

INSTRUCTION:

1. BACKGROUND: Students have been locating troubles in the AN/TCC-7 using the handbook. These troubles were mostly open filaments of tubes. However, the last trouble was an open coupling capacitor. Students learned how to find this trouble and became familiar with the TRA-8 mock-up of the AR102. They have the basic theory of the vacuum tubes used in the AR102 and TRA-8.

2. OBJECTIVES: This main point should familiarize students with the circuit symbol which identifies an electronic component on a schematic. Students should be able to associate the schematic symbol with the physical component. The TRA-8 will be used for the purpose of teaching circuit elements and symbols.

3. CONCEPTS: Symbols of vacuum tubes, resistors, transformers, capacitors, primary and secondary, coils ¼ watt, ½ watt, and 1 watt resistors: fixed capacitors of various shapes and sizes: all fixed resistors are identified by the same symbol, schematic drawings.

4. SPECIAL INSTRUCTIONS: Use the TRA-8 mock-up of the AR102. Components are covered in such a manner as to provide the tie-in. All components are eventually covered. Point out that all fixed capacitors, regardless of shape or size, use the same symbol: likewise with resistors or transformers, each is identified by only one symbol. Do not refer to the components by their function, e.g., Grid Return Resistor or Plate Load, etc.

BEGIN: At this time you should become more familiar with the schematic symbols which represent the components on this board. This knowledge is necessary throughout the remainder of your work in electronics. You will soon become so familiar with the symbols that you will not have to think what they are and you will, in time, be able to read a schematic diagram like a book. It has its own story to tell about the circuit without use of words. We will look at each component on the board and at the symbol which represents it so that you will be sure to associate them properly. At the extreme left side of the board, is the 21 pin connector. Each pin on the connector is numbered for easy identification and similar numbers are used on the schematic.

1. What is the purpose of a schematic drawing?

   You already know that a block diagram consists of blocks drawn on paper which represent the major sections or portions of a piece of equipment. For instance, one square represents the channel modem another the sub-group panel, etc. This permits us to view the big picture without all the details. We want to see the forest not the trees in this case. On the other hand, a *schematic* drawing permits viewing the trees and even their bark but not much of the forest. Usually we only look at the schematic of a small portion of an equipment. The schematic drawing of the entire AN/TCC-7 would cover many pages.

2. Now, back to the TRA-8: What pin on P1 connects to ground?

   Pin 12 connects to ground. You will notice that many other parts connect to ground. We will cover these as we get to them.

3. Which pins on P1 connect current to the filaments of the tubes?

   Pins 6 and 8 connect filament voltages and current to the tubes. This current flows through the wires you see connected to the tube filaments, causing them to glow and so you see the tube glow when power is applied.

4. What is pin 13 of P1 used for?

   It connects +200 volts to the vacuum tubes. If you follow the wire from pin 13, it should lead you to pins 6 and 5 of each of the tubes. Of course it goes through some other components on the way. Remember last hour we said that both the plate and the screen grid were highly positive compared to the cathode. Well, that is the reason for the +200 volts DC.

5. Where is the input signal applied?

   To pins 0 and 2 of P1.

6. What signals could we expect to find at these pins?

   Either voice signals from the distant operator or the 1 KC test oscillator signal.

7. What signals should be present at pins 17 and 19?

   The output of the amplifier is applied to pins 17 and 19. Naturally, the same signals as the input signal would be present here, except they are amplified. That completes the 21 pin connector. Let's go back to pins 0 and 2 of the connector where the signal comes in. The input to the TRA-8 is applied to a transformer T1. The symbol for a transformer is a couple of coils which look like springs with lines separating them. This component is T1. The story it tells is that it has two coils, the one on the left is called the *primary* and the one on the right is called the *secondary*. The lines in between indicate that this transformer has a metal core separating the two coils. Some transformers do not have the metal core, only air. They would be drawn with no lines separating the two coils.

8. Can you identify the transformer T1 on the TRA-8 by pointing it out?

   Yes it is the small metal can just to the left of tube V1. You cannot see the coils because they are sealed in the can, but the connections come out through the underside. For easy identification you can see the numbers on the side of the can telling which part of the coils connects to each lead protruding from the bottom.

9. Can you identify the same transformer on the AR102?

   Hold your AR102 so that the words "receiving amplifier" are pointed to the right and the transformer T1 is the closest component to the right hand side on top. T1 on the TRA-8 and on the AR102 are identical.

10. Back to the TRA-8 now and locate T2. It is on the extreme right side. From what we have just said, would you describe transformer T2?

   This transformer differs from T1 in that it has three coils in it. It has a metal core and naturally it has more connections to it. It is called the output transformer.

11. Will you identify T2?

   It is immediately above the schematic symbol. It is larger than T1 and a little different in shape. Its leads are also identified by numbers corresponding to the leads which connect to the coils inside.

12. Arrange your AR102 as before and you will see T2 on the top left hand side of AR102 it is the largest component on the AR102.

13. Look at the TRA-8 again and you will see across the secondary of T1 the symbol for a capacitor. It is marked C1, 150 UUF. What does that mean?

   It means capacitor C1 and its value is 150 micromicro farads. It is connected across the secondary of T1 to ground, as you can see if you follow from Pin 6 straight down.

14. Capacitors come in various shapes and sizes and are constructed using many different materials, but when it comes to the schematic symbol, all capacitors which are *fixed* (their value is not variable) use the same symbol. Look for capacitor C2. Will you describe it to the class?

    It is a tubular capacitor in a metal can. Its value is .1 microfarad. It connects between pin 6 of V1 and ground.

15. The only other capacitor we see here which is different from the others is C5. How does it differ physically?

    It is larger in size and a little larger in value. It is .68 microfarad, tubular, in a metal can, and is connected between pin 8 of T2 and ground.

16. Find R1 and describe it.

    It connects between pin 1 of V1 and ground. The symbol for a resistor is a zig-zag line. The component is right beside the symbol. This resistor is 200,000 ohms in value. The ohm is the unit of opposition or resistance offered to the flow of current in a circuit. This resistor dissipates ¼ watt of power without burning up. The only way to tell this is by its size.

17. Find R9 on your TRA-8. Will you describe this resistor?

    It connects to pin 7 of V2 and to ground. It is represented by a zig-zag line on the schematic. This resistor is physically larger than R1. Its wattage rating is ½ watt.

18. Does the value of the resistor determine its size or wattage rating?

    No: Look at R1, its value is 200,000 ohms and it is ¼ watt whereas R9 is only 620 ohms in value and it is ½ watt. The wattage rating is only determined by the amount of power it must be able to handle. If very little current flows through a resistor then it can be of low wattage.

19. Locate resistor R8. What do we know about it?

    It is 3000 ohms and its symbol is the same as the ones used for R1 and R9, but it has a higher wattage rating. This resistor is 1 watt. It connects between pin 13 of P1 and pin 8 of T2. All other resistors on the board are similar to one of these types. The symbols for resistors used on this TRA-8 are all alike. The values are different in almost every case. The resistors are located on the underside of the AR102 chassis. Just take a good look at all of them on the AR102 for a moment.

MAIN POINT II: COLOR CODE

INSTRUCTION: 1. OBJECTIVES: Trainees should be able to recognize components by their color code and determine their value. At this point students have not been able to distinguish whether the proper value component was in its proper location. At the completion of this main point, students should be able to remove all components from the TRA-8 and to reassemble the board, properly placing each component in its respective place.

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2. CONCEPTS: Color code for resistors, color code for capacitors, bands, dots, arrows, sequence of reading color markings on capacitors and resistors.

3. SPECIAL INSTRUCTIONS: Students are given a printed formula card to carry on their person at all times. If some students do not have formula cards, provide them with cards. On the last page of the folded card is the color code which applies to resistors and capacitors alike. This card may be supplemented with the well known verse which is often used to help remember the color code and may be recited to the class at the discretion of the instructor. A large chart of the color code should also be on display before the class.

BEGIN: Now you know the symbol for resistors and capacitors and the various sizes and shapes of each one used in the AR102. It is easy to identify the component and to know its value as long as you can read it on the TRA-8 board. Suppose two of the resistors were suspected of being in the wrong position on the TRA-8. How could you distinguish the proper one?

The color code is the answer. Does everyone have a formula card like this? (Demonstrate formula card). On the last page you will see the color code chart. It is not necessary that you memorize the color code perfectly at this time. The more you work with the electronic components the better you will be able to recognize the components by the color code.

20. What does the color code tell us about resistor R1?

Use the chart. The background color on the composition resistor is usually brown and the colors are put on in bands. Resistor R1 has a first band color red so the first number of its value is 2. The next color tells the second number of its value and in this case black represents 0. So far we know that the value is 20. The third band is yellow, measuring 4, but we don't just use the number 4 because if you look at the chart you will see that the third color means the number of zeros to follow the first two numbers. This means that we have 20 and this number is followed by 4 zeros. So our value for R is 200,000 ohms. This last band is gold and on your chart you see it says tolerance. In this case the tolerance is 5%. This means that resistor R1 will offer 200,000 ohms of resistance in a circuit with a tolerance of +5% or -5%. From its size we know it is ¼ watt.

21. I want everyone to find R1 in the AR102. Did everyone find R1?

It is very close to pin 0 of the 21 pin connector. Do you agree that it would be pretty difficult to distinguish R1 from any other resistor without use of the color code?

22. Using your color code chart locate resistor R8 in AR102. It is a 3,000 ohm resistor. Can you describe how to find it?

It is the largest resistor on the underside of the chassis, but using the color code what would distinguish this component? The steps in determining the colors of a 3,000 ohm resistor are: The

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first number is 3, so the first band is orange; 0 is the second number, so the second band is black; then the number of zeros to be added is two, so the third band is red. We would look for a resistor having orange, black, and red bands in that order and you would have a 3,000 ohm resistor. Its tolerance is not too important while you are looking for it among many resistors. However in this case it is gold which means ± 5%.

23. So much for resistor color code. At the moment, we want to consider capacitors for a few minutes. The same color code applies to capacitors. However they are sometimes a little more difficult to read due to the many types and shapes which have been manufactured. Remove capacitor C3 from your TRA-8 for careful study. Notice an arrow on the capacitor. It should point to the right. Capacitors are also read from left to right on the top row where the arrow is then from right to left on the lower row of colors. For details of capacitor color code you are referred to Appendix III of TM 11-681. The capacitor in question, C3, is read as follows. The first color is black which describes its construction, it is a mica molded type. If the first color had been silver it would be a paper molded type. The second color is red and it is the first number of the value and of course it is 2. The next color is yellow which is 4, so now we have 24. The first color on the bottom right corner is the number of zeros. In this case it is brown which means 1. The value of this capacitor is 240 micromicro farads. Capacitors are generally assumed to be rated in UUFDS. The next color is red which is the tolerance, in this case + or - 2%. The last color is orange which signifies the number of hundreds of volts DC it can work under and not break down. This capacitor will withstand 3,000 volts because the last color is orange.

24. I want someone to recap what we have just said about this capacitor.

    (1) Black dot - made of mica.
    (2) Red dot - first significant figure 2.
    (3) Yellow dot - second significant figure 4.
    (4) Brown dot - number of zeros.
    (5) Value is 240 micromicro farads.
    (6) Red dot - tolerance is ± 2%.
    (7) Orange dot - 300 working volts in DC.

    Most capacitors will be of this type. Power supplies usually use much larger capacitors. Those types are not color coded but have all the information printed on them.

25. Remove capacitor C1 from the TRA-8. Now will you describe the markings on this capacitor and their meanings?

    (1) Arrange the arrow to point right.
    (2) Black dot - mica molded.
    (3) Brown dot - 1st figure is 1.
    (4) Green dot - 2nd figure is 5.
    (5) Brown dot - number of zeros 1.
    (6) Value of capacitor C1 is 150 UUFDS.

(7) Red dot - tolerance ± 2%.
(8) Red dot - 2 hundred working volts DC.

26. Locate these two capacitors on the AR102. Notice that the metal tubular capacitors used on the AR102 have the pertinent information printed on them.

MAIN POINT III: PRACTICE EXERCISE

INSTRUCTION:

1. OBJECTIVES: Students will practice identifying components by use of color code and schematic symbol. It provides practice in learning the color code and in properly identifying the schematic symbol.
2. CONCEPTS: No new concepts.
3. SPECIAL INSTRUCTIONS: For the remainder of the period of instruction, have students remove all components from the TRA-8, and, using the color code and schematic symbol of the component, replace it in its proper position. Students may use the large demonstrator and the color chart as a reference. All boards should be examined to see that they are properly restored before the end of the lesson.

BEGIN: You should now have a pretty good idea of how to identify the components on the TRA-8. To become more familiar with these parts, you should practice identifying them. For the remainder of this period, this is our objective. First, remove all components and tubes from your TRA-8 then, using your color code to identify values, replace them in the proper position on the board according to the schematic symbol. If you become stumped on something refer to the color chart, or if you are unable to proceed take a look at the large mock-up. It is best to do as much as you can without using the crutch. This way you will learn more. Proceed!

MAIN POINT IV:

1. What is the symbol for a resistor?
2. What is the symbol for a capacitor?
3. What would be the colors on a 4,300 ohm resistor?
4. What would be the markings on a 120 UUFD capacitor?
5. What are transformers used for?
6. What is a capacitor used for?
7. Describe the symbol for a pentode tube.
8. Why does the schematic show several wires connecting to ground?

END

Appendix E

CONTROLLED LAB AND PRACTICE EXERCISE EXAMPLES

The next pages contain one of the controlled lab lesson plans which was constructed for the experimental training program. In a controlled lab, the trainee works a problem up to the point where no solution is possible using previously learned techniques. The instructor then leads the trainee through a series of new responses with new concepts and procedures. During the session, the trainee is able to solve the problem with the guidance of the instructor.

Immediately following a controlled lab, a number of practical exercises are given. A practical exercise sheet for one problem is illustrated on the last page of this Appendix. Normally, the trainee will fill out the sheet, answering all the appropriate questions, after working the problem. Then, if the trainee has responded correctly, four questions (listed for this example under the heading "Critique") are asked of the trainee. If the trainee has not responded correctly, he is told to go back and continue working. If he is not able to satisfactorily answer the four questions, he is told the correct answer by the instructor.

The controlled lab and the practical exercise critique provide the means for the experimental training program by which a major portion of the theoretical material was taught.

U.S. ARMY SOUTHEASTERN SIGNAL SCHOOL
FORT GORDON, GEORGIA

LESSON PLAN

TITLE:	TRA-8
ANNEX:	MOS 294.1 EXPERIMENTAL TRAINING PROGRAM
OBJECTIVES:	TO FAMILIARIZE THE STUDENTS WITH THE TRA-8 AND COMPARE IT WITH THE AR102.
TRAINING AIDS:	AN/TCC-7 TERMINAL: AR102; TRA-8
REFERENCES:	TR 11-2139-20
METHOD OF INSTRUCTION:	CONFERENCE, DEMONSTRATION, PRACTICAL EXERCISE
TIME:	1 HOUR
MAIN POINTS:	I. TESTING AR102. II. TESTING TRA-8. III. SIGNAL TRACING IV. PRACTICE SIGNAL TRACING. V. SUMMARY
MAIN POINT I:	TESTING AR102.

INSTRUCTION:

1. BACKGROUND. Students are familiar with using test points on the AN/TCC-7 to locate troubles. They have found tube troubles where any element within the tube may be bad. They have spent the past day troubleshooting the AN/TCC-7 and localizing tube troubles using the handbook and TV-7/U. The past hour was spent trying to locate a trouble in the order wire receive amplifier. This trouble was an open coupling. The students were unable to find this trouble because they did not have the necessary test equipment. They realize now, that other troubles can disable the equipment besides bad tubes.

2. OBJECTIVES: Now the students are to use the headset and make output tests at AR102; then move to the input: then to the midpoint. They will find that the headset points to the faulty stage. They next replace the AR102 with the TRA-8 and perform the same tests. They now find proper signals. The exercise lab should not be interrupted and the AR102 and TRA-8 be compared. The signal path will be traced through the amplifier. Students will be permitted to use their headset to examine points for tone or no tone for the remainder of the period.

3. CONCEPTS: AR102, input, output, midpoint, TRA-8, headset TS-190, Signal tracing, stand off, multipin connector, subchassis, amplifier, amplification, mock-up, patch cord, transformer, capacitor, and resistor.

4. SPECIAL INSTRUCTIONS: First, permit the students to apply power to the AN/TCC-7 and explain that you want them to follow the procedure they learned earlier in the lesson on methods of troubleshooting, and that they should perform output, input, and midpoint tests. They use their headset TS-190/U and the proper test points are pointed out to them. Next they replace the AR102 with the TRA-8 using the patch cord. The output, input, and midpoint tests are repeated by the group using the TS-190. They find this panel to be good. Caution students regarding the proper method of connecting the plug and jack of the 21 pin connector. The pins are brittle and break easily. The plug and jack are designed to connect only one way. Never use force. If any student is not convinced that his AR102 receive amplifier is bad, have him connect his equipment and, using the test cord and test jack of the test panel, show him how he had input but improper output, before proceeding.

MAIN POINT I: TESTING AR102.

BEGIN:

1. We said earlier that you should not be discouraged because you could not locate the trouble in your order wire panel. To date you have been locating troubles caused by bad tubes, but you must realize that tubes are not the only cause of failure. This means that you must know something more about the circuitry and how to perform other tests. The tests, involving the test panel, showed that there was proper input to the receive amplifier, but incorrect output - the tubes were found to be good. Now the question is, "What to do?". Here is a training aid board, which performs just as the AR102. It is called TRA-8 and it is a mock-up of the AR102, which means it is the same as the amplifier assembly except it is larger and is spread out for easy viewing. There is a cord with suitable adapters which we will plug into the TRA-8 and to the order wire panel.

INSTRUCTION: ISSUE PANELS AND PATCH CORDS TO STUDENTS AND BE SURE THEY ARE PROPERLY CONNECTED.

MAIN POINT II: TESTING TRA-8.

INSTRUCTION:

1. OBJECTIVES: To show students that the signal is able to pass from input to output on the TRA-8 and provide amplification. Then compare these signals with those of the bad AR102. By making midpoint checks the capacitor C# is assumed to be bad.

2. CONCEPTS: Transformer Pins 1 and 3; tone tracing; coupling capacitor.

3. SPECIAL INSTRUCTION: Do not progress with the testing for signals at a rate which is too fast for the slowest student. Be sure all students are aware of the significance of the tests, namely that the normal signals are available throughout the TRA-8 but do not pass through the AR102.

BEGIN: Each of you will not connect his TS-190 headset to the primary of transformer T1 at pins 0 and 2 and listen for tone. If you don't hear anything notify the instructor. Now move your headset to pins 17 and 19 and listen to the output. If the output is not considerably louder than the input you have trouble somewhere. Let's now compare these signals with those in the AR102. Replace the TRA-8 with the AR102 and look on the underside of AR102 near the 21 pin connector and locate pin 1 and 3 of T1 and at these points connect your TS-190/U. Be careful not to allow your leads to touch other pins or components. Now move your TS-190/U leads to pins 1 and 3 of T2 and listen. You probably hear a very weak signal or no signal at all. You have now tested the input and the output. Since the output is weak you normally test the midpoint. Place your headset on pin 1 of V1 and ground and listen for tone. If you hear no tone what component could be bad?

MAIN POINT III: SIGNAL TRACING.

INSTRUCTION:

1. OBJECTIVES: Signals are traced from the 1KC oscillator to the input to the AR102. Students connect TRA-8, and listen for tone at input. They locate test points E1 and E2 on both the TRA-8 and AR102, then they tone trace at these points. They recognize amplification as they follow the signal through the amplifier. They compare signals of TRA-8 with those of the AR102. They learn to locate capacitor C3 on the AR102. They test but get no signal on grid side of C3. Students then finish tracing the signal through the TRA-8 to the output.

2. CONCEPTS: Test points E1 and E2, coupling capacitor C3, open capacitor, vacuum tube, amplitude, volume, transformers as coils of wire, transformer coupling.

3. SPECIAL INSTRUCTIONS: Do not permit students to go too fast. Try to pace the class so that the slowest student can follow each step and understand it.

BEGIN: Let us stop for a few minutes and see why it could be capacitor C3 which is blocking our signal.

1. Where does the signal come from? It comes from the 1KC oscillator in the test panel.

2. How do we know it is good? It came through the TRA-8 fine.

3. Where does it come in to the AR102? At the 21 pin connector, pins 0 and 2, then it goes to transformer T1, pins 1 and 3.

4. Let's check this signal path as we trace it. Reconnect your TRA-8 to the AN/TCC-7 using the patch cord. Using your TS-190/U headset, connect to pins 0 and 1 of J1. Do you hear tone? You should hear 1KC. Now connect to pins 1 and 3 of T1. Do you still hear tone?

5. To trace the signal as it progresses through the amplifier requires a certain knowledge of where to make tests. Sometimes convenient test points are available and easy to reach

such as E1 and E2. They are marked on TRA-8 but the test points are not made available. Pick up your AR102 and on the underside locate test points E1 and E2 and notice how easily available they are made for testing. Now back to the TRA-8 and let's test at E2 which is at the left hand side of the resistor R6 immediately above E2. Use your headset and place one lead at E2 and the other at ground which is located at the extreme lower left corner of your TRA-8. Do you hear 1KC tone? You should hear the 1KC tone.

6. Is there any noticeable difference in the signal between the tone at the transformer T1 and at T2? It should be considerably louder at E2.

7. Next, let's check for signal at both sides of C3. Do you hear the 1KC tone? You should hear about the same as at E2.

8. What purpose does C3 serve then if it didn't have any noticeable sound effect on the signal? It serves to provide a good path for the signal from one vacuum tube, V1 to the next, V2. The capacitor is called a coupling capacitor because it couples the signal from one point to another.

9. Before going any further it will be interesting to check the signal on your AR102 as we just did on the TRA-8 and compare them. Disconnect the TRA-8 and connect the AR102. Connect your headset across pins 1 and 3 of T1, then to test point E2 and chassis which is ground. Does the sound get louder? It should, just as it did in the TRA-8.

10. Now try to locate capacitor C3. Do not connect your headset across it until I tell you. When you are able to identify it, hold up your hand. Would you like to tell me how he was able to locate C3? It is connected between pin 5 of V1 and pin 1 of V2. You can see it quite easily on the TRA-8, but it is quite difficult on the actual equipment until you become able to use landmarks. We used the tube pins as a landmark. It is necessary to know which pin on the tube base of V1 is pin 5. You can see a wide gap between the pins. The pin to the left of the gap is pin 1 and they are numbered clockwise from there so, count to 5 and you have pin 5. Look at V2 base and you know that the lug to the left of the wide gap on this tube base is lug 1 and they are numbered clockwise from there through lug 7. Now you can identify pins 1 and 5 on the tube bases. Find a component connected between them and mounted against the chassis and you have found C3. It was not very difficult, was it?

11. We were looking at the tube from the underside when you identified the pins. If you remove the tube V1 and look at the holes in the tube socket from the top, the pins are counted just the opposite. You locate the gap, then look to the right and that is pin 1, then count counterclockwise through pin 7. Can you identify pin 5 from the top of the board? Sure, it is the fifth pin starting from the right of the gap and counting in a counterclockwise direction.

12. Okay, now let's connect the headset first to pin 5 of V1 and ground. Do you hear anything? You should hear the 1KC tone.

13. Now place your headset on pin 1 of V2 and ground and listen. Do you hear anything? You hear either no signal or a very weak signal compared to the one you heard at the same test points on the TRA-8.

14. What do you suppose is the trouble? Of course capacitor C3 is bad in the AR102 and is not coupling our signal to the next stage. We call this an *open* capacitor because it is just like a bridge that is out; the traffic stops. When the capacitor is open, no path is provided for the signal to follow. If you heard a weak signal it may be that the signal took a detour just as traffic will when the bridge is out.

15. Now we want to trace the signal flow further and we know it is not possible using the AR102 because the signal cannot progress beyond C3; so disconnect the AR102 and connect the TRA-8. Where would you connect the headset next? A good place would be at pin 5 of V2. There is a snap connector there; place one lead of the headset to pin 5 and the other on ground. Do you hear any signal? You should hear a loud 1KC tone. Now compare that tone with the one at E2. Go back to the left side of the resistor immediately above test point E2 on the TRA-8. You should notice a considerably louder signal at pin 5 of V2 than you do at E2.

16. Why did the signal get louder? Because it passed through an amplifier. The vacuum tube V2 made the signal get louder in volume. Now check the output. From the vacuum tube where does the signal go? It goes to transformer T2.

17. What is the transformer for? It is sort of like the capacitor C3, it couples the signal from one point to another using coils of wire. In this case the transformer is made up of three coils all wound up and sealed in a can with only the ends of the wires sticking out for us to make connections. The leads or wires we are most interested in are numbered 1 and 3. There is no place on TRA-8 to connect to pins 1 and 3 though. So where can we connect our headset to hear the 1KC tone? We can connect to pins 17 and 19 of the 21-pin connector on the left side of the board.

18. Do you hear the 1KC? You should because the signal goes directly from T2 to the 21-pin connector.

19. We said that transformer T2 couples the signal from the vacuum tube to the output. What does transformer T1 do? T1 is also used for coupling. It couples input to the vacuum tube V1. It has only two coils sealed in a can with six wires brought out for connections. It is physically smaller than T2.

MAIN POINT IV: PRACTICE SIGNAL TRACING.

INSTRUCTION:

1. OBJECTIVES: To allow students to become better acquainted with the TRA-8 at their own speed.
2. CONCEPTS: No new concepts will be presented at this time.
3. SPECIAL INSTRUCTIONS: Students will work on the TRA-8 for the remainder of the period. They should use their headsets to listen for tone at various points on the circuit. They may remove one component at a time and observe the effect it has on the output.

BEGIN:

Now that you have been shown where and how to test for tone at vital points on the TRA-8, it is your turn to experiment. Use your headset for the remainder of the hour until break time and examine the circuit on your own. Use your headset and test for tone at various places throughout the circuit. You may remove one component at a time and observe the effect it has on the signal. The more familiar you become with the action each component has on a circuit, the more confident you will become to work with that circuit.

MAIN POINT V: SUMMARY

1. How can you tell if the P1 and J1 are properly lined up for connection?
2. Where is the 1KC signal applied to the AR102?
3. What does T1 do in the circuitry?
4. How can pins be identified on a tube?
5. Does it make any difference if you count pins on a tube base looking from the top side or bottom?
6. What effect does an open coupling capacitor have on an amplifier circuit?

END

U.S. ARMY SOUTHEASTERN SIGNAL SCHOOL
Fort Gordon, Georgia

SYNOPSIS OF PRACTICE EXERCISE

1. Main Test M-7* Equipment TA-182
2. Sub Test ______ Practice Exercise No. II 720
3. Localization Test ______ Lab Bench No. ______
4. Isolation Test I-7A* Ser. No. ______
5. Defect C-29 Open*
6. FSN ______
7. Test Equipment ______
8. Cause of failure

Power surge	Short to chassis	Dampness
Low voltage	Aged part	Dirt
High voltage	Part changed value	Wrong fuse
Loose cable	Tube shorted	Cold solder joint
Lightening	Operator trouble	Capacitor shorted
Open	Short	Open resistor
Other		

Critique

9.* What is the purpose of C29 and C30?

C29 and C30 along with C31 and C32 change the output of the oscillator to 1225 cps.

10.* Why doesn't this affect the operation in the TP position?

C29 and C30 are disconnected by S-2 and are not in the circuit when the switch is in the TP position.

11.* Does V6 oscillate continuously or only when you wish to signal?

V6 oscillates continuously and is only applied to the line when K1 and K2 are energized.

12.* How may the frequency of the oscillator be changed?

The frequency of the oscillator may be changed by varying C27.

* These entries appear only in the instructor's copy.

END

SUBJECT MATCHING

Table F-1

294.1 Carrier Equipment Repairman Experimental Comparison by Pairs

Pair	Native Born	Normal Color Vision	Vision Correctible			No Psychiatric Disturbance	Completed High School	1 Year College	High School Subjects[a]						No relevant civilian occupation	Electronic Aptitude (EL)					
			To 20/20	To 20/40	To 20/40 or 20/20				Electronics	General Science	Algebra	Algebra, Chemistry	Geometry	Trigonometry, Chemistry		Over 130	125–129	120–124	110–119	105–109	100–104
1 Experimental	X	X			X	X	X						X		X	X					
Standard	X	X	X			X	X							X	X	X					
2 Experimental	X	X	X			X	X				X				X	X					
Standard[b]																					
3 Experimental	X	X		X		X	X							X	X	X					
Standard	X	X	X			X	X								X	X					
4 Experimental	X	X		X		X		X			X			X	X	X					
Standard	X	X		X		X	X							X	X	X					
5 Experimental	X	X			X	X	X						X		X	X					
Standard	X	X	X			X	X						X		X	X					
6 Experimental	X	X	X			X	X				X				X	X					
Standard	X	X	X			X	X						X		X						
7 Experimental	X	X	X			X	X								X						
Standard	X	X		X		X	X				X				X						
8 Experimental	X	X			X	X	X								X						
Standard	X	X	X			X	X						X		X				X		
9 Experimental	X	X	X			X	X								X				X		
Standard	X	X	X			X	X						X						X		
10 Experimental	X	X			X	X	X								X				X		
Standard	X	X	X			X					X				X				X		
11 Experimental	X	X	X			X					X				X				X		
Standard	X	X		X		X					X				X				X		
12 Experimental	X	X		X		X	X				X				X				X		
Standard	X	X		X		X	X				X				X				X		
13 Experimental	X	X	X			X				X					X				X		
Standard	X	X	X			X	X			X					X				X		
14 Experimental	X	X	X			X				X					X				X		
Standard	X	X	X			X	X			X					X				X		
15 Experimental	X	X	X			X	X			X					X				X		
Standard	X	X		X		X	X			X					X				X		
16 Experimental	X	X		X		X	X			X					X				X		
Standard	X	X		X		X	X			X					X				X		
17 Experimental	X	X		X		X	X		X						X				X		
Standard	X	X	X			X	X						X		X					X	
18 Experimental	X	X	X			X	X			X					X					X	
Standard[b]																					
19 Experimental	X	X		X		X	X			X					X					X	
Standard	X	X	X			X	X						X		X					X	
20 Experimental	X	X		X		X	X					X			X					X	
Standard[b]																					
21 Experimental[b]																					
Standard	X	X	X			X	X								X						X
22 Experimental	X	X	X			X				X					X						X
Standard	X	X	X			X					X				X						X

[a]Only one high school subject is recorded within the priority (lowest to highest) listed.
[b]Dropped from training for administrative and/or scholastic reasons.

Appendix F

77

Unclassified

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13. ABSTRACT

The JOBTRAIN IV research was designed to develop methods for producing a combination of training and manuals (job aids) that would require less training time than the standard course for the 294.1 Carrier Equipment Repairman. The methods developed were those of an equipment malfunction analysis for producing content for special manuals and methods of course construction which introduced theory as the student needed it to solve practical maintenance problems. Twenty-two students graduating from an 11-week JOBTRAIN course were tested on the same job performance test as graduates of the 25-week standard (294.1 MOS) course. The students from the two groups were matched and each was individually tested for 22 hours during a 6-day period. There were no statistically significant differences in performance between the two groups. It was concluded that the combination of JOBTRAIN training and job aids is as effective for the 294.1 MOS as conventional school training and manuals and that a 50% reduction in academic hours can be achieved by this combination.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Electronic Maintenance						
Job Aids						
Job Analysis						
Job Requirements						
MOS 294.1						
Systems Analysis						
Technical Manuals						
Test Construction						
Training						
Training Content						

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1 CINC USA PACIFIC ATTN G3 COC APO SAN FRAN 96610
2 CG SOUTHERN EUROPEAN TASK FORCE APO 09168 NY
1 CG US ARMY JAPAN APO 96343 SAN FRAN ATTN G3
10 CG USA FORCES SOUTHERN COMD ATTN SCARCD FT AMADOR CZ
1 CG US ARMY ALASKA ATTN ARACD APO 98749 NY
2 CG US ARMY EUROPE APO 09403 NY ATTN OPNS DIV
1 CG US ARMY AD COMD ENT AFB ATTN ADGCB
1 CG 1ST ARMY ATTN DCSOT FT MEADE MD
1 CG 3RD ARMY ATTN DCSOT FT MCPHERSON
2 CG 4TH ARMY ATTN AKAOC-B(UT) FT SAM HOUSTON
1 CG FOURTH ARMY FT SAM HOUSTON ATTN G3
2 CG FIFTH ARMY FT SHERIDAN ATTN ALFGC TNG
1 CG EUSA ATTN AG-AC APO 96301 SAN FRAN
1 DIR HEL APG MD
1 CG USA CDC EXPERIMENTATION COMD FT ORD
2 ENGNR PSYCHOL LAB PIONEERING RES DIV ARMY NATICK LABS NATICK MASS
1 TECH LIB ARMY NATICK LABS NATICK MASS
3 CO DEF DEVEL ENGNR LAB EDGEWOOD ARSENAL
2 INST OF LAND CBT ATTN TECH LIB FT BELVOIR VA
1 REDSTONE SCIENTIFIC INFO CTR US ARMY MSL COMD ATTN CHF DOC SEC ALA
1 CO USAPA MBLTV DET TOBYHANNA ARMY DEPOT
1 CO FT HUACHUCA SPT COMD USA ATTN TECH REF LIB
12 CO 1ST AIR DEF GUIDED MSL BRGD TNG FT BLISS
1 SIXTH USA LIB DEPOT BLDG M 13 14 PRES OF SAN FRAN
1 PLANS OFFICER PSYCH HOQTRES USACDCEC FORT ORD
5 CG FT ORD ATTN G3 TNG DIV
2 DIR WRAIR WALTER REED ARMY MED CTR ATTN NEUROPSYCHIAT DIV
1 CO HQ ARMY ENLISTED EVAL CTR FT BENJ HARRISON
1 TECH LIB BOX 22 USACDC EXPERIMENTATION COMD FT ORD
1 HUMAN FACTORS TEST DIV (ADHZ) USAF HOSP EGLIN AFB
1 CO USA MOBILITY EQUIP R&D CTR ATTN TECH DOC CTR FT. BELVOIR
1 CO FRANKFORD ARSNL ATTN SMUFA-N6400/202-4
3 6TH RGN USARADCOM FT BAKER
1 4TH ARMY MSL COMD AIR TRANSPORTABLE SAN FRAN
2 CO PICATINNY ARSNL DOVER N J ATTN SUMPA VCI
1 DEF SUPPLY AGY CAMERON STATION ATTN LIB
2 CO USA CDC AG AGCY FT BENJ HARRISON IND
1 REF M MS IS NASA ALA
1 CBT OPRS RES GP USACDC SP OPRS ANALYST HUMAN FACTORS ALEX VA
1 CO ARMY CDC INF AGY FT BENNING
1 CO ARMY CDC ARMOR AGY FT KNOX
8 ARMY CDC SPEC WARFARE AGY FT BRAGG
1 EVAL DIV DAD ARMY SIG CTR + SCH FT MONMOUTH
1 CO US ARMY CDC AVN AGCY FT RUCKER
15 CG USA TNG CTR AD ATTN ACOFS G3 FT BLISS
1 CG USA TNG CTR ARMOR ATTN ACOFS G3 FT KNOX
12 CO USA TNG CTR (FA) ATTN ACOFS G3 FT SILL
1 CG USA TNG CTR & FT LEONARD WOOD ATTN ACOFS G3
1 CG USA TNG CTR INF ATTN ACOFS G3 FT BENNING
1 CG USA TNG CTR INF ATTN ACOFS G3 FT DIX
1 CG USA TNG CTR ATTN ACOFS G3 FT JACKSON
1 CG USA TNG CTR INF ATTN ACOFS G3 FT LEWIS
1 CG USA TNG CTR INF & FT ORD ATTN ACOFS G3
30 CG USA TNG CTR INF ATTN ACOFS G3 FT POLK
5 CO USA MED TNG CTR ATTN DIR OF TNG FT SAM HOUSTON
1 CG USA TNG CTR INF ATTN ACOFS G3 FT BRAGG
1 CG USA TNG CTR INF ATTN ACOFS G3 FT CAMPBELL
3 CIVLN PERS OFCR US ARMY SPT CTR ST LOUIS ATTN EMPLOYEE DEVEL OFCR
3 LIB ARMY WAR COLL CARLISLE BKS
1 COMDT USA INTELL SCH ATTN AHBH-S-AD FT HOLABIRD
1 US MILIT ACAD WEST POINT ATTN LIB
1 COMDT ARMY AVN SCH ATTN DIR OF INSTR FT RUCKER
2 COMDT ARMY SECUR AGY TNG CTR + SCH FT DEVENS ATTN LIB
1 MED FLD SERV SCH BROOKE ARMY MED CTR FT SAM HOUSTON ATTN STIMSON LIB
3 DIR OF INSTR ARMOR SCH FT KNOX
1 COMDT ARMY ARMOR SCH FT KNOX ATTN WEAPONS DEPT
1 COMDT ARMY CHEM CORPS SCH FT MCCLELLAN ATTN EDUC ADV
1 EDUC ADV USAIS ATTN AJIIS-H FT BENNING
1 DIR OF INSTR USAIS ATTN AJIIS-D-EPRD FT BENNING
1 COMDT ARMY TRANS SCH FT EUSTIS ATTN EDUC ADV
2 COMDT US ARMY SOUTHEASTERN SIG SCH ATTN: EDUC ADVISOR FT GORDON
1 COMDT USA AD SCH FT BLISS
1 CO USA ORD CTR & SCH OFC OF OPS ATTN AHBN-O APG MD
5 ASST COMDT ARMY AIR DEF SCH FT BLISS ATTN CLASSF TECH LIB
5 CG USA FLD ARTY CTR ATTN AVN OFCR FT SILL
1 COMDT ARMED FORCES STAFF COLL NORFOLK
1 COMDT USA SIG CTR & SCH ATTN DOI FT MONMOUTH
1 COMDT JUDGE ADVOCATE GENERALS SCH U OF VA
1 DPTY COMDT USA AVN SCH ELEMENT GA
1 DPTY ASST COMDT USA AVN SCH ELEMENT GA
1 USA AVN SCH ELEMENT OFC OF DIR OF INSTR ATTN EDUC ADV GA
1 EDUC CONSLT ARMY MILIT POLICE SCH FT GORDON
6 COMDT USA ENGR SCH ATTN EDUC ADV FT BELVOIR
2 COMDT US ARMY SCH EUROPE ATTN REF LIB APO 09172 NY
1 DIR OF INSTR US MIL ACAD WEST POINT NY
1 USA INST FOR MIL ASSIST ATTN LIB FT BRAGG
4 USA INST FOR MIL ASSIST ATTN COUNTERINSURGENCY DEPT FT BRAGG
1 ARMY SIG CTR + SCH FT MONMOUTH ATTN TNG LIT DIV DAO
2 COMDT USA MSL & MUN CTR & SCH ATTN CHF OFC OF OPS REDSTONE ARSNL
2 COMDT US WAC SCH US WAC CTR ATTN AJMCT FT MCCLELLAN
2 HQ ABERDEEN PG ATTN TECH LIB
1 COMDT USA INTELL SCH ATTN DIR OF ACADEMIC OPS FT HOLABIRD
1 COMDT USA INTELL SCH ATTN DIR OF DOC & LIT FT HOLABIRD
1 COMDT USA C&GSC OFC OF CHF OF RESIDENT INSTR FT LEAVENWORTH
1 COMDT USA CA SCH ATTN DEPT OF RSCH ANALYSIS & DOC FT GORDON
1 COMDT USA CA SCH ATTN DOI FT GORDON
1 COMDT USA CA SCH ATTN EDUC ADV FT GORDON
1 COMDT USA CA SCH ATTN LIB FT GORDON
1 COMDT USA SCH & TNG CTR ATTN ACOFS G3 TNG DIV FT MCCLELLAN
1 COMDT USA SCH & TNG CTR ATTN ACOFS G3 PLNS & OPS DIV FT MCCLELLAN
10 COMDT USA INST FOR MIL ASSIST ATTN DOI FT BRAGG
1 COMDT USA CBR WPNS ORIENTATION COURSE ATTN ODI DUGWAY UTAH
1 COMDT USA FLD ARTY SCH ATTN DOI FT SILL
1 COMDT USA ARTY & MSL SCH ATTN EDUC SERVICES DIV FT SILL
1 COMDT USA ARTY & MSL SCH ATTN EDUC ADV FT SILL
1 COMDT USA TRANS SCH ATTN DIR OF DOC & LIT FT EUSTIS
1 COMDT USA TRANS SCH ATTN LIB FT EUSTIS
1 USA INST FOR MIL ASST ATTN EDUC ADV FT BRAGG
1 COMDT USA ARTY & MSL SCH ATTN LIB FT SILL
1 CG USA SCH & TNG CTR ATTN ACOFS G3 FT GORDON
1 COMDT USA AD SCH ATTN AKBAAS-DL-EA FT BLISS
2 DIR BRGD + BN OPNS DEPT USAIS FT BENNING
1 DIR COMM ELEC USAIS FT BENNING
1 DIR ABN-AIR MOBILITY DEPT USAIS FT BENNING
1 CG US ARMY SIGNAL CTR & SCH ATTN SIGDTL-3 (COBET II)
1 SECY OF ARMY, PENTAGON
1 DCS-PERS DA ATTN CHF C+S DIV
1 DIR OF PERS STUDIES & RSCH DDCSPER DA WASH DC
2 ACSFOR DA ATTN CHF TNG DIV WASH DC
1 CG USA MAT COMD ATTN AMCRD-TE
1 HQ ARMY MAT COMD R+D DRCTE ATTN AMCRD-RC
1 CHF OF PERS OPNS OFCR PERS DRCTE DA ATTN SIG BR
1 US ARMY BEHAVIORAL SCI RES LAB WASH, D.C. ATTN: CRD-AR
1 DPO PERS MGT DEV OFC ATTN MOS SEC (NEW EQUIP) OPOMO
1 ARMY PROVOST MARSHAL GEN
1 OFC RESERVE COMPON DA
2 CG USA SEC AGCY ARL HALL STA ATTN AC OF S G1 VA
50 ADMIN DDC ATTN: TCA (HEALY) CAMERON STA ALEX., VA. 22314
1 CO US ARMY MED RES LAB FT KNOX
1 CG ARMY ELECT COMD FT MONMOUTH ATTN AMSEL CB
1 CHF OF R+D DA ATTN CHF TECH + INDSTR LIAISON OFC
1 CO USA ELCT COMD ATTN AMSEL-RDD
1 U S ARMY BEHAVIORAL SCI RES LAB WASH, D.C. ATTN CRD-AIC
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATT ED ADV FT HUACHUCA
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATTN ORG DOC & NEW EQUIP ARIZ
2 TNG + DEVEL DIV DDCS-PERS
1 COMDT USA CBT SURVEIL SCH & TNG CTR ATTN 1ST CBT TNG BDE ARIZ
1 CAREER MGT BR ATTN R DETIENNE CAMERON STA ALEX VA
1 PRES ARMY ARMOR BD FT KNOX
1 PRES ARMY INF BD FT BENNING ATTN FE+SP DIV
2 PRES ARMY AIR DEF BD FT BLISS ATTN MST DIV
1 PRES ARMY MAINT BD FT KNOX
2 PRES ARMY AVN TEST BD FT RUCKER
2 PRES ARMY ARTY BD FT SILL
1 LIB ARMY ABN ELEC & SPEC WARFARE BD FT BRAGG
1 DPTY PRES ARMY MAT COMD BD ABERDEEN PG
15 CG USCONARC ATTN ATIT-RD-RD FT MONROE
2 CG USCONARC ATTN LIB FT MONROE
1 US ARMY ARCTIC TEST CTR R & D OFFICE SEATTLE
1 CHF USA AD HRU FT BLISS
1 CHF USA ARMOR HRU FT KNOX
1 CHF USA AVN HRU FT RUCKER
1 CHF USA INF HRU FT BENNING
1 CHF USA TNG CTR HRU PRES OF MONTEREY
1 CG 4TH ARMORED DIV ATTN DCSOT APO NY 09326
1 CO 14TH ARMORED CAV REGT APO 09026 NY
2 CO 1ST BN 63RD ARMOR 1ST INF DIV ATTN S3 FT RILEY
1 CO 1ST BN 64TH ARMOR 3RD INF DIV ATTN S3 APO NY 09031
1 CO 3RD BN 37TH ARMOR 4TH ARMORED DIV ATTN S3 APO NY 09066
3 CO 2ND BN 34TH ARMOR 25TH INF DIV ATTN S3 APO SAN FRAN 96266
1 CALIF NG 40TH ARMORED DIV LOS ANGELES ATTN AC OF SG3
1 55TH COMD HQ DIV ARMY NG JACKSONVILLE FLA
1 CG HQ 27TH ARMORED DIV NY AIR NG SYRACUSE
1 TEXAS NG 49TH ARMORED DIV DALLAS
2 CG 1ST INF DIV ATTN ACOFS G3 APO SAN FRAN 96345
1 CG 3RD INF DIV ATTN ACOFS G3 APO NY 09036
3 CG 4TH INF DIV ATTN ACOFS G3 APO SAN FRAN 96262
1 CG 7TH INF DIV ATT ACOFS G2 APO SAN FRAN 96207
1 CG 8TH INF DIV ATTN ACOFS G2 APO NY 09111
1 CG 5TH INF DIV (MECH) & FT CARSON ATTN ACOFS G2 COLO
3 CG 82ND ABN INF DIV ATTN ACOFS G3 FT BRAGG
1 CO 197TH INF BRGD FT BENNING ATTN S3
2 CO 3RD BN 6TH INF REGT ATTN S3 APO NY 09742
3 CG 25TH INF DIV APO 96225 SAN FRAN
~~1 CO 2ND BN 15TH INF 3RD INF DIV ATTN S3 APO NY 09026~~
3 CG 24TH INF DIV ATTN ACOFS G3 FT RILEY
4 CO 1ST BN (MECH) 52ND INF 198TH INF BDE ATTN S3 APO SAN FRAN 96219
1 CO 4TH BN (MECH) 54TH INF ATTN S3 FT KNOX
1 CO USA PARTIC GP USN TNG DEVICE CTR FLA
1 DA OFC OF ASST CHF OF STAFF FOR COMM-ELCT ATTN CETS-6 WASH
1 DIR ARMY LIB PENTAGON
1 CHF OF MILIT HIST DA ATTN GEN REF BR
1 CO USA 10TH SPEC FORCES GP FT DEVENS
1 CO 24TH ARTY GP (AD) ATTN S3 RI
1 CG 31ST ARTY BDE AD ATTN S3 PA

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1 CO 49TH ARTY GP AO ATTN S3 FT LAWTON
2 HQS 4TH BN 59TH ARTY REGT ATTN S3 NORFOLK
1 CO 28TH ARTY GP AO ATTN S3 SELFRIOGE AFB
1 CO 52NO ARTY BDE AO ATTN S3 FT HANCOCK
1 HQ NIAGARA-BUFFALO OEF 31ST ARTY BRGO AIR OEF LOCKPORT
1 HQS 45TH ARTY BOE AO ATTN S3 ARL HTS ILL
1 CO 35TH ARTY BDE AD ATTN S3 FT MEAOE MO
1 CG 101ST ABN DIV (AIRMOBILE) ATTN ACOFS G3 APO SAN FRAN 96383
1 CG 1ST CAV (AIRMOBILE) ATTN ACOFS G3 APO SAN FRAN 96383
1 US ARMY TROPIC TEST CTR PO ORAWER 942 ATTN BEHAV SCIEN CZ
8 CG III CORPS & FT HOOD ATTN G3 SEC FT HOOD
30 CO 1ST ARMORED DIV ATTN G3 SEC FT HOOD
30 CG 20 ARMOREO OIV ATTN G3 SEC FT HOOD
25 CO 13TH SUPT BGOE ATTN S3 SEC FT HOOD
10 CG USAFAC ATTN G3 SEC FT SILL
20 CO III CORPS ARTY ATTN G3 SEC FT SILL
20 CG USA AD CTR ATTN G3 SEC FT BLISS
3 CG ATTN G3 SEC FT POLK LA
1 BESO ARO OFC CHF OF R&D WASH OC
1 CHF OF R&D DA ATTN SCI INFO BR RSCH SPT OIV WASH OC
2 CINC US PACIFIC FLT FPO 96614 SAN FRAN
1 CINC US ATLANTIC FLT CODE 312A USN BASE NORFOLK
1 CDR TNG COMMANO US PACIFIC FLT SAN OIEGO
5 TECH LIB PERS 11B BUR OF NAV PERS ARL ANNEX
3 DIR PERS RES OIV BUR OF NAV PERS
1 TECH LIB BUR OF SHIPS COOE 210L NAVY OEPT
2 NAV AIR SYS COMD REP ATLANTIC NAV AIR STA NORFOLK
1 HUMAN FACTORS BR PSYCHOL RES OIV ONR
1 ENGNR PSYCHOL BR ONR CODE 455 ATTN ASST HEAD WASH OC
3 CO + OIR NAV TNG OEVICE CTR ORLANOO ATTN TECH LIB
1 CO FLT ANTI-AIR WARFARE TNG SAN DIEGO
1 CO NUCLEAR WEAPONS TNG CTR PACIFIC U S NAV AIR STA SAN OIEGO
2 FLT ANTI-AIR WARFARE TNG CTR OAM NECK VA BEACH
2 CO FLT TNG CTR NAV BASE NEWPORT
1 CDR FLT TNG GP NAV BASE CHARLESTON
2 CO FLT TNG CTR NORFOLK
1 CO FLEET TNG CTR U S NAV STA SAN OIEGO
3 CO NAV GUIOEO MSL SCH OAM NECK VA BEACH
1 CO NUCLEAR WEAPONS TNG CTR ATLANTIC NAV AIR STA NORFOLK
2 CO FLT SONAR SCH KEY WEST
1 CO FLT ANTI-SUB WARFARE SCH SAN OIEGO
1 CHF OF NAV RES ATTN SPEC ASST FOR R & O
1 CHF OF NAV RES ATTN HEAO PERS + TNG BR COOE 458
1 DIR US NAV RES LAB ATTN COOE 5120
1 DIR NAVAL RSCH ATTN LIB COOE 2029 (ONRL) WASH OC
1 CO MED FLD RES LAB CAMP LEJEUNE
1 CDR NAV MSL CTR POINT MUGU CALIF ATTN TECH LIB COOE 3022
1 DIR AEROSPACE CREW EQUIP LAB NAV AIR ENGNR CTR PA
1 CO + DIR NAV ELEC LAB SAN OIEGO ATTN LIB
3 OIC NAV PERS RES ACTVY SAN OIEGO
2 NAVAL MSL CTR (COOE 5342) PT MUGU CALIF
1 NAV TNG PERS CTR NAV STA NAV YO ANNEX COOE 83 ATTN LIB WASH
1 COMOT MARINE CORPS HQ MARINE CORPS ATTN COOE AO-18
1 HQ MARINE CORPS ATTN AX
1 OIR MARINE CORPS EOUC CTR MARINE CORPS SCH QUANTICO
1 OIR MARINE CORPS INST ATTN EVAL UNIT
1 CHF OF NAV OPNS OP-01P1
1 CHF OF NAV OPNS OP-07T2
1 COMOT HQS 8TH NAV DIST ATTN EOUC AOV NEW ORLEANS
1 CHF OF NAV AIR TECH TNG NAV AIR STA MEMPHIS
1 OIR OPS EVAL GRP OFF OF CHF OF NAV OPS OP03EG
2 COMOT PTP COAST GUARO HQ
1 CHF OFCR PERS RES + REVIEW BR COAST GUARO HQ
1 CO US COAST GUARO TNG CTR GOVERNORS ISLANO NY
1 CO US COAST GUARO TNG CTR CAPE MAY NJ
1 CO US COAST GUARO TNG CTR & SUP CTR ALAMEOA CALIF
1 CO US COAST GUARO INST OKLA CITY OKLA
1 CO US COAST GUARD RES TNG CTR YORKTOWN VA
1 SUPT US COAST GUARD ACAD NEW LONDON CONN
1 HQ AIR TNG COMD ATTES RANOOLPH AFB
1 TECH DIR TECH TNG DIV(HRO) AFHRL LOWRY AFB COLO
1 CHF SCI OIV ORCTE SCI + TECH OCS R+O HQ AIR FORCE AFRSTA
1 CHF OF PERS RES BR ORCTE OF CIVILIAN PERS OCS-PERS HQ AIR FORCE
1 HQ AFSC SCBB ANOREWS AFB
1 ROME AIR DEVEL CTR RASH GRIFFISS AFB
2 COR ELEC SYS DIV L G HANSCOM FLO ATTN ESRHA BEOFORO MASS
2 SMAMA (SMACU-PERS RSCH) MCCLELLAN AFB
1 ATC ATXRQ RANOOLPH AFB
1 HQ SAMSO (SMSIR) AF UNIT POST OFC LA AFS CALIF
2 MILIT TNG CTR OPE LACKLAND AFB
2 AFHRL (HRT) WRIGHT-PATTERSON AFB
1 AMO AMRH BROOK AFB TEXAS
2 HQS ATC (ATCTO-M) RANOOLPH AFB TEXAS
1 COR ELEC SYS OIV LG HANSCOM FLO ATTN ESTI
1 OIR AIR U LIB MAXWELL AFB ATTN AUL3T-63-253
1 OIR OF LIB US AIR FORCE ACAO
1 COMOT OEF WPNS SYS MGT CTR AF INST OF TECH WRIGHT-PATTERSON AFB
1 COMOT ATTN LIB OEF WPNS SYS MGT CTR AF INST OF TECH WRIGHT-PAT.
1 ORCTE OF AEROSPACE SAFETY AFIAS-L OPTY IG NORTON AFB
2 AF HUMAN RESOURCES LAB MRHTO WRIGHT-PATTERSON AFB
2 CO HUMAN RESOURCES LAB BROCKS AFB
1 PSYCHOBIOLOGY PROG NATL SCI FOUNO
1 OIR NATL SECUR AGY FT GEO G MEAOE ATTN TOL
1 DIR NATL SECUR AGY FT GEO G MEAOE ATTN OIR OF TNG
5 CIA ATTN OCR/ADD STANDARD DIST
1 SYS EVAL DIV RES DIRECTORATE DOD-OCD PENTAGON
1 DEPT OF STATE BUR OF INTEL + RES EXTERNAL RES STAFF
1 SCI INFO EXCH WASHINGTON
2 CHF MGT & GEN TNG OIV TR 200 FAA WASH OC
1 BUR OF RES & ENGR US POST OFC OEPT ATTN CHF HUMAN FACTORS BR
1 EOUC MEOIA BR OE OEPT OF HEW ATTN T O CLEMENS
1 OFC OF INTERNATL TNG PLANNING & EVAL BR AIO WASH OC
1 OEPT OF TRANS FAA ACQ SEC HQ 610A WASH OC
1 SYS OEVEL CORP SANTA MONICA ATTN LIB
2 OUNLAP + ASSOC INC OARIEN ATTN LIB

2 RAC ATTN LIB MCLEAN VA
1 OIR RANO CORP SANTA MONICA ATTN LIB
2 U OF SO CALIF ELEC PERS RES GP
1 COLUMBIA U ELEC RES LABS ATTN TECH EOITOR
1 MITRE CORP BEOFORO MASS ATTN LIB
2 U OF PGH LEARNING R+O CTR ATTN OIR
1 HUMAN SCI RES INC MCLEAN VA
2 TECH INFO CTR ENGNR DATA SERV N AMER AVN INC COLUMBUS O
1 CHRYSLER CORP MSL DIV OETROIT ATTN TECH INFO CTR
1 RAYTHEON SERV CO ATTN LIBN BURLINGTON MASS
2 EOUC & TNG CONSULTANTS ATTN L C SILVERN LA
1 GEN OYNAMICS POMONA DIV ATTN LIB OIV CALIF
2 MARQUAROT INOSTR PROO CO CUCAMONGA CALIF
2 OTIS ELEVATOR CO OIV ATTN LIB STAMFORO CONN
1 MGR BIOTECHNOLOGY AEROSPACE SYS OIV MS 8H-25 BOEING CO SEATTLE
1 IDA RSCH & ENG SUPT OIV ARL VA
1 HUGHES AIRCRAFT COMPANY CULVER CITY CALIF
1 OIR CTR FOR RES ON LEARNING + TEACHING U OF MICH
1 EOITOR TNG RES ABSTR AMER SOC OF TNG OIRS U OF TENN
5 BRITISH EMBSY BRITISH OEF RES STAFF WASHINGTON
3 CANAOIAN JOINT STAFF OFC OF OEF RES MEMBER WASHINGTON
3 CANAOIAN ARMY STAFF WASHINGTON ATTN GSO2 TNG
3 ACS FOR INTEL FOREIGN LIAISON OFCR TO NORWEG MILIT ATTACHE
2 ARMY ATTACHE ROYAL SWEDISH EMBSY WASHINGTON
1 OEF RES MEO LAB ONTARIO
3 AUSTRALIAN NAV ATTACHE EMBSY OF AUSTRALIA WASH OC
1 OFC OF AIR ATTACHE AUSTRALIAN EMBSY ATTN: T.A. NAVGN WASH, O.C.
2 AUSTRALIAN EMBSY OFC OF MILIT ATTACHE WASHINGTON
1 MENNINGER FOUNOATION TOPEKA
2 AMER INST FOR RES SILVER SPRING
1 AMER INST FOR RES PGH ATTN LIBN
1 OIR PRIMATE LAB UNIV OF WIS MAOISON
3 MATRIX CORP ALEXANORIA ATTN TECH LIBN
1 AMER TEL+TEL CO NY
1 OBERLIN COLL OEPT OF PSYCHOL
1 OR GEORGE T HAUTY CHMN OEPT OF PSYCHOL U OF OEL
1 GEN ELECTRIC CO SANTA BARBARA ATTN LIB
1 VITRO LABS SILVER SPRING MO ATTN LIBN
1 HEAO OEPT OF PSYCHOL UNIV OF SC COLUMBIA
1 TVA ATTN CHF LABOR RELATIONS BR OIV OF PERS KNOXVILLE
1 U OF GEORGIA OEPT OF PSYCHOL
1 GE CO WASH O C
1 AMER INST FOR RES PALO ALTO CALIF
1 MICH STATE U COLL OF SOC SCI
1 N MEX STATE U ATTN PROF OF PSYCHOL
1 ROWLANO + CO HAOOONFIELO NJ ATTN PRES
1 NORTRONICS OIV OF NORTHROP CORP ANAHEIM CALIF
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1 TUFTS U HUMAN ENGNR INFC + ANLS PROJ
1 AMER PSYCHOL ASSOC WASHINGTON ATTN PSYCHOL ABSTR
1 NO ILL U HEAO OEPT OF PSYCHOL
1 BELL TEL LABS INC TECH INFO LIB NJ
1 WASHINGTON ENGNR SERV CO INC KENSINGTON MO
1 LIFE SCI INC FT WORTH ATTN PRES
1 AMER BEHAV SCI CALIF
2 OIR INSTR RESOURCES STATE COLL ST CLOUO MINN
1 COLL OF WM + MARY SCH OF EOUC
1 SO ILLINOIS U OEPT OF PSYCHOL
2 WASH MILITARY SYS OIV BETHESOA MO
1 NORTHWESTERN U DEPT OF INOSTR ENGNR
1 HONEYWELL ORO STA MAIL STA 806 MINN
1 NY STATE EOUC DEPT ABSTRACT EOITOR AVCR
1 AEROSPACE SAFETY DIV U OF SOUTHERN CALIF LA
1 MR BRANDON B SMITH RES ASSOC U OF MINN
1 CTR FOR THE ADVANCED STUOY OF EOUC ADMIN U OF OREG
1 OR V ZACHERT RT 2 NORMAN PARK GA
1 MR S AILES STEPTOE & JOHNSON WASH OC
1 OR W BEVAN VP & PROVOST THE JOHNS HOPKINS UNIV MO
1 OR W C BIEL U OF SOUTHERN CALIF LA
1 OR C W BRAY BOX 424 QUOGUE LI NY
1 MR J M CHRISTIE PRES RIGGS NATL BANK WASH OC
1 OR C W CLARK VP FOR RSCH RSCH TRIANGLE INST NC
1 GEN H P HARRIS (USA RET)PRES THE CITAOEL SC
1 OR L T RACER CHMN DEPT OF ELEC ENGNR U OF VA
1 CHF PROCESSING OIV OUKE U LIB
1 U OF CALIF GEN LIB OOCU OEPT
1 FLORIOA STATE U LIB GIFTS + EXCH
1 PSYCHOL LIB HARVARO UNIV CAMBRIOGE
1 U OF ILL LIB SER OEPT
2 U OF KANSAS LIB PERIOOICAL OEPT
1 U OF NEBRASKA LIBS ACQ DEPT
1 OHIO STATE U LIBS GIFT + EXCH OIV
1 PENNA STATE U PATTEE LIB DOCU OESK
1 PURCUE U LIBS PERIOOICALS CHECKING FILES
1 STANFORO U LIBS DOCU LIB
1 LIBN U OF TEXAS
1 SYRACUSE U LIB SER OIV
1 SERIALS REC UNIV OF MINN MINNEAPOLIS
1 STATE U OF IOWA LIBS SER ACQ
1 NO CAROLINA STATE COLL OH HILL LIB
2 BOSTON U LIBS ACQ OIV
1 U OF MICH LIBS SER DIV
1 BROWN U LIB
2 COLUMBIA U LIBS OOCU ACQ
1 OIR JOINT U LIBS NASHVILLE
1 U OF OENVER MARY REED LIB
2 LIB GEO WASH UNIV ATTN SPEC COLL DEPT WASH OC
2 LIB OF CONGRESS CHF OF EXCH + GIFT OIV
1 U OF PGH OOCU LIBN
1 CATHOLIC U LIB EOUC & PSYCHOL LIB WASH OC
1 U OF KY MARGARET I KING LIB
1 SO ILL U ATTN LIBN SER DEPT
1 BRIGHAM YOUNG U LIB SER SECT
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