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ABSTRACT

A battery of criterion referenced Job Task Performance Tests (JTPT) was developed because paper and pencil tests of job knowledge and electronic theory had very poor criterion-related or empirical validity with respect to the ability of electronic maintenance men to perform their job. Although the original JTPT required the use of actual equipment, the later battery utilized graphic symbolic substitutes. In this effort, a battery of symbolic tests was developed including a companion symbolic test for each of the job activities for which a criterion referenced JTPT had previously been developed. Based on two limited validations, all of the graphic symbolic tests, with the exception of the symbolic test for soldering, indicated sufficient promise to justify further consideration and refinement. All of these promising symbolic tests should be given more extensive validations using larger numbers of experienced subjects. The validation of any such symbolic test requires the administration of a companion JTPT as a validation criterion. As a result, a validation is an expensive process in terms of equipment and experienced manpower. The troubleshooting symbolic tests require the most extensive refinement. Several suggestions are made for improving their empirical validity. (Author/BJG)

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EVALUATING MAINTENANCE PERFORMANCE: THE DEVELOPMENT OF GRAPHIC SYMBOLIC SUBSTITUTES FOR CRITERION REFERENCED JOB TASK PERFORMANCE TESTS FOR ELECTRONIC MAINTENANCE

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An in-depth review of the literature reported in AFHRL-TR-74-57(I), of this series of documents strongly reiterated the fact that paper and pencil tests of job knowledge and electronic theory tests have very poor criterion-related or empirical validity with respect to the ability of electronic maintenance men for performing their job tasks. As a result, a battery of criterion referenced Job Task Performance Tests (JTPT) was developed and tried out and results were reported in AFHRL-TR-57(II).

The battery included tests for the various job activities performed by electronic maintenance technicians such as checkout, align/adjust, remove/replace, soldering, use of general and special test equipment, and troubleshooting.

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Past experience with tests similar to these criterion referenced JTPT has indicated that even though criterion referenced JTPT were recognized as being superior by many training people, paper and pencil tests were substituted because they were more easily and cheaply developed and administered. The JTPT developed required the test subject to use actual equipment and they could only be administered to very small groups, in some cases, to only one subject Graphic symbolic substitutes would probably overcome these administrative problems. *But* such substitutes must have high empirical validity. Most previous attempts to develop such tests resulted in low validity. This volume describes another attempt to develop a battery of graphic symbolic substitutes of improved validity.

A review of previous attempts resulted in a hypothesis that previous attempts had weaknesses in realism that could possibly be rectified The successful accomplishment of most maintenance tasks must follow a main line procedure or strategy. *But* this main line usually is "cluttered" with distraction and subprocedures which interfere with the accomplishment of the main line procedure or strategy. For example, when troubleshooting, the technician must usually interrupt his strategy several times to set up his test equipment and to obtain check point information. Unless he is well organized and very persistent in following his strategy, he may lose track of his strategy. Even if he stays on the main line, he may gather faulty information from his test equipment which will prevent him from finding the trouble. Based on this rationale, it was concluded that previously developed symbolic tests such as the tab test did not provide such clutter. It was hypothesized that symbolic substitute tests could be developed that would retain a large amount of realistic task "clutter" and that such tests would have higher empirical validity than previously developed symbolic tests.

In this effort, a battery of symbolic tests was developed including a companion symbolic test for each of the job activities for which a criterion referenced JTPT had previously been developed. Based on two limited validations, all of the graphic symbolic tests, with the exception of the symbolic test for soldering, indicated sufficient promise to justify further consideration and refinement. All of these promising symbolic tests should be given more extensive validations using larger numbers of experienced subjects. The validation of any such symbolic test requires the administration of a companion JTPT as a validation criterion. As a result, a validation is an expensive process in terms of equipment and experienced manpower. The troubleshooting symbolic tests require the most extensive refinement. Several suggestions are made for improving their empirical validity.

SUMMARY

Problem

An in-depth review of the literature reported in AFHRL-TR-74-57(I) of this series of documents strongly reiterated the fact that paper and pencil tests of job knowledge and electronic theory tests have very poor criterion related or empirical validity with respect to the ability of electronic maintenance men for performing their job tasks. As a result, a battery of criterion referenced Job Task Performance Tests (JTPT) was developed and tried out and was reported in AFHRL-TR-74-57(II), Part I. The battery included tests for the various job activities performed by electronic maintenance technicians such as checkout, align/adjust, remove/replace, soldering, use of general and special test equipment and troubleshooting. These tests require the test subject to perform such activities using the actual equipment found in the job environment. Past experience with tests similar to these criterion referenced JTPT has indicated that even though criterion referenced JTPT were recognized as being superior by many training people, paper and pencil tests were substituted because they were more easily and cheaply developed, and administered. The JTPT developed required the test subject to use actual-equipment and they can only be administered to very small groups, in some cases, to only one subject. If empirically valid symbolic substitute tests could be developed, they would be much more economical to administer. As a result the reviews of previous attempts concerning the development of graphic symbolic substitute tests such as the tab tests, it was hypothesized that previous attempts had weaknesses in realism that possibly could be rectified and thus improve their empirical validity.

Approach and Results

The successful accomplishment of most maintenance tasks must follow a main line procedure or strategy. *But* this main line usually is "cluttered" with distraction and subprocedures which interfere with the accomplishment of the main line procedure or strategy. For example, when troubleshooting, the technician must usually interrupt his strategy several times to set up his test equipment, and obtain check point information. Unless he is well organized and very persistent in following his strategy, he may lose track of his strategy. Even if he stays on the main line, he may gather faulty information from his test equipment which will prevent him from finding the trouble. Based on this rationale, it was concluded that previously developed symbolic tests, such as the tab test, did not provide such clutter. It was hypothesized that symbolic substitute tests could be developed that would retain a large amount of realistic task "clutter" and that such tests would have higher empirical validity than previously developed symbolic tests. In this effort, a battery of symbolic tests was developed including a companion symbolic test for each of the job activities for which a criterion referenced JTPT had previously been developed.

These symbolic substitute tests were validated in a limited manner against companion criterion referenced JTPT at Altus AFB, Oklahoma, using 14 novice technicians as test subjects. Novice technicians were utilized because previously developed plans for use of experienced technicians did not materialize. The result of this first validation was that all of the symbolic tests indicated higher correlations than obtained from the previously reported studies, with the exception of the symbolic tests for troubleshooting and soldering.

With the limited remaining available funds, it was decided to concentrate on improving troubleshooting symbolic tests. It was felt that most of the difficulty with the troubleshooting symbolic tests during the first validation were due to the inexperienced subjects and to the manner in which test equipment symbolization was presented. To present realistic "clutter" in the original troubleshooting symbolic tests, a pictorial representation of the test equipment had been prepared for each test point for which information would be required. Two problems developed. *First,* the bank of pictorials was placed in a book and the Test Administrator was required to search this bank when a test subject required a bit of information. This proved to be an impossible task for the test administrator. *Second,* the number of pictorials in the bank was insufficient to meet the needs of the novice subjects used in the validation. To overcome these problems, an attempt was made to consolidate the test point information into a matrix format with printed values for voltage and resistance measurements and small waveform drawings for oscilloscope readouts. These modified symbolic tests were validated at Langley AFB, Virginia, and Little Rock AFB, Arkansas, using a total of 15 experienced technicians as test subjects. The resulting symbolic tests indicated a high empirical correlation to the criterion JTPT for the black box or chassis level of troubleshooting, a fair correlation for the stage level and an extremely low correlation for the piece/part level. A secondary finding of this second validation was that the sample of experienced technicians used for

this validation could not troubleshoot very well to the piece/part level. They identified only 33 percent of defective piece/parts.

Conclusions

1. Based on two limited validations, all of the symbolic tests with the exception of the one for soldering indicated sufficient promise to justify further consideration and refinement.

2. All of these promising symbolic tests should be given more extensive validations using larger numbers of experienced subjects. The validation of any such symbolic test requires the administration of a companion JTPT as a validation criterion. As a result, a validation is an expensive process in terms of equipment and experienced manpower. Until such support can be guaranteed, no further work on symbolic tests should be pursued.

3. A validation of troubleshooting symbolic tests requires special considerations. Before administering the modified troubleshooting symbolic tests again, it should be ascertained that the test subjects can use their test equipment adequately. This prerequisite may result in higher correlations at the stage and piece/part levels of troubleshooting.

4. The modified troubleshooting symbolic tests are a giant step removed from the original hypothesis concerning the requirement for realistic "clutter." The action recommended in paragraph 3 may not be sufficient to raise the correlations of the piece/part symbolic test to an acceptable level. A system for the random access projection of test equipment pictorials of the type included in the original version of the troubleshooting symbolic tests should be developed. A matrix system, similar to that used for the presentation of printed voltage and resistance information in the modified troubleshooting symbolic tests, could serve as the basis for a simplified indexing system. This could be accomplished by substituting projector access numbers for the printed voltage or resistance numbers in each cell of the matrix.

5. The fact that the experienced subjects, used in this project, could not troubleshoot well to the piece/part level is another bit of hard data that supports other available hard data which indicate that a widespread weakness exists in this area.

PREFACE

This document represents a portion of the Exploratory Development program of the Advanced Systems Division, of the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio. It is a compilation and expansion of materials submitted by URS/Matrix Research Company, Falls Church, Virginia 22042 under contracts F33615-70-C-1550 and F33615-71-C-1505. Dr. Edgar L. Shriver was the principal investigator.

This document is the third volume (AFHRL-TR-74-57(III)) of a four-volume report to be published concerning the evaluation of maintenance performance. The other documents are entitled:

1. *Evaluating Maintenance Performance: An Analysis.* AFHRL-TR-74-57(I), in press.

2. *Evaluating Maintenance Performance: The Development and Tryout of Criterion Referenced Job Task Performance Tests for Electronic Maintenance.* AFHRL-TR-74-57(II) Part I, in press.

3. *Evaluating Maintenance Performance: Test Administrator's Manual and Test Subject's Instructions for Criterion Referenced Job Task Performance Tests for Electronic Maintenance.* AFHRL-TR-74-57(II) Part II, in press.

4. *Evaluating Maintenance Performance: A Video Approach to Symbolic Testing of Electronic Maintenance Tasks.* AFHRL-TR-74-57(IV), in press.

The preparation of all these documents have been documented under Task 171010, Evaluating the Performance of Air Force Operators and Technicians of Project 1710, Training for Advanced Air Force Systems. Work reported in this document was accomplished under work units 17101004, 17101005, and 17101006. Dr. John P. Foley was task scientist. Dr. John P. Foley and Mr. John K. Klesch of the Advanced Systems Division shared the contract monitorship. Dr. Ross L. Morgan was the project scientist.

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EVALUATING MAINTENANCE PERFORMANCE:
THE DEVELOPMENT OF GRAPHIC SYMBOLIC SUBSTITUTES
FOR CRITERION REFERENCED JOB TASK PERFORMANCE TESTS
FOR ELECTRONIC MAINTENANCE

I. INTRODUCTION

Background

Volume I (AFHRL-TR-74-57(I)) of this series of documents provides an analysis of the effectiveness of current measurement practice concerning electronic maintenance tasks. One of the common findings of the many studies considered in that analysis was that the empirical validity of the paper and pencil tests with respect to performance is notable for the low correlations found and for the frequent use of dubious criterion measures such as supervisory rating of job performance. Yet, test validity is frequently assumed and advancement in grade is partially based on these dubious test results. Another conclusion of that analysis was that little systematic work had been reported on attempts to define the scope and to improve the effectiveness of criterion referenced Job Task Performance Tests (JTPT). Among the recommendations made were that:

1. A battery of JTPT should be developed that would independently measure each type of job activity; namely, (1) checkout; (2) remove and replace; (3) use of test equipment; (4) use of hand tools; (5) align, adjust, and calibrate; and (6) troubleshoot.

2. An appropriate scoring scheme should be developed for each of these types of job activities.

3. More experimental work should be accomplished aimed at developing and refining symbolic electronic equipment troubleshooting tests.

Under a previous contract with URS/Matrix Research Company (F33615-69C-1232), the Air Force Human Resources Laboratory (AFSC) supported the development of the recommended JTPT. The development and tryout of a battery of such JTPT is described in Volume II of this series of documents (AFHRL-TR-74-57(II)). As a result of the work reported in Volumes I and II and the insight gained from this work, certain conclusions can be stated that effect the development of symbolic substitute tests.

1. The classification of job activities proposed for the development of criterion referenced JTPT is a viable method for structuring the activities of the maintenance technician. JTPT can be developed for each activity and each can be measured in its own right.

2. The activities are not mutually exclusive. They can be arranged in a four level hierachy of dependencies as follows:

(a) Check out, remove and replace, and soldering activities.

(b) Use of general and special test equipment.

(c) Align, adjust, and calibrate activities.

(d) Troubleshooting.

To illustrate, the troubleshooting activity may include all of the activities in the first three levels. These dependencies have implication as to the order in which tests should be administered. For example, it should be ascertained that an individual can use his test equipment before he is permitted to take a troubleshooting test.

3. After considering *product, process,* and *time* as to their appropriateness for scoring the results for each activity measured, it was decided that a test subject has not reached criterion until he has produced a complete, satisfactory *product.* This is a go, no-go criterion.

4. Considering the complexity and diversity of maintenance activities, it was decided that abilities required to perform maintenance cannot be realistically represented under the umbrella of a single score. A profile is recommended which displays precisely what maintenance activities an individual has demonstrated that he can or cannot perform. This gives a much more meaningful picture of an individual's maintenance abilities.

The above considerations support the following statements:

1. Symbolic substitute tests should be developed and tried out for each type of maintenance activity. The experience gained from the in-depth study of the nature of maintenance tasks made during the development of the JTPT indicated the requirement for symbolic substitutes for all maintenance activities.

2. The effectiveness of the symbolic test for each type of activity should be determined on its own merits against the criterion referenced JTPT for the same activity. Unless it can be demonstrated that a symbolic substitute test has a high empirical relationship to its criterion JTPT, it should not be used as a substitute.

3. Symbolic substitutes may be successfully developed for some maintenance activities, but not necessarily for all.

4. The same implications for ordering of test administration that apply to JTPT apply to symbolic tests.

Discussion of the Nature of Maintenance Tasks

In addition to the above considerations concerning the development of empirically valid symbolic tests for maintenance, special consideration must be given to the nature of the maintenance tasks. The maintenance man's job is comprised of many tasks, related primarily by the electrical and/or mechanical organization of the equipment which he is responsible for maintaining. The relationships established by the equipment are of several types:

1. Cause-effect between components.
2. Physical proximity and accessibility.
3. Similarities of function, appearance, and types of tools needed for maintenance.
4. Descriptions provided in equipment documentation.

For every maintenance task, there is a requirement for the maintenance man to organize his main line of approach to accomplishing the task. In addition to this "main line," there are many auxiliary lines that contribute to the main line. For example, the main line could be to remove, service, and replace a main drive shaft. The auxiliary lines would be collection of the proper tools, obtaining the proper solvents and lubricants for servicing, identification of the proper pages in documentation, locating the main drive shaft, performing actions and making discrimination to gain access to the shafts, proper use of the tools to disassemble shaft connections, obtaining the appropriate equipment for moving the shaft if necessary, and obtaining appropriate information to perform this task (i.e., steps, following cross-references in documentation if necessary, finding cross-referenced documentation, considering substitute lubricants if the recommended ones are unavailable, following disassembly instructions, following instructions on use of special tools, interpreting ambiguous instructions, etc.).

These auxiliary lines each require many discriminations, responses, and use of some information stored in the maintenance man's memory. Every one of the discriminations involves sorting through irrelevant information, or cues, to select the appropriate ones. Every response involves the selection of the appropriate one from among many possible ones. In addition to these job-oriented activities, there are those of the environment; human, physical, and organizational. Each of these introduces certain distractions; talking with co-workers, answering their questions, being human, unlocking combination locks, finding keys, answering calls, and attending meetings or other organization functions.

The picture obtained from this description of the maintenance man's activities, is one of great distraction as a function of discriminations and responses that are essentially unrelated except by the needs of the equipment for which he is responsible.

The example chosen is representative of all electrical and mechanical maintenance activities, except that troubleshooting probably represents an even greater burden. Troubleshooting requires even more from stored memory, in a decision-making sense, than procedural maintenance tasks. The distractions are similar, if not greater, but it is even harder to remain organized in troubleshooting tasks in the environment of distraction. It must be emphasized that most of the "distraction" from the main line of endeavor is necessary to accomplish the task. Even the discussions between people are often necessary in the larger picture of maintenance. They communicate information about location of components needed for maintenance, absence of people who have keys or other necessary ingredients such as spare parts or special tools.

Previous Symbolic Substitute Tests

Symbolic substitutes for performance tests have a long or a very short history, depending on the definition of symbolic substitutes. In the decade of the fifties there was a burst of research activity in testing maintenance and especially troubleshooting ability. Gagne reviewed this activity in his Annual Review of Psychology article on "problem solving and thinking" in 1959. As Gagne said in this review, "To summarize, troubleshooting of complex equipment typically consists of problem solving which is sequential in nature; there is a sequence of hypotheses that must be tested in order to narrow progressively the area in which the malfunction is located." Experimenters in this period were using a certain type of paper and pencil substitute for troubleshooting in their research. They were using test materials which represented the "problem solving" aspect of troubleshooting. This approach is based on an assumption that an abstract logic, such as that described by Gagne in his review of "problem solving," is the "key" to troubleshooting. If this were true, there would be a relatively high correlation between such tests and troubleshooting on the real equipment.

But attempts to develop symbolic substitute tests which concentrated entirely on the cognitive aspects of "problem solving" did not produce high correlations. For example, there were two studies of the effectiveness of the tab test; one by Crowder, Morrison, and Damaree (1954) and the other by Evans and Smith (1953). Both indicated very low correlations. Those studies, and similar studies discussed in AFHRL-TR-74-57(I), reflect the same pattern of low correlation. None of these tests included any of the "distractions" from the main line of "problem solving" found in the real world of troubleshooting. In the job environment an individual must, for example, set up and operate his test equipment to obtain test point information, as well as obtain instructions and information from his Technical Orders. These are very essential job skills. But their performance provide serious "distractions" or breaks in the test subjects "problem solving" thought processes. If he does not operate his test equipment properly, he also introduces false information into these thought processes. In the symbolic tests, such as the tab test, he is given this information without the distraction of using his test equipment. As a result such symbolic tests measure neither the ability to apply a troubleshooting strategy in a realistic job-like setting nor the ability to perform the essential, but distracting, support skills.

Rationale for Symbolic Substitute Development

An hypothesis underlying the symbolic substitute tests, then, is that the process of maintenance is essentially a "hodgepodge" of activities. This picture of the maintenance process would have as the good maintenance man one who systematically organizes essentially independent and disconnected activities and perceptions into his performance. This is not an "idealized" picture of the maintenance man. Previous research has treated troubleshooting as a logical, problem-solving situation. The present writers regard this as only one element in the actual troubleshooting process. Other elements include specific bits of practical information, ways of finding specifics in documentation, having certain skills with tools and test equipment and so on. The good maintenance man must bring together many small bits of information and combine them, with information obtained from the equipment, into an evolving plan for executing the maintenance he is called on to perform. The symbolic substitutes tests are designed to simulate this situation. The subject's job on the test is to "thread his way" through this "hodgepodge" in the same way he must in the real world.

This makes the symbolic substitute test a "hodgepodge" itself. It is not designed to measure any "pure" elements such as logic or knowledge of theory. It is designed to simulate the real world of criterion referenced performance. This makes tests very specific to the performance simulated. It "gives up" generality for accuracy of prediction. The techniques for generating symbolic substitute tests have a certain generality, but not the tests generated by these techniques. Whether it gains predictive power or not, lies in the correlation obtained between this type of test and criterion referenced performance.

This hypothesis underlying the symbolic substitute test, that the maintenance process involves an assortment of discriminations and activities which are unrelated except that they are required to accomplish the specific goals of the maintenance task at hand, differs from the hypotheses used for many other types of paper and pencil tests. *A part of our hypothesis is that the successful performance of a maintenance activity requires an "organizing factor" from the performer, and a failure of the performer to correctly organize the unrelated discriminations and actions will result in his being unable to perform the required maintenance activity.*

A corollary to this is that the omission of any of these unrelated discriminations or responses will reduce the correlation of the symbolic/substitute tests with respect to measured criterion related performance activity. With this premise certain deductions can be made.

First, if a test does not require the subject to engage in all of the unrelated actions, it is not placing on him some of the crucial requirements of the actual job; that is, organization of the disparate "pieces." For instance, if we consider two tests containing the same discriminations and activities but give one test "piecemeal" and the other as a "whole," the hypothesis is that the piecemeal test will not be as accurate a predictor of actual performance as the "whole test." The conclusion is derived from the premises above. The piecemeal test would not require the subject to "organize" his unrelated discriminations and responses, while the whole test would. An example of "piecemeal" test items would be multiple-choice tests, and true-false tests on specific elements of the maintenance process.

Another deduction from this premise is that a test which abstracts from the actual job only the "logic" of troubleshooting without including all the necessary distractions of obtaining measurements, setting test instruments, accessing documentation, etc., will not correlate as well with actual performance as will a test which does include necessary distractions of unrelated discriminations and activities. That is, the hypothesis on which symbolic substitutes is based is that success of the maintenance job is largely a function of the ability to engage in unrelated discriminations and activities and at the same time to remain organized, in spite of this necessary "noise" or "clutter."

This hypothesis is a basic one which, if true, would represent a new and effective approach to testing which has not previously been explored. The first criterion that this basic hypothesis must meet for confirmation is that the symbolic tests based on it will correlate well with tests of actual performance. If this proves to be true, the next step is to investigate why this kind of test is an accurate predictor. This would be done by making deductions from the basic hypothesis (as above) and generating different types of tests that represent these alternative hypotheses. These tests would then be correlated with actual performance. From this, certain hypotheses will be confirmed and others will not, representing confirmation or denial of the basic hypothesis. The hypothesis might be modified or stand in its original form. If confirmed, it will stand as a basic criterion and guideline for preparation of effective tests.

The present writers have hypothesized that the context of unrelated detail and the need to remain organized toward the main line of activity and be resilient to distraction, is the key to predictive accuracy of paper and pencil tests with respect to actual performance of maintenance. The symbolic substitute tests represent the first step in the direction of testing this hypothesis. In the resulting symbolic tests described below, there are several cases in which the implemented symbolic substitute tests do not conform completely with the basic hypothesis. They are largely a function of the fact that all types of distraction cannot be symbolized on paper. But unlike the other approaches to testing that have been mentioned, the symbolic substitute tests attempt to represent as much of the "bits and pieces" as possible of the maintenance distractive situation. This is in direct distinction to simulating only some single element; such as "theory" or "logic" or "problem solving" as the other tests do.

II. DETAILED DESCRIPTION OF SYMBOLIC TESTS

Introduction

The criterion referenced JTPT that have been developed to date in this overall program represent a cross section of the organizational maintenance tasks associated with a radar system, the Doppler Radar AN/APN-147 and its Computer, the AN/ASN-35. This system is one of the maintenance responsibilities of the Air Force Speciality Code (AFSC) 328X4, Avionic Inertial and Radar Navigation Systems Specialist; there are a large number of other systems for which this AFSC is also responsible. A technician in this AFSC usually deals with only a few systems at any one time and these systems vary with his assignments. It is not unusual to find a five-level technician in this AFSC who has no experience on the AN/APN-147. Likewise, individuals can be found who have spent several years on nothing else but this one system. The point is that this series of tests is not meant to be applicable to testing the total proficiency requirements of the AFSC 328X4 technician. One system in this area of responsibility was selected as a vehicle for the investigation of performance testing techniques.

This effort to develop symbolic substitutes for the performance tests proceeded without refining or otherwise treating the original criterion referenced JTPT. The focus has been to examine and try out techniques for simulating the performance requirements of the tests. The JTPT are used as the criterion for measuring how well the symbolic tests measure the same criterion related factors. The measure of success of how well the simulation was accomplished is the degree to which any given individual performs the same on the two versions of the tests. Thus, whether the individual is high or low in proficiency should be equally demonstrated on either the performance or symbolic versions of the tests if the symbolic substitute tests are reliable, valid predictors.

The development of the symbolic-substitute tests generally reflect the hypotheses and ground rules discussed in Section I. As mentioned earlier, in the development of the symbolic substitute tests there was a deviation from the basic hypothesis of criterion referenced JTPT. Of the discriminations and perceptions that would be required to bring an equipment back to flight-ready status, only a representative sample was taken for use in the symbolic substitute tests. A number of minor task requirements, such as checking out test equipment and locating replacement parts, have been eliminated for administrative efficiency of the test. However, each sample includes most of the total task and is large enough that the total context is present. This creates for the subject the impression that this is a complete task. Certain other discriminations and responses had to be eliminated from the symbolic substitute tests due to difficulty in simulating certain elements of the tasks with paper and pencil. These are described in the context of the test in which they are encountered.

Symbolic Test Development

System Checkout. System checkout of the AN/APN-147 system requires that the equipment be set up on a bench which has a special test harness installed that provides for signal input and readout of the associated displays. When a radar set is suspected of malfunctioning, it is removed from the aircraft and brought into the shop where this checkout is performed. Further, this initial check serves to point to the general nature of the malfunction, providing guidance as to the location of the problem. In the criterion JTPT the technician is provided with a radar set that has been misadjusted to give a faulty reading. He then must set up and run the checkout according to Technical Order (TO) procedures and determine whether it is functioning properly.

Analyzing the elements of this task showed that the main actions required were to make the proper connections between the radar set components and the test harness, to set the controls on the radar and on the test harness to the proper positions, and to follow an established set of instructions for checking the radar's tracking capability. These actions were required before the technician could establish that the set was in fact not functioning properly.

In the JTPT, it is only necessary to grade his conclusion about the equipment once he has performed all of these actions. Unless he had performed them properly and could describe the resultant symptoms, he had not correctly performed the task.

To simulate this task via symbolics, it was necessary to insure that the symbolic task required all of the actions that the real task did, and not, for example, only the conclusions or only the control settings. Further, the symbolic displays would be non-responsive and yield no variable signal to the technician for interpretation. Therefore, it would be necessary to test this portion of the task differently. The important part of the hookup portion of the task is to connect the correct outlets of the radar and the test harness to the simulator that is used. The symbolic approach taken to this action was to present a display of the various equipments required, plus several irrelevant items and request the technician to draw lines between the proper outlets indicating the required hookup. The control settings were tested by having the technician indicate on the display what the proper position would be for each relevant control. The checkout procedures were similarly checked since they consist of a sequence of control position settings.

The rational for selecting this particular method of symbolically testing the technician's ability to perform the discriminations and actions involved in the checkout task lies in the analysis of the cue-response requirements of the real task. To perform the hookup portion of the task the technician, in the real world, is presented with the test harness, the radar set, and access to a supply of assorted cable connections. He must make discriminations regarding the proper connections, either from his knowledge and past experience or from his documentation, secure the proper cables, and physically make the hookups. The symbolic task simulates the same stimulus field to which the subject must make very similar discriminations and responses. He is presented with an array of equipment (Figure 1); some relevant, some not. From this array he must select that which is required and by drawing lines, indicate the proper connections that must be made. These connections are indicated not just from one piece of equipment to another but from the proper terminals on each item of equipment. *Next*, the technician must indicate on pictorial displays of each selected item of equipment the proper control settings for accomplishing the checkout.

The final part of the checkout procedure, interpretation of a dynamic display (the groundspeed indicator must "lock-on" to a pre-set input speed from the simulator within 20 seconds), could not be simulated realistically in the paper and pencil medium. Consequently, this discrimination was not part of the sample of discriminations that the symbolic substitute test takes from the total field required in performance. Whether or not this necessary omission from the sample is important for prediction, will be answered by the nature of the correlation between this symbolic test and actual performance.

There are two system checkouts that are required by this system, one for the AN/APN-147 Radar and the other for the AN/ASN-35 Computer which provided the basic inputs to the radar system. The same approach has been taken to both checkouts.

Soldering. The development of methods for evaluating an individual's physical dexterity to perform a task is the most difficult challenge for symbolic testing. *It may be that such tasks as soldering are not amenable to testing by symbolic substitution.* But if this is the case, it is not a serious problem to test this small, but crucial, task by performance only. However, rather than prejudge the outcome, a symbolic substitute test was prepared on this task.

The symbolic form of testing this skill must concentrate on knowledges and representations of physical acts, as all paper and pencil tests do. The symbolic tests that were developed in this area deal with the individual's knowledge of how to proceed with the tasks. While this is a necessary condition, it is not a sufficient one. The subject still must have the physical dexterity to employ the tools properly. This problem is sufficiently pronounced in this area that there is no assumption possible, for example, that successful completion of the symbolic tests on soldering is a sufficient demonstration of the individual's ability to solder an electrical connection. The greater the physical skill required to perform the task, the less valid the symbolic indicator of that skill. *Soldering represents the most complex physical skill required of the electronic technician; and therefore, symbolic tests dealing with the measurement of this skill are the most limited.*

The other hand tools that the technician uses are primarily small screwdrivers, wrenches, etc. These are less demanding in terms of physical dexterity, and so the tests relating to tasks that require their use are less limited by this difficulty. The least demanding physical skills of the electronic technician are those relating to setting equipment controls and making connections. These skills can easily be assumed to be part of the normal repertoire of behaviors found in the population that are selected for entry into maintenance specialties in the United States Armed Forces.

For JTPT, the soldering task was divided into two tests, due to the number of related factors that influence the overall soldering task. The complete soldering task requires proper identification of component location, which may involve schematic drawing interpretation, selection of the correct replacement component, proper removal of the old component, preparation of the new one for installation, and finally, use of proper soldering techniques so that a good connection is made and adjacent components are not damaged in the process. While soldering was the main focus of the testing, these associated requirements could not be ignored.

The *first* soldering JTPT dealt with just soldering. The technician was given several components and told where to install them on a printed circuit board. He was then graded on how well he solders them in place, based upon inspection of the soldering job and comparison to a photographic standard. In the

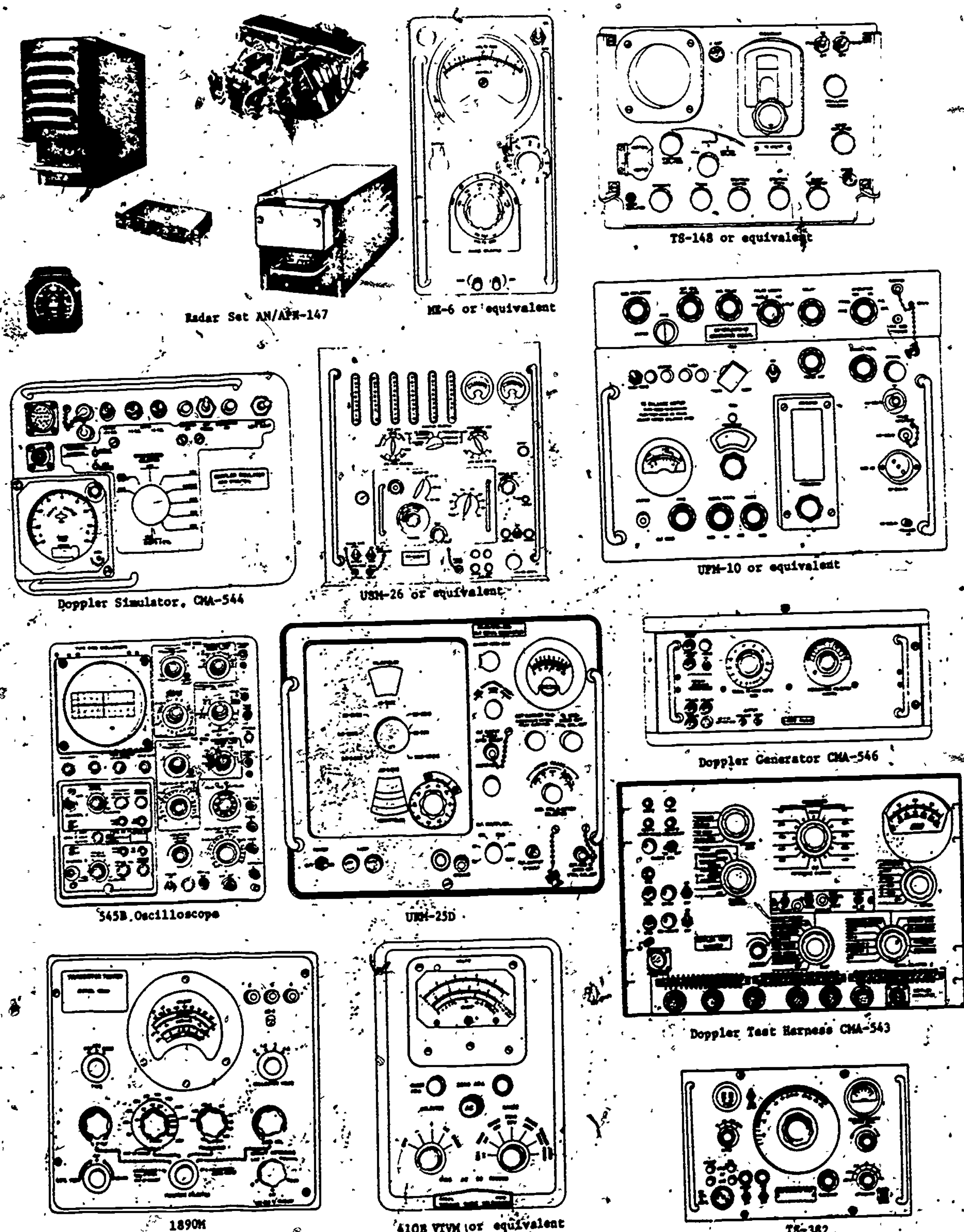
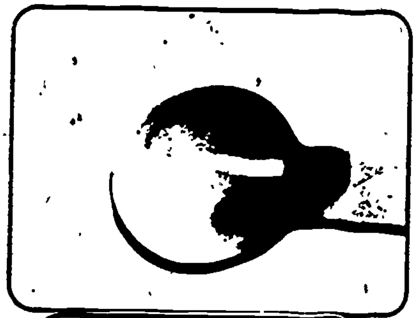


Figure 1. System checkout equipment array.

CIRCUIT BOARD SOLDERING ANSWER SHEET - PT 1

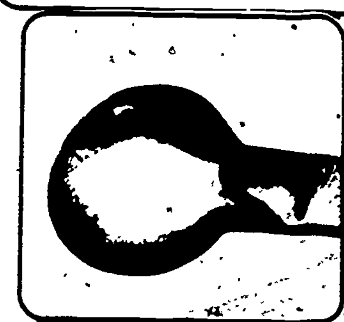
☐ Acceptable Minimum Solder

1



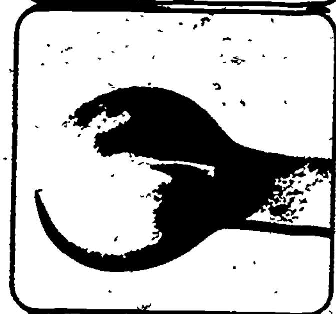
☐ Preferred Solder

2



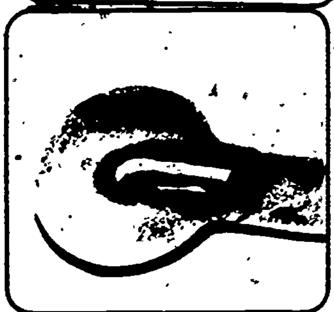
☐ Unacceptable Insufficient Solder

3



☐ Unacceptable Excessive Solder

4



☐ Acceptable Maximum Solder

5

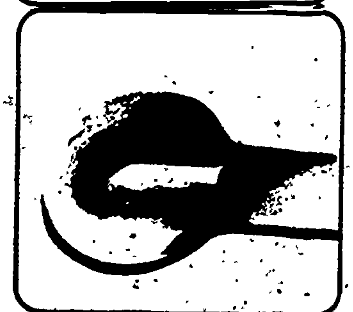


Figure 2. **Soldering answer sheet.**

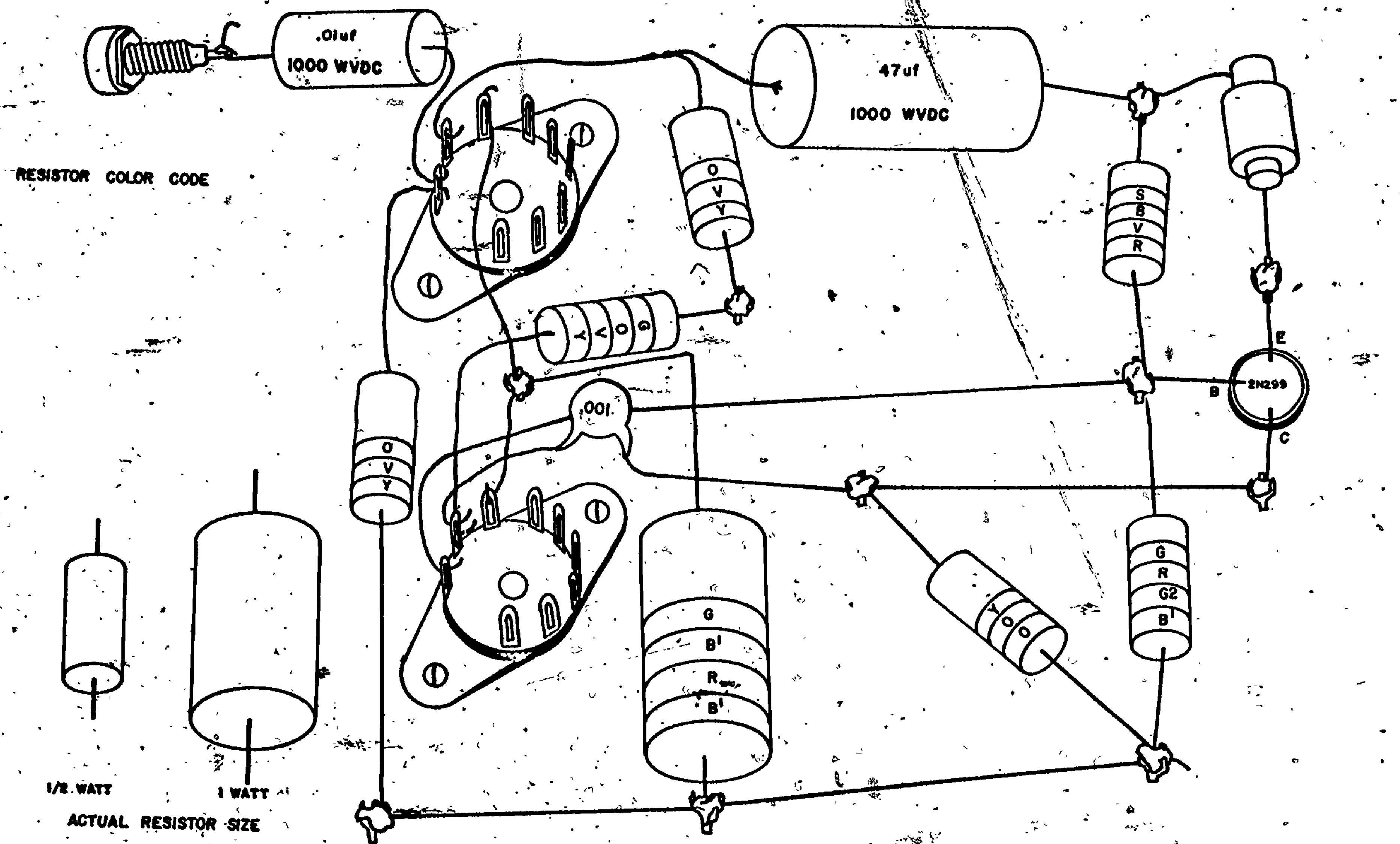


Figure 3. Soldering information sheet.

symbolic substitute for this test the technician is shown a series of solder joints and must match them with the list of descriptors that describe each (Figure 2). The difference between ability to recognize a proper solder joint and ability to execute one is fully appreciated.

The *second* soldering JTPT included all of the ancillary components previously mentioned. The technician was given a module with a number of components on it along with a schematic of the module. His instructions were to replace several components identified on the schematic. He then had to translate from the schematic to the proper components on the module, select the correct replacement parts from a supply of assorted parts, and properly install the new component. In the symbolic version of this test, he is provided the same instructions and schematic; however, instead of the actual module he is given a series of physical drawings (not schematics) of the module (Figure 3). He is to select the drawing which depicts the proper execution of the instructions. The technician must translate from the schematic to the actual module in the same manner as in the performance test and must be aware of such factors as polarity and coding to select the proper drawing. Again, however, the actual skill in executing the soldering task is not represented.

Remove and Replace Tests. The other tasks of the electronic technician that require use of hand tools primarily revolve around removal and replacement of modules within the radar and computer systems. The prime requirements of these tasks are that the technician be able to correctly locate the module he must remove and accomplish the removal and replacement without damage to the equipment. For performance testing purposes, the technician was required to remove and replace a series of modules, and was graded upon proper selection, successful removal, and replacement. The latter was determined by whether the equipment functioned properly upon completion of the task. For the symbolic tests, detailed photographs of the modules were provided to the technician. He was required to select the proper photographs based upon the module that he was told to replace, and then mark the fasteners that would have to be disconnected in order to release or gain access to the subject module.

General Test Equipment Usage Tests. Another general category of activities required of the AFSC 328X4 technician is the use of standard electronic test equipment. This equipment would be used in virtually all types of electronic maintenance. Those general items of test equipment required for use with the AN/APN-147 system are the PSM-6 Voltmeter, the 545-B Tektronic Oscilloscope, the 1890M Transistor Tester, and the TV-2 Tube Tester. While in practice any number of other types of similar equipment may be substituted for these specific items, those that are specified by the official maintenance documentation were used as the standard for testing purposes.

Voltmeter Symbolic Test. Analyses of cue-responses presented by these items indicated that they presented a fairly wide-range of requirements that had to be treated individually. These items of test equipment ranged both in mode of application and complexity of usage so that no single symbolic testing strategy could be applied to all. The *voltmeter* is the most widely used and the most simple to operate and interpret. Typically the technician is given a voltage value that should be present at a given point in the system by his documentation. He then employs the voltmeter to determine whether that voltage is in fact present at the specified point. Thus, he is comparing actual values with given ones. In the JTPT, the technician was given a series of values that were supposed to be present at given points on a voltage simulator. He took readings at the specified points and indicated whether each was within acceptable limits of the specified values.

For the *symbolic version* of this test, he was given the same specified values (Figure 4) and then shown a voltmeter display for each problem (Figure 5). He had to interpret the display against the given value and make the same determination of whether or not it was within tolerance limits. An alternative strategy for this test was tried out, in which the technician would take an unmarked display and indicate the control settings and needle position necessary to give the specified values. While this was more realistic in terms of the setting of the controls, the drawing in of the needle position did not correspond to any job activity. Further, variations and inaccuracies introduced by having the technician draw in the needle position made interpretation of the results difficult. The use of the pre-set display which the individual had to interpret was felt to be sufficient exercise of whether the technician could properly set the controls himself, since there are only two involved on the voltmeter.

TECHNICIANS

VTVM TEST ANSWER SHEET – SS-GE3

Figure	Assigned Value	In Tolerance? YES	In Tolerance? NO
1	4.5 vdc	____	____
2	15 vdc	____	____
3	3 vdc	____	____
4	10 vdc	____	____
5	24 vdc	____	____
6	22 vdc	____	____
7	6 vdc	____	____
8	6 vdc	____	____
9	27 vdc	____	____
10	20 vdc	____	____
11	100 ohms	____	____
12	10 ohms	____	____
13	370 ohms	____	____
14	1 k	____	____
15	11 k	____	____
16	47 k	____	____
17	160 k	____	____
18	200 k	____	____
19	7.5 M	____	____
20	7.5 M	____	____

Figure 4. **VTVM Test Answer Sheet.**

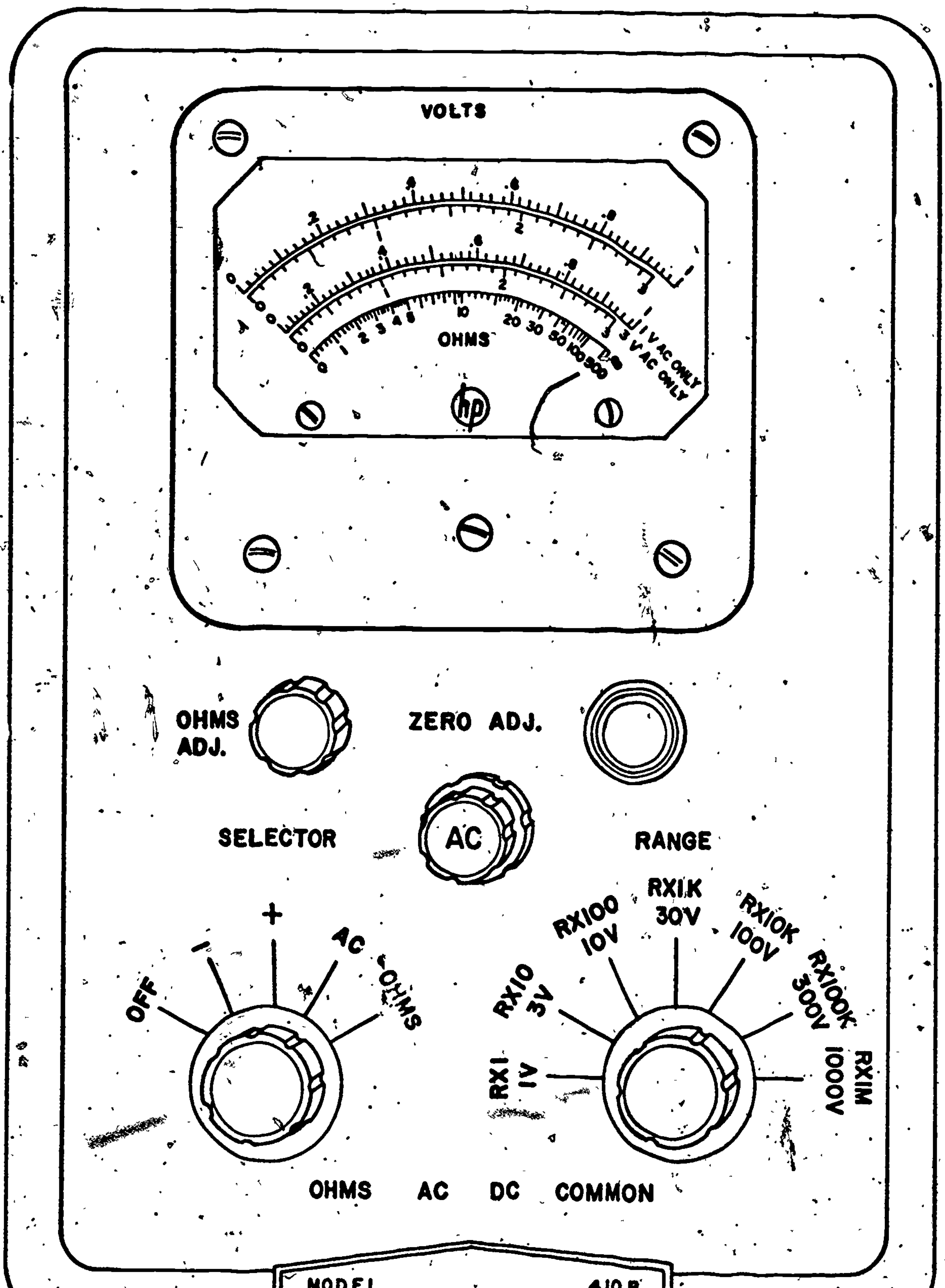


Figure 5. **Voltmeter test display.**

Oscilloscope Symbolic Test. The use of the *oscilloscope* follows the general pattern of the voltmeter except that it is considerably more complex. Again, values are specified in the TO for signals that are supposed to be present at given points. The oscilloscope is employed to verify whether such signals do in fact exist. There are, however, many more controls on the oscilloscope than on the voltmeter increasing the number of discriminations and responses required to perform adequately. The oscilloscope also displays its results as waveforms rather than meter readings, which means a more complex type of discrimination is required. However, the same basic format is used as in the voltmeter test, even though the number of discriminations and responses is greater. A waveform is given to the technician along with the necessary explanatory information. In the JTPT, the technician takes readings from specified points on a waveform generator and compares the results with the standard.

For *the symbolic test,* the technician is given a pictorial display of an oscilloscope, as shown in Figure 6. He must interpret the display (i.e., the interaction of the control settings, waveform, and grid notations) and determine whether the simulated output is in tolerance with the standard given in the problem. The technician is given seven problems that exercise all of the features of the oscilloscope from test probe calibration to dual trace. Because of the multitude of controls on the oscilloscope, however, it is not as likely that correct interpretation of the results on any particular one of these seven problems implies ability to properly set all of the controls, as is the case in the voltmeter test. Therefore, in addition to results interpretation, the subject must indicate the correct position of *certain key controls* for each problem. This insures that he has properly set the scope for determining the answer. The same technique is used in both the performance and symbolic versions of the tests. In the performance version, the subject must obtain an actual waveform on the oscilloscope, which requires setting the appropriate controls, whereas, in the symbolic version the display is provided to him and he must indicate the appropriate settings with a pencil.

The specific technique of having the subject mark the position of all of the controls to be used for a given function and draw in the resulting waveform on the oscilloscope was considered and rejected for several reasons.

First, the same objection as in the voltmeter test was encountered; that is, that drawing a waveform on the scope face has no counterpart activity in the real world. *Second,* while indicating the position of a given control with an arrow or mark would correspond rather well with actually setting it, there is a critical difference between the actual and symbolic task on the oscilloscope display. In actually using a scope, the technician can employ trial and error on the controls to try to achieve what he is after. This serves to refresh his memory and to provide a very useful form of feedback that helps him perform the task. As a gross example, if the technician forgot to activate the POWER ON switch in actual performance, he would not proceed far before realizing what was wrong. If he overlooked it in the symbolic test, however, he would get no such feedback. Thus, this type of symbolic test would be over-demanding of the individual's knowledge of the oscilloscope. For this reason, an approach was taken that also offered the individual some clues – not the same ones as in the actual job, but analogous ones – by naming a small subset of controls and focusing his attention on the settings required for each of them.

Symbolic Tests for Transistor and Tube Testers. The other two general test equipment items are similar to each other in function and both different from the voltmeter or oscilloscope. The purpose of the transistor and tube testers is to determine if a suspected part is good or bad. The *1890M transistor tester* is designed to make incircuit checks of transistors. The JTPT are designed to determine whether the technician can distinguish between good and bad transistors when using the device. When translated to the *symbolic* medium, the task becomes one of using the 1890M instruction booklet to set up the device according to the given specifications of the transistor to be tested. This is done by the technician looking up the transistor value and accompanying device setting instructions, indicating them on an Answer Sheet display of the device (Figure 7), and drawing in the limits of acceptable values that would indicate a good transistor. The *TV-2 Tube Tester* follows exactly the same format, providing a technician with a display of the device (Figure 8) and the accompanying instructions that he would have in the job environment, specifying a tube to be checked, and then requiring him to indicate the proper device control settings and the acceptable range of readings for a good tube of that type.

Special Test Equipment Usage Tests. In addition to the general type of test equipment described previously, the AFSC 328X4 technician must also be able to employ several specialized items of test equipment that are not common to many other electronic maintenance tasks. These are the AN/URM-25

Test - GE4 Problem 3 Technician Information Sheet

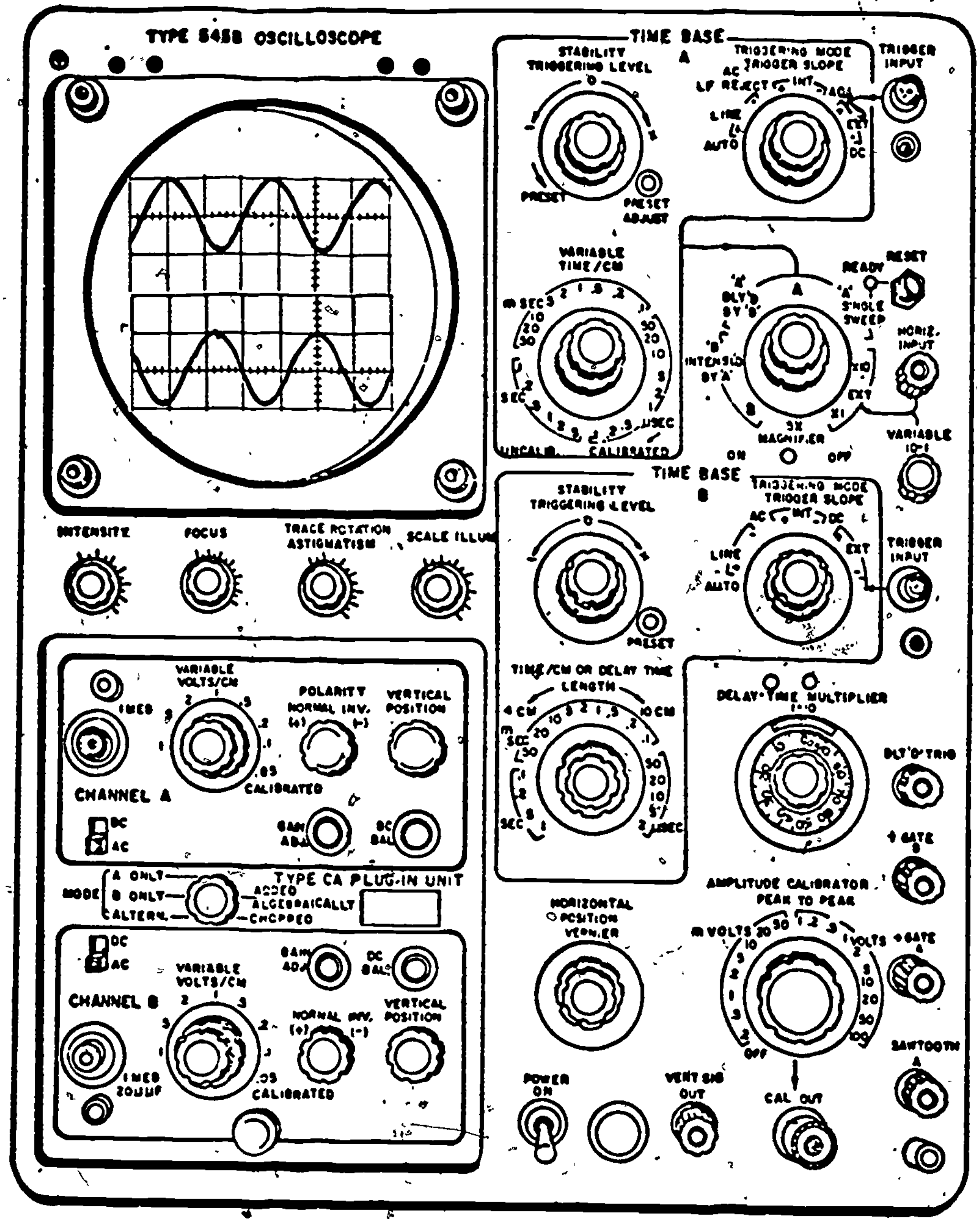


Figure 6. **Oscilloscope display.**

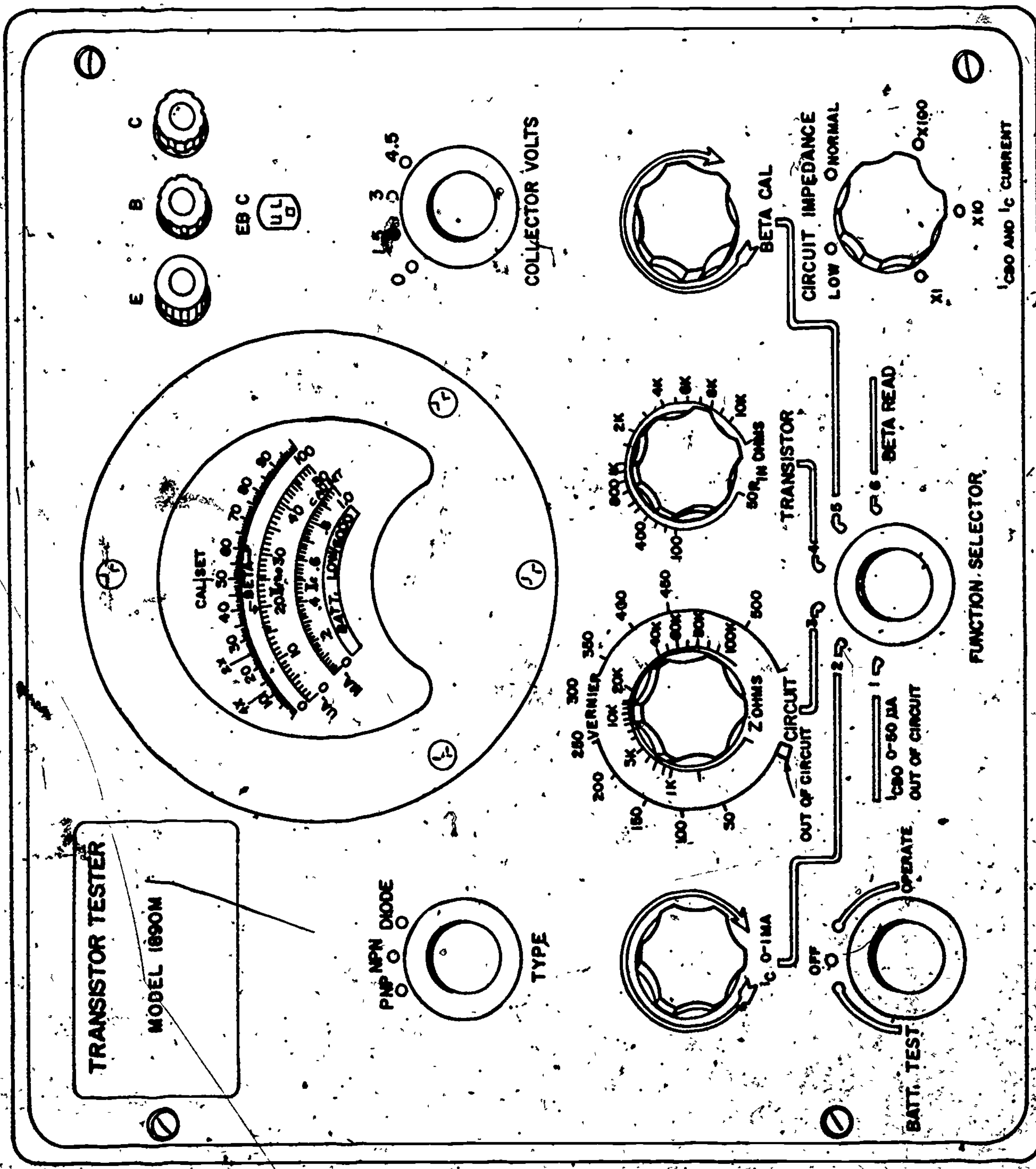
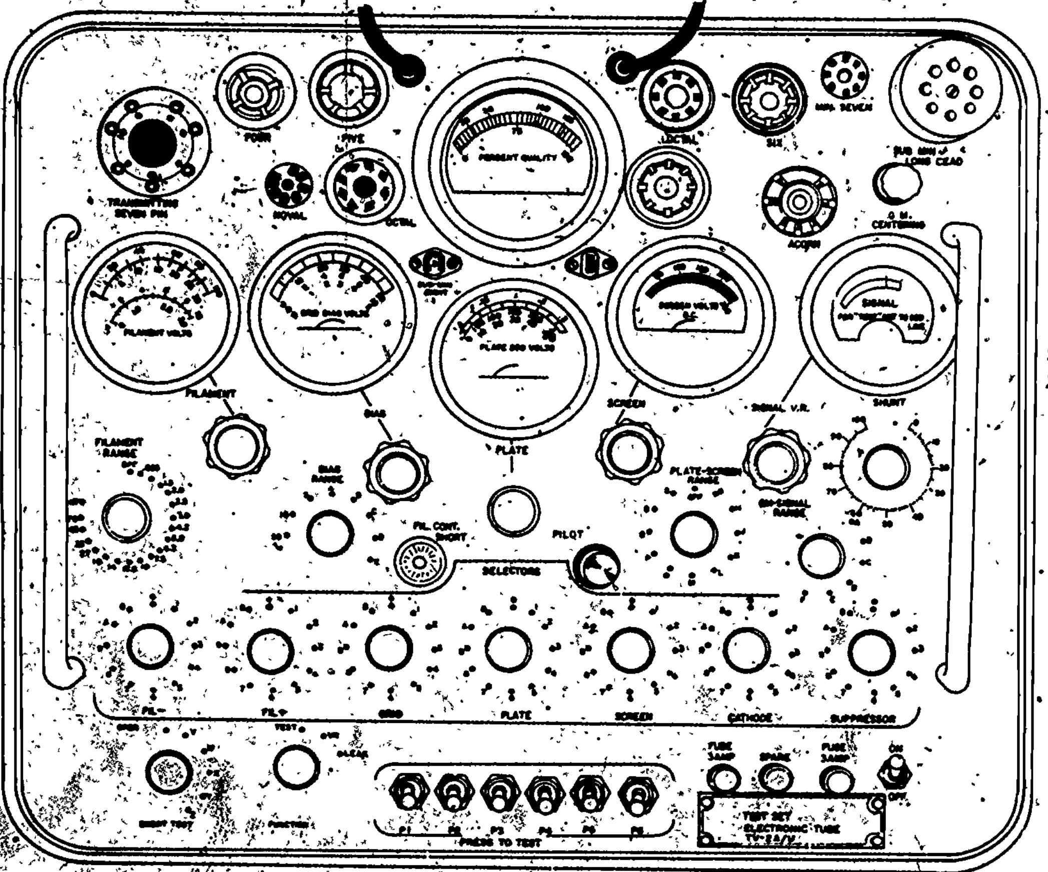
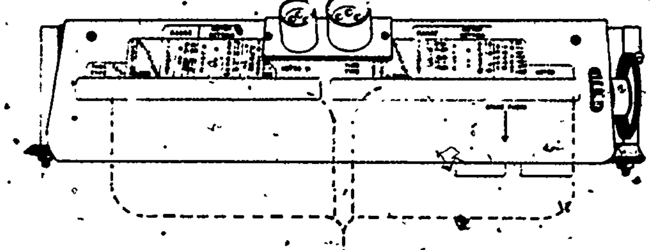


Figure 7. **Transistor tester panel display.**





TUBE TYPE	TEST	FUNCTION	SELECTORS (LTOR)	FILAMENT	SIIS	FL SCR	GM SIG	PLATE	BIAS	SCREEN	SIG VR	SHUNT	PRESS	TO TEST MIL MI IN MI UT ES	NOTES
6AB4	GM	T	34 610 70	6.3	D	G	S	225	CCW		RL	76	P4	69	
6AQ5	GM	T	34 156 22	6.3	50	G	C	230	12.5	225	RL	42	P4	60	
6AQ6	GM	T	34 170 20	6.3	5	J	D	225	3		RL	68	P4	57	TRIODE SECTION
6AQ6	EM	T	34 060 20	6.3	5	S	A	20AC	0		RL	90	P2	25	DIODE # 1
6AQ6	EM	T	34 050 20	6.3	5	S	A	20AC	0		RL	90	P2	25	DIODE # 2
6AR7	GM	T	34 156 22	6.3	50	G	D	230	18	225	RL	36	P4	55	
6AU6	GM	T	34 156 72	6.3	B	H	C	210	CCW	150	RL	33	P4	60	
6AV6	EM	T	34 060 20	6.3	5	S	A	20AC	0		RL	90	P2	63	TRIODE SECTION
6AV6	EM	T	34 050 20	6.3	5	S	A	20AC	0		RL	90	P2	58	SHORT IN Z
6AV6	GM	T	34 170 20	6.3	5	J	D	225	2		RL	52	P4	65	SHORT IN Z
6BK5	GM	T	54 718 60	6.3	10	G	S	230	5	225	RL	42	P4	60	
6BK7	GM	T	54 760 80	6.3	5	H	S	90	.9		RL	73	P4	60	DIODE # 1
6BK7	GM	T	54 210 30	6.3	5	H	B	90	.9		RL	73	P4	60	DIODE # 2

Figure 8. **TV-2 tube tester display.**

Signal Generator, the TS-382 Audio Oscillator, and the CMA-546 Doppler Generator. These items of equipment are specifically related to particular functions on the AN/APN-147 Radar and, consequently, must be tested in that context. The demonstration of the subject's capability to use these devices, then, is done in the context of specific maintenance tasks on the radar set. The difference between these tests and those in other categories that also require the use of this equipment is in what is graded. In these tests, the individual's ability to properly set up and employ the items of special test equipment is evaluated in a manner similar to the general equipment tests. In the adjustment and checkout tests, where these items are used as part of the distractive aspects of a larger task, the evaluation is based upon accomplishment of that larger task, not the distractive discriminations and responses that are auxiliary to it.

To demonstrate that he can properly employ this special test equipment, the technician is presented a problem that requires its use. He then must indicate on a suitable display, how this item of equipment is connected to other units and the control settings that would be made on the subject piece of test equipment for a specified check. Figures 9 through 13 show the displays for the special equipment tests which the technician uses to indicate the control settings.

Dependency Relationships. The foregoing series of tests – checkout, special and general test equipment, and soldering – represent discrete elements of the larger tasks that are the primary function of the electronic technician. These larger tasks are those of equipment repair and maintenance composed of adjusting and troubleshooting the equipment. These tasks are also tested via the performance tests, however, the individual components of these tasks are not graded separately. Thus, while these JTPT will indicate whether or not a technician is fully qualified on the maintenance of the AN/APN-147 system, they will not yield diagnostic information about specific weaknesses without the subtests that deal with the individual elements. In this way, the tests of the total maintenance tasks are not graded in such a manner as to confound the evaluation process. Troubleshooting, for example, is not graded on the basis of the particular procedures followed or some composite of the number of errors and assists the individual made and received while solving the problem. It is simply a matter of whether or not the subject was able to satisfactorily repair the equipment and bring it back to flight-ready condition, symbolically or actually. For purposes of simple evaluation, the troubleshooting and adjustment tests would be sufficient. For more detailed analysis of performance strengths and weaknesses, however, the other tests would be required. Also, the hypothesis underlying these tests is that all of this "auxiliary performance is important as 'distraction' in creating the job context."

Alignment Tests. The process of bringing various parameters of electronic equipment into correct performance tolerances is variously referred to as alignment, adjustment, or calibration. In the criterion series of JTPT, there were both adjustment and alignment series of tests and the distinction between the two was simply a matter of how they were referred to in the TO. No significant, generally accepted definitions or distinctions have been developed or are in existence to the knowledge of the authors. The strategies for testing these tasks were the same in the performance tests and are necessarily the same in the symbolic versions of these tests. Therefore, the distinction will not be retained in subsequent discussion and the term alignment will be used to encompass all three terms.

In the performance version of the alignment tests (there are a total of 16 alignment and adjustment JTPT) a given parameter of the radar or computer system is placed out of alignment by a known, standard amount. The technician is then told to perform a certain adjustment procedure which would result in the set being brought back into performance tolerances. If at the end of the test, the test subject can demonstrate on the appropriate item of test equipment that the set is within specified tolerances, he passes the test. (The technician is told what adjustment procedure to perform rather than having to decide what to do in the interest of saving test administration time. If the adjust problems were treated as troubleshooting problems (faulted parts), the technician would have to spend an unacceptable amount of testing time checking out a wide range of possible problems.) Thus, the troubleshooting and alignment aspects of the job are kept separate in the tests.

To test the technician's ability to make the same alignment in the symbolic version of the test, it is necessary to shift from the desirable objective criterion of "is the equipment back in adjustment" to a more procedurally oriented criterion. This is necessary since there is no feedback from a "live" system to determine successful completion of the activity. The symbolic substitute test provides a display of a wide range of test equipment, from which the technician selects and indicates those that would be used and draws lines to properly connect them for use as in the checkout tests.(Figures 14 & 15). For each piece of

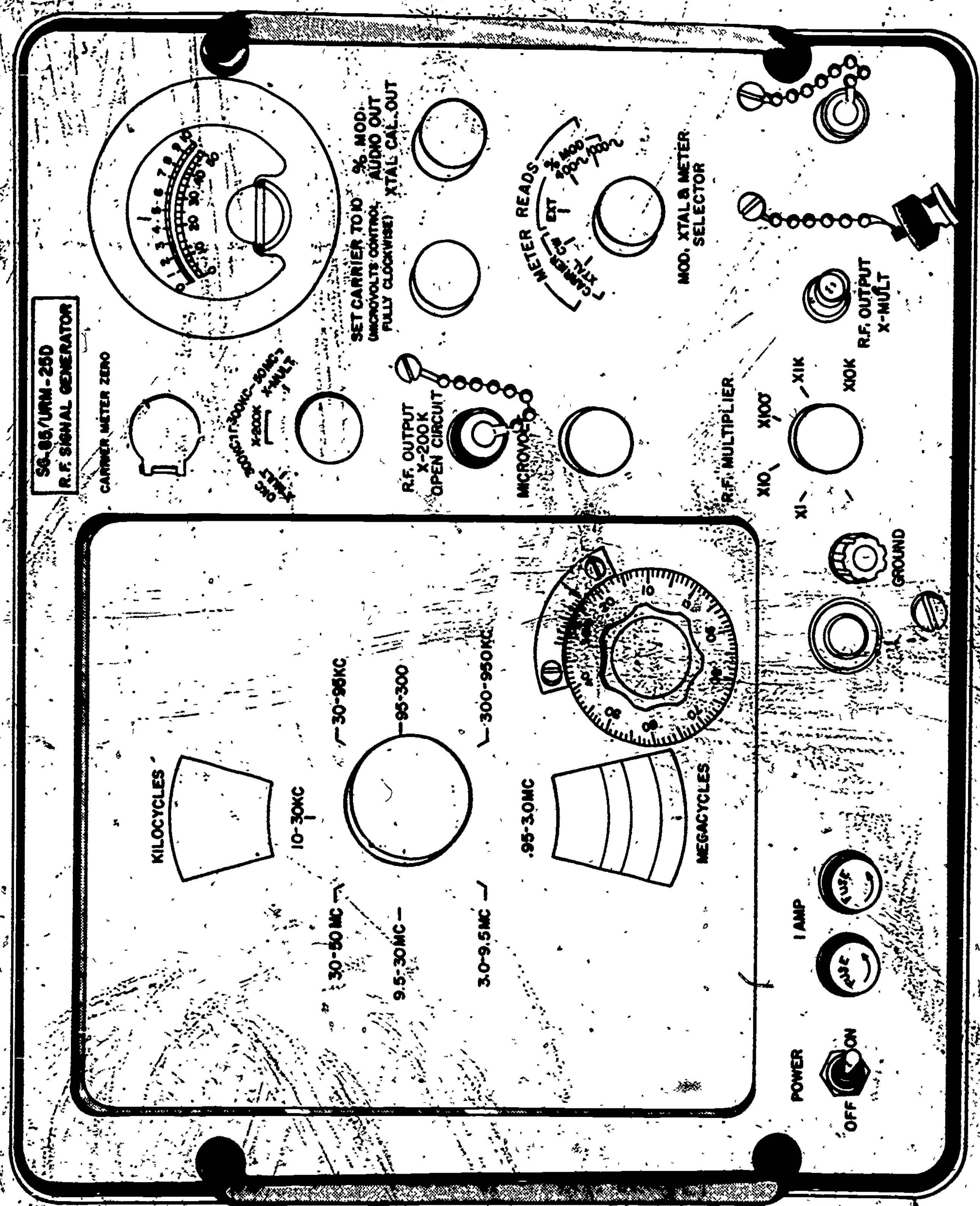


Figure 9. Signal generator panel display.

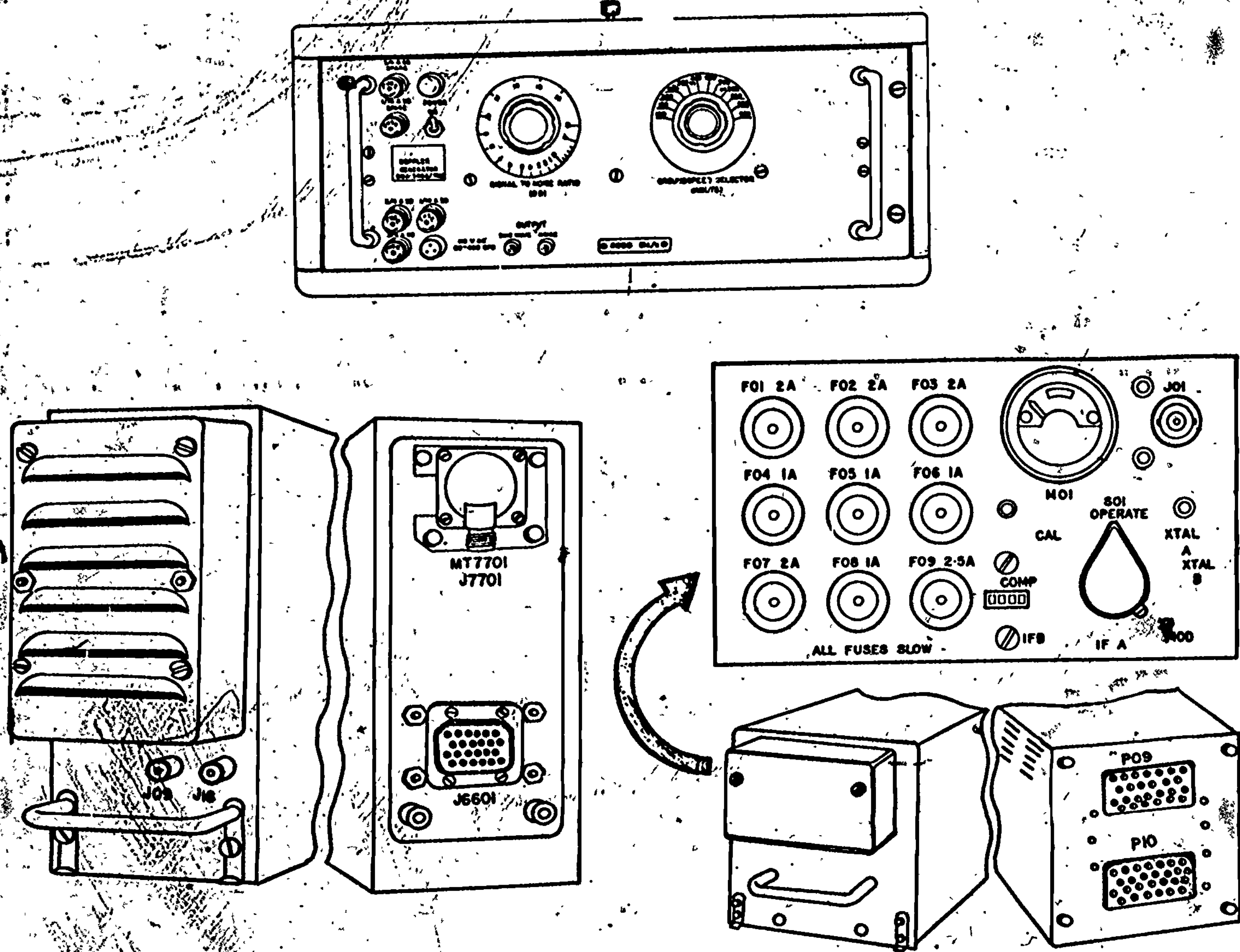


Figure 10. **Doppler generator usage display (1).**

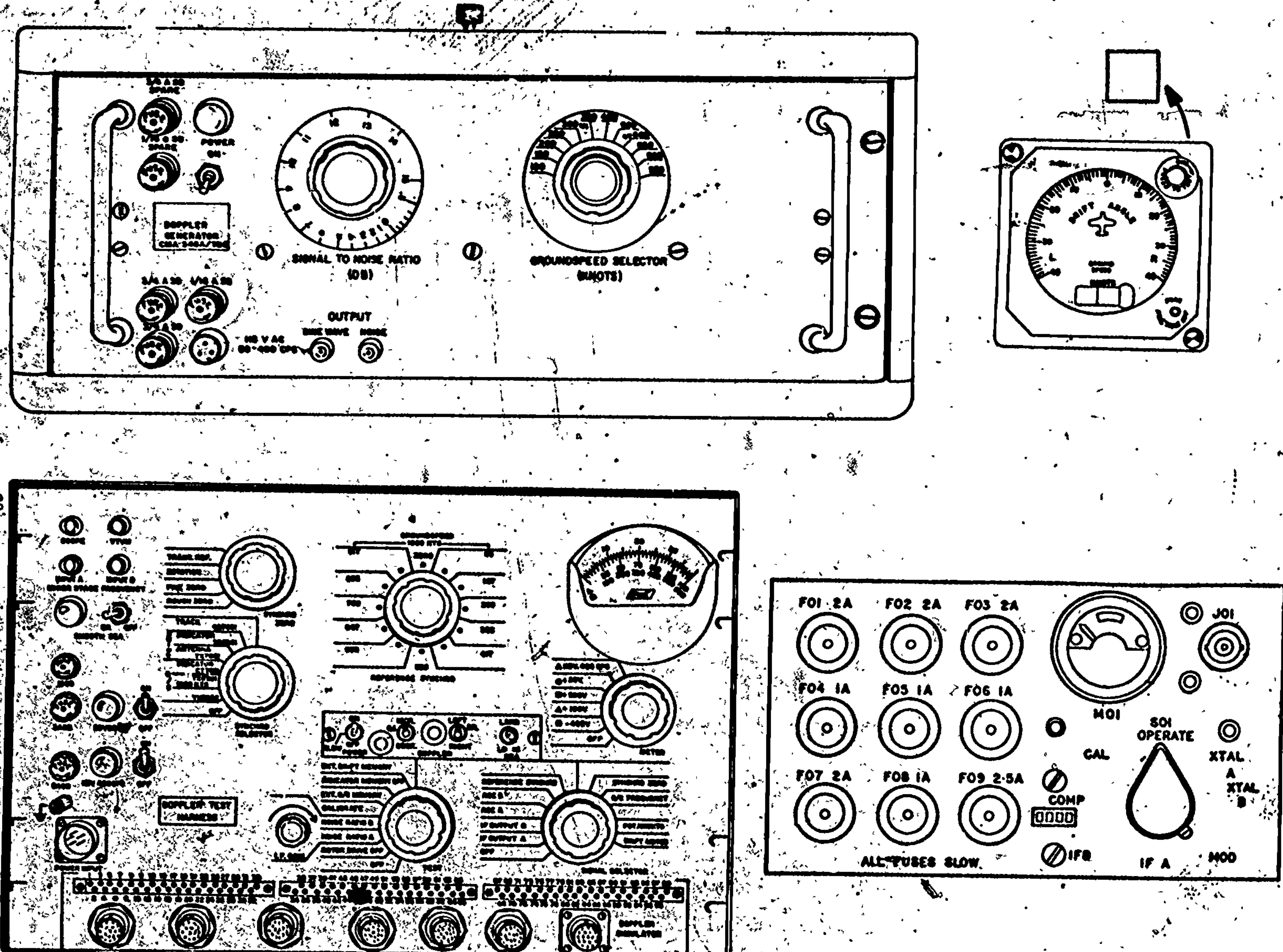


Figure 11. Doppler generator usage display (2).

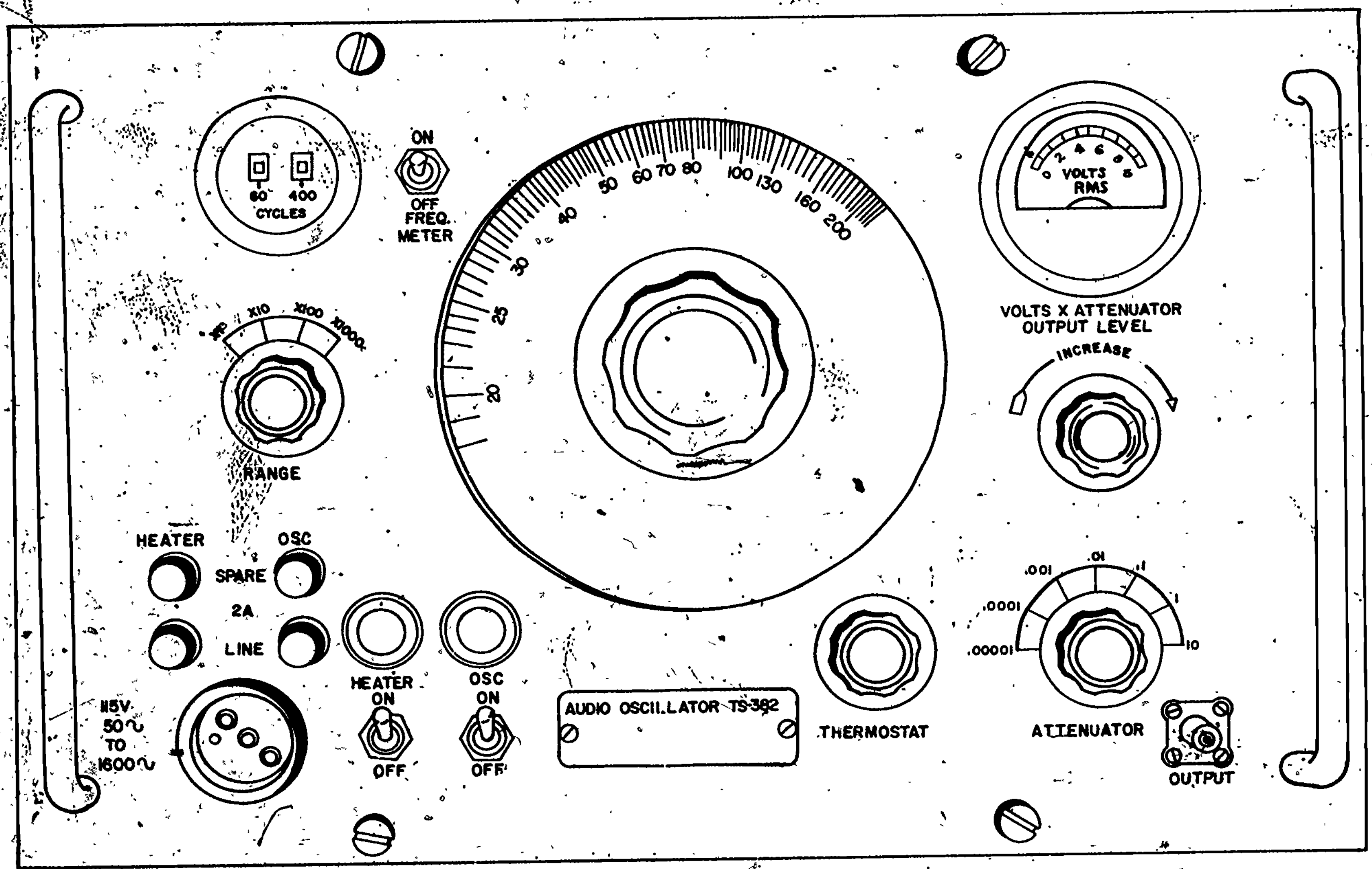


Figure 12. **Audio oscillator usage display.**

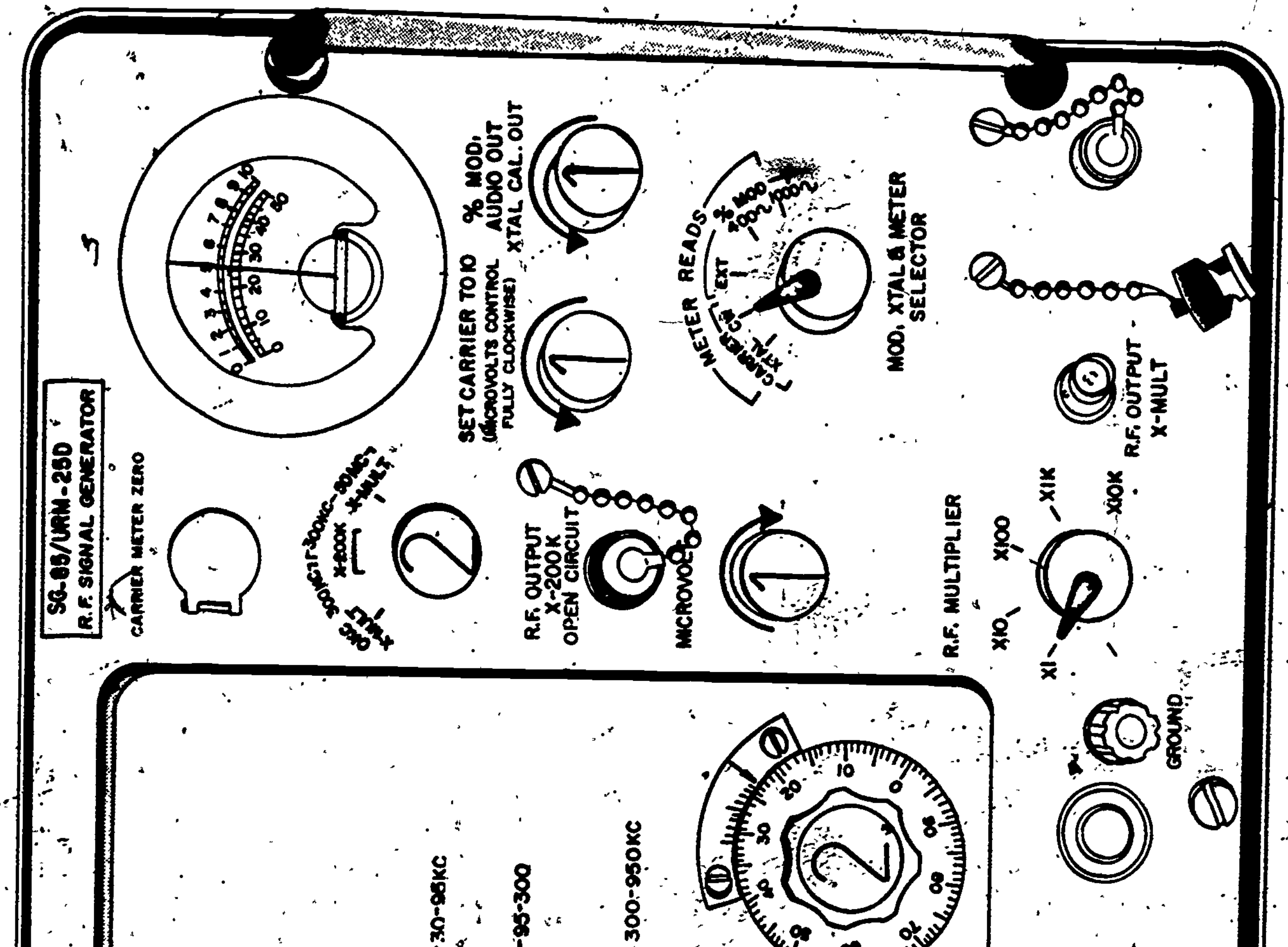


Figure 13. **Audio oscillator usage answer key.**

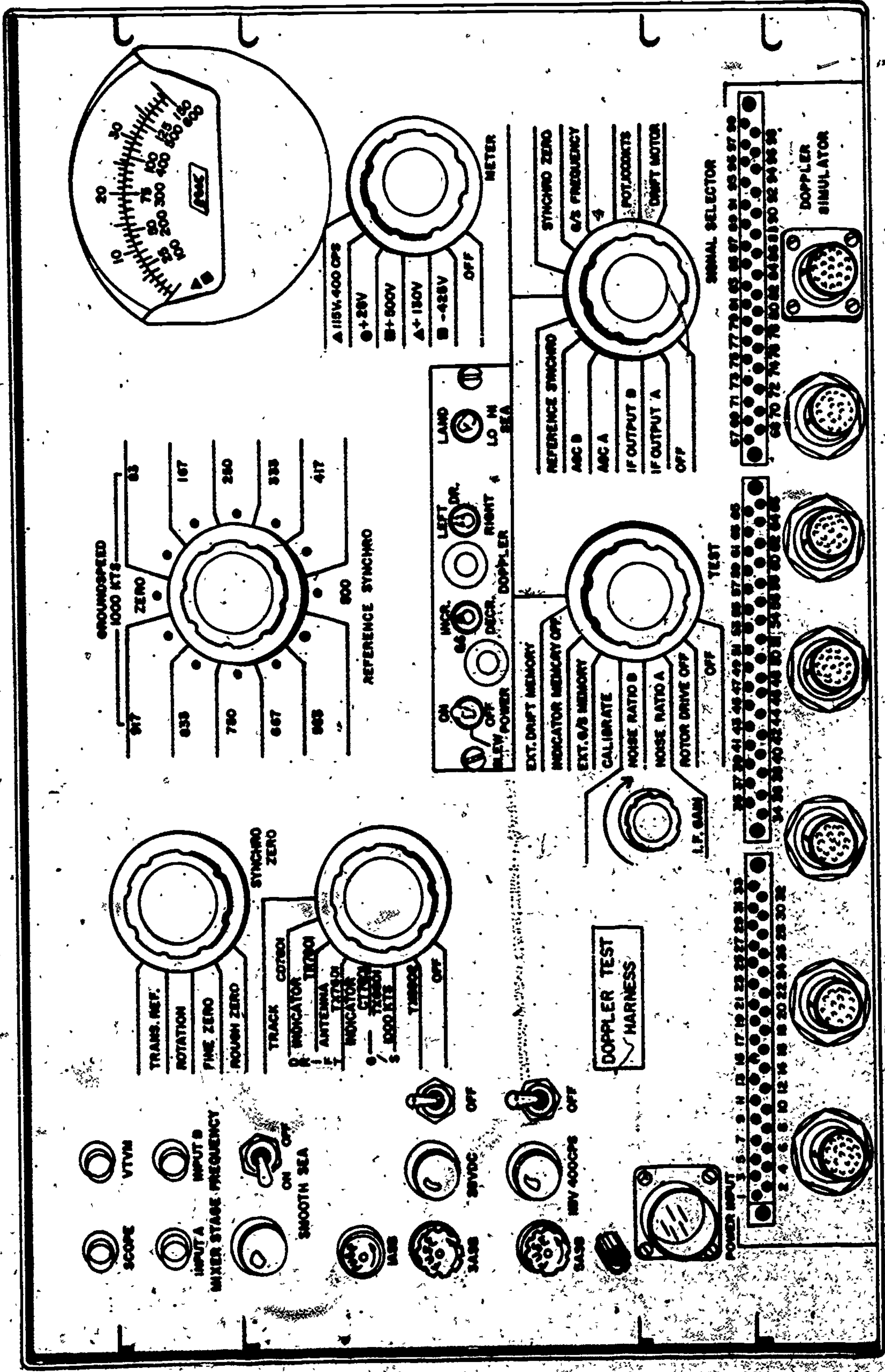


Figure 14. **Doppler test harness display.**

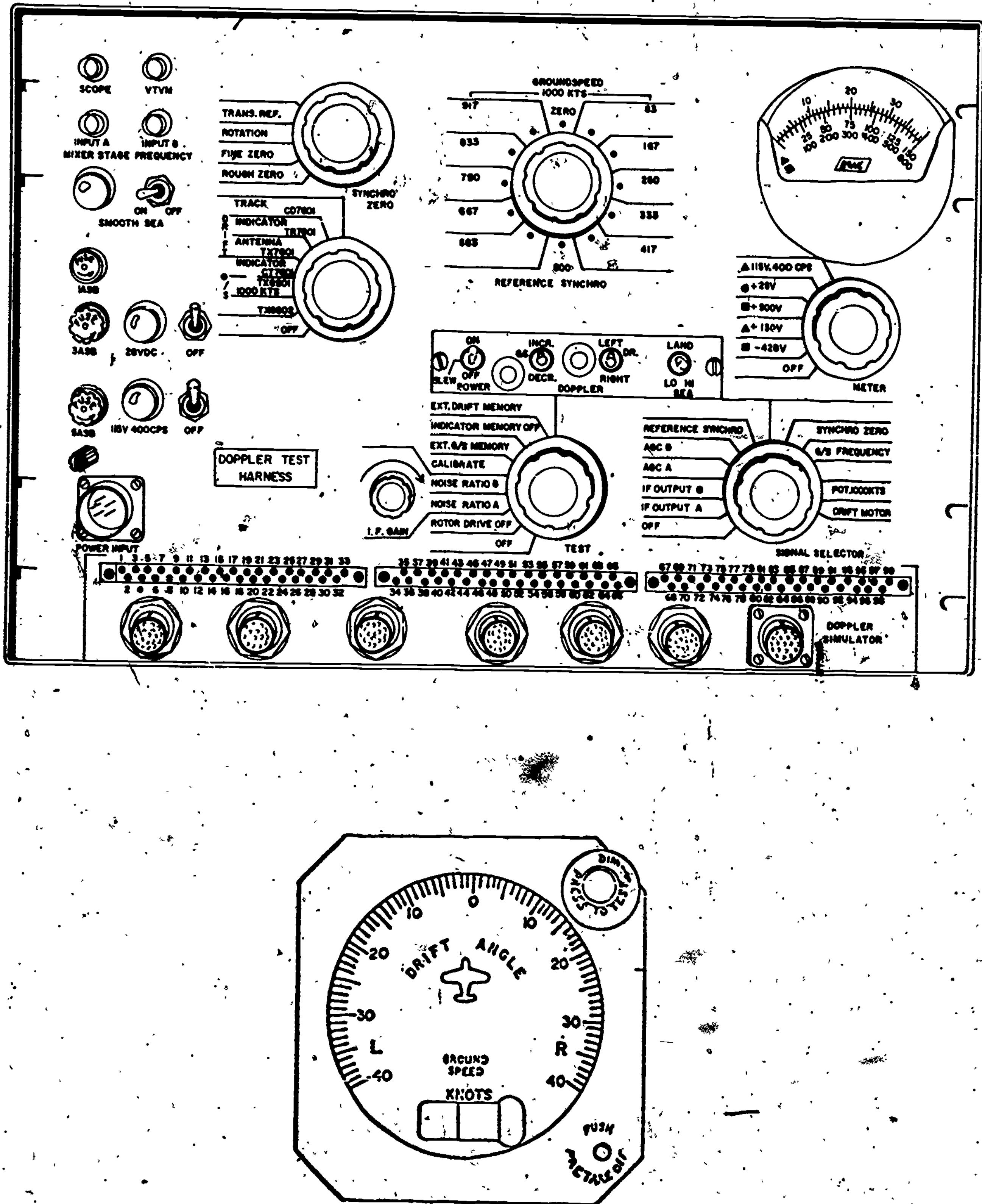


Figure 15. **Radar set checkout answer sheet.**

equipment used, he must indicate on a picture of that equipment what the proper control settings would be as well as what indications he would get which would indicate that the set was operating correctly. Further, he has to indicate the particular control (trimpot, etc.) on the set that would be used to make the required adjustment. There is still a lot of "distraction" in the test.

Due to the need to keep the amount of symbolic testing materials within manageable bounds for these tests, it was necessary to limit the acceptable approaches to making the test adjustment to those that are sanctioned by the TO. In the JTPT, it was possible to permit the technician to use any procedures and equipment that he chose. All that was graded was whether or not he successfully accomplished the required adjustment. For *symbolic* testing, there is no indication from the real equipment to show whether it is flight-ready or not. Therefore, it is necessary to grade on the correctness of the procedures used. The grading standards that are imposed are based upon the method specified by the TO for making each adjustment. One of the prime characteristics of the symbolic approach is that it necessarily limits the range of choice to that which has been provided. It did occur in administering the performance tests that equipment required by the TO for a particular task was not available in many shops. Such discrepancies between prescribed and actual procedures complicate symbolic testing. One advantage of the symbolic adjustment tests over the performance tests, however, is that they do provide a convenient "audit trail" of an individual's performance. Analysis of the detailed answer sheets can provide diagnostic information that is not captured by the performance tests.

Troubleshooting Tests. The troubleshooting process has been of continuing interest to researchers for many years, and there have been many studies directed at describing, teaching, and improving the processes involved. The purpose in this study was to simulate it rather than explain it. In observing the actions of technicians when troubleshooting, it was found that the information sought for any given problem varied considerably. Some based their information requests on a fairly obvious interpretation of the malfunction symptoms observed. Others appeared to be operating largely on less obvious experience factors and relating the symptoms to previously encountered difficulties, while still others followed even less decipherable patterns. Testing such random patterns of troubleshooting, without penalizing the individual for using the wrong "process" while solving the problem, was accomplished in the performance versions of the troubleshooting tests. The technician was graded solely on whether he was able to render a set which was inoperable due to a known, planted fault, operable. When translating to the symbolic medium the initial problem was encountered as in the adjustment area; the non-responsiveness of the paper simulations provided no feedback as to correct accomplishment of the task. While this could be handled in the alignment area by specifying the process, this was not possible in the troubleshooting area due to the lack of an absolute "right way" of solving each problem. It was necessary to provide some semblance of the high degree of latitude allowed in the actual troubleshooting process if the tests were to be accurate reflections of the job process.

It was decided that the test had to provide a store of information that the test subject could tap at will, much as the actual equipment contains all of the information the test subject needs to solve the problem if he can ask the right questions and correctly interpret the answers. Preliminary approaches were tried that gave the test subject information based upon a theoretical "branching" or "action tree" structure. The difficulty was, as mentioned previously, that few technicians used the same "tree." What may make sense to one, would be unenlightening to others. Further, there was the problem of giving away a good bit of information by having to confirm or deny the accuracy of each step.

As this approach broke down, it gave way to the idea of simply providing the information to the test subject in a "cafeteria" style, letting him choose any information he desired and make his decisions and conclusions on his own. This has a great deal of similarity to the actual troubleshooting process, but the problems in executing the idea appeared formidable. Trials with giving "good-bad" indications, or with providing printed voltage read-outs were not satisfactory in that these were not the type of displays the test subject received from the equipment. It was finally decided to provide the display of the requested information as the test subject would actually see it. If he wanted to know the signal present at a given point, he would be shown a picture of a voltmeter, oscilloscope, or other appropriate item of test equipment with the requested information depicted on it in the same manner as if he actually took the reading. This provided extensive "distraction" with respect to the "main line" of troubleshooting, but not as much as in the real situation.

The next problem in accomplishing this approach was to anticipate all of the possible requests and to document what the actual readings would be in a set with the specified fault present. While it was physically impossible to document and provide to the test subject a complete set of parameter values for every possible condition, a sufficient population of values (that would be requested by a test subject who had some competence) was developed. In addition, a standard set of answers were generated to be given by the test administrator to questions that dealt with values outside of the bounds of the problem at hand. When the test subject got too far afield, he was told that the requested signal values were "in tolerance," rather than being shown the actual displays. While this serves to limit the wrong paths the test subject can follow more than the actual criterion JTPT, it did not, in practice, provide significantly more useful clues.

One anticipated problem was how to prevent the test subject from "playing the test" by simply requesting an abundance of information until he got an indicated answer. This certainly was one of the drawbacks of the "good-bad" type of indications previously considered. Beyond converting the feedback information to actual displays that had to be interpreted by the test subject, the use of time penalties for each piece of information sought was considered. In this, if he asked for an item of information that would have taken him 15 minutes to acquire in the real world, he would be penalized 15 minutes on the symbolic test. This would reduce the amount of random guessing that he might pursue. This was considered when the bank of information was being provided to the test subject for his own use. The scoring problems associated with the administration of this system, however, were undesirable. Instead, it was decided that the test administrator would serve as a filter for requests for information. The TA has the manual that contains all of the system values for the problem under consideration. When the test subject requests information, the TA looks it up and shows him the requested display. The test subject observes it and records what he considered necessary and continues on from there. This prevents random perusal of the displays and also tends to encourage the test subject to ask more considered questions. The TA then responds to requests by either showing a relevant display on a piece of test equipment or gives a standard response if the requested information is outside of the problem boundaries. In either case, the response of the TA is "value free." He is not to give any indication as to the relevance or irrelevance of the question. *This display function should, of course, be relegated to some neutral mechanical device. Development of such a device, however, was beyond the scope of the present study.*

Summary Concerning Symbolic Tests Developed. In a previous effort reported in AFHRL-TR-74-57(II) of this series of documents, a battery of criterion referenced JTPT was developed. These tests were developed for the key activities of the maintenance jobs concerning electronic systems. The activities for which such tests were developed include checkout, soldering, removal and replacement of components, use of general and special test equipment, alignment, and troubleshooting. JTPT of this type require actual prime equipments and test equipments for their administration and can be administered to only a limited number of subjects at any one time. These limitations make the administration of criterion referenced JTPT expensive. In this section, the development of a battery of symbolic substitutes for these JTPT is described. The objective of these symbolic substitute tests was to overcome the expensive administrative cost of the criterion referenced JTPT but to retain the empirical validity of the JTPT. Attempts were made to simulate, as closely as possible, the actual tasks of the criterion referenced JTPT using paper and pencil simulation techniques. The symbolic tests developed require no actual equipment for their administration and most of them can be administered to a group of subjects. In order to accomplish this administrative objective, at least some of the realism of the criterion referenced JTPT had to be sacrificed. The remainder of this document is concerned with how much these compromises affected the empirical validity of the various symbolic tests described.

III. SYMBOLIC TEST EMPIRICAL VALIDATION

Test Tryout Plans

During the development and tryout of the symbolic tests the maintenance personnel of several bases of the Military Airlift Command (MAC) and the Tactical Air Command (TAC) were involved.

1. During the development of the initial symbolic tests, several contacts were made with the maintenance personnel at McGuire AFB, NJ. The contacts were for the purpose of obtaining information as to how the various maintenance activities were performed in MAC.

2. After the original symbolic substitutes were developed, they were given a "shakedown" by the contractor at Norton AFB, CA. The subjects were experienced personnel with the AFSC 328X4. This was a very limited tryout. The purpose of this "shakedown" was to determine the administrative feasibility of each of the symbolic tests. At that time, no attempt was made to determine their empirical validity. It was found that all of the tests could be administered without too much difficulty with the exception of the troubleshooting tests. The presentation of pictorial test point information using a book media proved difficult in the symbolic troubleshooting tests. All of the symbolic tests were modified to some extent as a result of this "shakedown."

3. The original plan for ascertaining the empirical validity called for the participation of the MAC Maintenance Standardization Team. It was planned to have team members administer the criterion referenced JTPT and their matching symbolic tests to experienced electronic technicians. This was to be done during their official evaluation visits to MAC maintenance squadrons. As explained earlier in Volume II, the standardization team did not make as many visits to maintenance squadrons as originally planned. *And* during the visits that were made, there was insufficient time available for administering the criterion referenced JTPT without regard to the symbolic tests.

4. As far as the empirical validation of the symbolic substitute tests in MAC was concerned, it was necessary to use fourteen novice subjects with limited training. This validation was performed at Altus AFB, OK. This section concerns the validation at Altus AFB.

5. Arrangements for experienced subjects were later made with TAC. The TAC validation took place at Langley AFB, VA, and at Little Rock AFB, AR. This validation was concerned with troubleshooting tests only. The modifications of the troubleshooting symbolic tests used for this validation are presented in Section IV of this document. The TAC validation plan and the results are presented in Section V.

Description of Validation Altus AFB

As stated above, the purpose of the validation effort at Altus AFB was to determine the degree of empirical validity of the symbolic tests for various electronic maintenance activities including checkout, soldering, use of test equipment, alignment/adjustment, and troubleshooting. In the Altus effort, the symbolic tests were compared against the JTPT as the criteria. In this comparison, a group of novice technicians were tested on a series of problems with both the symbolic and performance forms of the tests. These test subjects were part of another experimental project. They had just completed a special training course in the maintenance of the equipment for which the tests were designed. As such, they represented a convenient population available for testing.

The 14 test subjects were all *novice personnel* who had not been trained in any of the standard Air Force electronics training courses. Instead, these personnel were selected directly from basic training and given an experimental four-week training course in electronics maintenance using newly developed Fully Proceduralized Job Performance Aids (FPJPAs). These FPJPAs were designed to guide maintenance personnel through the organizational maintenance activities associated with the AN/APN-147 and AN/ASN-35 system. (These FPJPAs and the associated training had been developed and administered independently by a separate contractor. For a complete report concerning this effort, see Mullen and Joyce (1974)).

Once the test subjects had received their training, they entered the testing program. The primary purpose of the testing program was to determine the predictive validity of the symbolic tests, and not to evaluate the test subjects, the FPJPAs, or the training course. For this reason, the test design employed is different than would typically be employed for evaluating training or documentation programs. To gain maximum information on the symbolic tests in the relatively limited time available for testing, the 48 symbolic tests were divided evenly (timewise) among half of the subjects, and each subject took five or six pairs of tests. However, no test subject took more than one pair of tests in a given category. The testing schedule was then repeated for the second group of seven subjects.

Testing was conducted in a specially designed trailer that contained a complete bench testing and check out set up for the doppler radar and computer, plus all of the required items of test equipment. Subjects were tested at the rate of two per day and each subject took the assigned test twice, once as a JTPT and once in the symbolic format. The testing schedule was arranged so that each subject took the symbolic version of the test *first* in half the tests and the performance version *first* for the other half. This sequence was then reversed for the second group. Also, the two forms of any given test were not given sequentially, but dispersed in time. Typically, a subject would take several symbolic tests, then several different performance tests, then the performance version of the earlier symbolic tests and finally the symbolic version of the first performance tests.

Except for the case of the troubleshooting tests, there was no single correct "answer" that could be learned in one or the other version of the test. The test subjects had to be able to "perform" the tasks in both versions. There was a possibility of practice or learning occurring during the first test on a given problem and the counterbalanced administration schedule was used to equalize this possible effect. It was necessary to give the same problems to an individual on both forms of the test (performance and symbolic) in order to establish the "pairs" on which to base the correlation.

Analysis of Results

The analysis applied to the results obtained was designed to yield information regarding each discrete category of test classifications. This was done because each test category represented a unique set of materials and testing strategies. The purpose of this study was to find which tests showed promise so that decisions regarding further investigation of symbolic substitute testing could be made.

As a measure of relative correlation between the two types of test given in each category, the phi coefficient (ϕ) was used (Hays, Guilford & Fruchtez, 1973), computed from χ^2 according to the formula:

$$\phi = \sqrt{\frac{\chi^2}{N}}$$

in which $\chi^2 = \Sigma \frac{(f_o - f_e)^2}{f_e}$

where f_o = the number of similar results observed

f_e = the number of similar results expected

The data necessary for these computations was derived by casting the results of testing into a series of contingency tables. The 2 x 2 contingency table applicable to each classification of tests is shown in Table 1:

Table 1. **Example of 2 x 2 Contingency Table for ϕ Statistic**

	Matched Results	Mismatched Results
Expected	n/2	n/2
Observed	x	n-x

That is, if there was no relationship between the symbolic and performance test results, we would expect that in half of the cases, the scores would be the same on both and in the other half they would differ, based on chance alone. The direction of difference is not of importance but the incidence of differences is important. The tests were designed with the intent that if an individual fails a test item under one test condition, he should also fail it under the other. Similarly, if he passes one form, he should pass the other.

Table 2 shows the results obtained in the tryout by category of test. The raw score given in the "matched" row is the total number of paired administrations in which test subjects attained the same score ("pass" or "fail") on both the symbolic and performance version of the tests. The "differ" row gives the number of test pairs in which the scores achieved on the two tests were different. The reader is again reminded that the subjects tested were *not* experienced electronic maintenance personnel but *novices* given a four-week training program on how to use test equipment, how to use hand tools, how to remove and replace components, and how to use *FPJPA* to perform checkout, troubleshooting and align and adjust activities. It should be noted that these novices did *not* have FPJPA to guide them on use of test equipment, hand tools, and how to remove and replace components. They were supposed to be able to perform these activities as the result, *only*, of their training. In this respect, these subjects were similar to experienced personnel who are usually expected to perform such activities as a result of their on-the-job training (OJT) and their experience. Column 5 of Table 2 indicates this difference in support of activities. "JPA" indicates that the subject used a FPJPA to help him perform the activity. "JOT" indicates that he was expected to perform the task completely on his own as a result of job oriented training exercises.

Table 2. Indicating Validation Results and Type of Training for Each Activity Measured

Activity Tested	N Pairs	Results Matched	Results Differ	Type of Training[a] and Test Directions
Checkout	4	4	0	JPA[b]
Soldering	4	2	2	JOT[c]
Remove and Replace	14	10	4	JOT
General Test Equip	6	5	1	JOT
Special Test Equip	6	4	2	JOT
Alignment/Adjustment	19	15	4	JPA
Troubleshooting	9	3	6	JPA

[a]All subjects received 4-weeks of Job Oriented Training on how to use test equipment, on how to solder, on how to remove and replace components and on how to use Job Performance Aids (JPA).

[b]JPA indicates that tests on activity was performed with Job Performance Aids (JPA).

[c]JOT indicates that subject had no JPA for activity and was expected to perform as a result of his Job Oriented Training (OJT).

The contingency tables for each test categories are given in Tables 3 through 9. Applying the previously defined statistics to these data, the correlations (shown in Table 10) were obtained. Due to the rather small N for each type of activity, no attempt has been made to estimate the statistical strength of each relationship – rather they should be considered only as trends. It will be noted that with the exception of the tests for soldering and troubleshooting, all the correlations are positive. Comments concerning the results obtained concerning the tests for each type of activity appear in the following paragraphs.

Review of Symbolic Test Results by Category

Checkout Tests *(ϕ = 1.00).* All test pairs of criterion referenced JTPT and symbolic tests taken in this category of activities produced the same scores. The checkout procedure was not anticipated to present any problems; however, two of the four subjects were not able to correctly accomplish the procedures on either form of the test. The computer checkout routine used in the FPJPA was considerably longer than the one normally used in the field, and a time adjustment was made in the JTPT to allow for this.

Table 3. Checkout (ϕ = 1.00)

	Results Matched	Results Differed
Expected Frequency	2	2
Observed Frequency	4	0

Table 4. Peripheral Skills (Soldering) (ϕ = 0)

	Results Matched	Results Differed
Expected Frequency	2	2
Observed Frequency	2	2

Table 5. **Removal and Replacement (ϕ = .43)**

	Results Matched	Results Differed
Expected Frequency	7	7
Observed Frequency	10	4

Table 6. **General Test Equipment (ϕ = .67)**

	Results Matched	Results Differed
Expected Frequency	3	3
Observed Frequency	5	1

Table 7. **Special Test Equipment (ϕ = .33)**

	Results Matched	Results Differed
Expected Frequency	3	3
Observed Frequency	4	2

Table 8. **Alignment and Adjustment (ϕ = .58)**

	Results Matched	Results Differed
Expected Frequency	9.5	9.5
Observed Frequency	15	4

Table 9. **Troubleshooting (ϕ = .33)**

	Results Matched	Results Differed
Expected Frequency	4.5	4.5
Observed Frequency	3	6

Table 10. **Indicating Validation Results, χ^2 and ϕ Coefficient for Each Activity Measured**

Activity Tested	N Pairs	Results Matched	Results Differ	χ^2	ϕ
Checkout	4	4	0	4.00	1.00
Soldering	4	2	2	0	0
Remove and Replace	14	10	4	2.57	.43
General Test Equip	6	5	1	2.67	.67
Special Test Equip	6	4	2	.67	.33
Alignment/Adjustment	19	15	4	6.37	.58
Troubleshooting	9	3	6	1.00	−.33

Soldering ($\phi = 0$). *As was anticipated, the soldering tests results showed little correlations between the two test forms.* The Physical requirements are extremely essential to the determination of whether a man can solder or not and this was demonstrated in PT-2 (circuit board soldering) where both subjects could recognize a good solder joint, but only one could produce such a joint. In PT-2 (conventional soldering), the subject who failed both test forms was unable to identify replacement parts (resistors, capacitors, etc.). In the case of the individual who performed the actual replacement correctly, when tested via symbolics, he did not deal with polarity properly and selected the wrong answer. His correct performance on the performance test may have been due to chance insofar as the matter of polarity was concerned.

Removal and Replacement ($\phi = .43$). The results in this category were somewhat higher than anticipated. It was generally expected that the vast difference in feedback available in these tasks would permit success in the JTPT that would not necessarily be reflected in symbolic tests. Two patterns were observed. *One* was that subjects generally failed because they could not identify the described module. When this occurred, they were unsuccessful in both versions of the test since they were given no confirmation of their actions, right or wrong, in the first administration of the test. The *second* feature of interest is that, of the four subjects who passed one test and failed the other, all failed the initial attempt and passed the second; this was true whether taking the symbolic or JTPT first. This suggested that without the learning effect of the test-retest, the first trial results would be the same. Thus, the correlation appears to have been reduced by learning effect rather than test format difference. *The symbolic substitute format appears highly promising in this area in spite of the imperfect correlation obtained.*

General Test Equipment ($\phi = .67$). General test equipment tests dealt with equipment that was generally used in a variety of tasks and could be tested out of the specific equipment context. That is, the test subject does not have to know anything about the AN/APN-147 Doppler Radar to take these tests, which is not the case for items in the special test equipment category.

A satisfactory correlation was found for the tests in this category. In the single mis-match encountered, the subject was able to set up the controls of the TV-2 properly for each problem (symbolic) but was not able to correctly interpret results (performance). (It must be pointed out that this device and the 1890M Transistor Tester were different models of devices than the subjects had been trained on; therefore, they had to orient themselves to these devices based on what they learned of the others.) It also should be noted that this was an extremely limited "validation" of general test equipment symbolic tests. Before such tests can be accepted as adequate, each type of test must be given a full scale validation on its own merits. This would require four separate validation efforts, one each for the PSM-6 Voltmeter, the 545-B Tektronic Oscilloscope, the 1890M Transistor Tester, and the TV-2 Tube Tester.

Special Test Equipment ($\phi = .33$). The special equipment tests dealt with equipment that had to be used in the context of a particular equipment alignment or procedure. These results were less satisfactory than anticipated; *however, one of the mis-matches may have been based upon the test subject's attitude rather than the test materials.* His inattention to detail in the JTPT caused the failure, while his knowledge of what to do allowed him to satisfactorily complete the symbolic test. If his results had matched, the phi coefficient would have been .67 instead of .33.

Alignment and Adjustment Tests ($\phi = .58$). The results of the tests in the alignment and adjustment areas were combined since the two areas use the same testing strategy. *A moderately strong correlation was attained between the symbolic and performance test results in these areas, suggesting that both test forms are measuring the same sets of skills.* In reviewing the four instances in which the results differed between the two test forms, it was found that three test subjects passed the symbolic test but not the performance version. This may have been partially due to the scoring strategy used for the symbolic materials. It was found that applying the scoring criteria for the answer sheet demonstrating equipment interconnections (test equipment to radar, radar to test harness) was more difficult for this group of subjects than it had been for conventionally trained personnel. This was due to a significant increase in the number of extraneous connections. The subjects tended to make not only the required connections, but a number of others as well. For purposes of this project, it was decided to score only on the basis of whether all of the correct connections were made, rather than on the existence of incorrect connections. Further work is required to determine how much "noise" of this nature is an indication of subject floundering versus incidental errors which would not particularly degrade performance.

In the adjustment and alignment tests associated with the AN/APN-35 computer, it was found that out of the seven tests, five of the associated procedures in the FPJPA used devices that were not included in the symbolic material. Those for which symbolic tests had been developed were a track resolver drive tester and a circuit board tester. These other items are generally considered Depot level equipment and are not normally found in Field Maintenance shops.[1] The TO calls for the use of a VTVM and different procedures, which were the basis for the development of the symbolic materials. Therefore, no results were obtained in these five areas.

Since the FPJPAs did not identify adjustment and alignment procedures as separate routines as is done in the TO, it was necessary to modify the testing strategy for alignments and adjustments. Normally, these tests required the subject himself to locate the technical data required to support performance. For personnel using the FPJPA, however, it was necessary to provide the exact page and instruction reference necessary to accomplish the specific task. Since the same procedures were used in both the symbolic and performance tests administration, this change did not affect test results.

Troubleshooting Tests *($\phi = .33$). Results of performance testing and symbolic testing in the area of troubleshooting showed a negative correlation.* The specially trained novice personnel used as test subjects had difficulties with both types of troubleshooting tests – the criterion referenced JTPT as well as their symbolic counterparts. As indicated earlier, these test subjects had been trained to perform troubleshooting tasks with FPJPA which provided step-by-step troubleshooting directions. The test difficulties experienced by these subjects were of, at least, four listed types; namely: (1) deficiencies in the FPJPA provided, (2) deficiencies in the sequencing of the troubleshooting criterion referenced JTPT in relation to the sub-tests in the JTPT battery, (3) maintenance difficulties with AN/APN-147 – AN/APN-35 system, and (4) difficulties with the content and administration of the bank of test equipment pictorials provided by the troubleshooting symbolic tests. The problems in any of these areas were of sufficient magnitude to prevent a high positive empirical relationship between the criterion referenced JTPT for troubleshooting and their symbolic substitutes.

The FPJPA had not been adequately validated prior to the Altus effort. As a result, the step-by-step guidance provided by these aids was not perfect. This resulted in subjects having difficulty finding the equipment troubles without regard to which type of test they were taking. The tests were evaluating both the FPJPA and the subjects' ability to use them. In most cases, it was difficult to determine which had the greater deficiencies.

The recommended sequence for administering the various sub-tests of the criterion referenced JTPT battery which is described in AFHRL-TR-74-57(II), had not been developed at the time of this Altus validation. *The test subjects were given these troubleshooting criterion referenced JTPT before it had been determined that they could or could not use their test equipments proficiently.* Observations of the Altus subjects taking the troubleshooting JTPT indicated that many of them had difficulty setting up their test equipments and obtaining accurate test point information after setting them up. An inaccurate test point reading would send the subject down a wrong branch in his FPJPA and as a result, he would not identify the trouble. The FPJPA, used in the Altus effort, did not tell the subject how to use his test equipment. His training was supposed to provide this "know how." The training program did provide instruction and some practice in the use of test equipments, but evidently it was not enough. This would support the hypothesis that technicians should be "over trained" in the use of test equipments, if they are to be expected to use them effectively in job situations. *This experience in administering these troubleshooting JTPT further supports the position that troubleshooting tests should not be administered to a subject until it is determined that he can use his test equipment adequately and can perform other necessary sub-tasks, such as checkout and alignment, in a proficient manner.*

Even if experienced subjects had been available for the Altus validation, the same test equipment problem would probably have occurred. As discussed in AFHRL-TR-74-57(II), other research efforts have indicated that many experienced technicians cannot use their test equipments well.

[1]The MAC field shops are authorized to perform these depot alignments; and they, also, have the necessary special test equipment. The test developers were not aware of this capability.

Another aggravating problem for both the test subjects and for the administrators concerning the criterion referenced JTPT was the unreliability of the AN/APN-147 and the AN/ASN-35. Due to difficulties in obtaining some critical spare parts at the time of the Altus effort, these equipments were not in prime operating condition. At times, an unwanted trouble would develop in the equipment under test while a test subject was troubleshooting for the "planted" trouble. In some cases, this invalidated the administration of a JTPT.

The symbolic substitute tests for troubleshooting were difficult to administer because of their book display of test equipment pictorials. This difficulty was experienced in their original "shake down" at Norton AFB and continued during the Altus validation.

Another difficulty concerning these symbolic tests for troubleshooting concerned the number of pictorials available. The criterion referenced JTPT make use of actual test equipments. When developing these tests, the developer does not have to anticipate what use the test subject will make of his test equipments. If the test subject desires some test point information whether he really needs it or not, he can set up his test equipment and obtain the desired information (provided of course he can use his test equipment). But the developers of symbolic substitute tests produced for this effort were required to anticipate *what* test point information the test subjects would request and to provide a test equipment pictorial display of the required information for each test point. The test developers had anticipated that the test subjects would be experienced technicians having received conventional training and using conventional TO. The test developers therefore, provided the test equipment pictorials which they felt would meet the needs of such personnel. The selection of these displays was based on a troubleshooting strategy which the test developers believed would probably be used by experienced personnel.

The test developers had not anticipated the troubleshooting strategies used in the FPJPA. When the test subjects used in the Altus validation asked for many of the test equipment displays called for by the FPJPAs, the displays were not available. When a display was not available, the TA would tell the subject what the test point information was for the problem. This action did not provide the test subject with the opportunity to misinterpret the test equipment display — thus decreasing the realism of the symbolic test. This action made the symbolic tests more like the tab tests (Crowder et al., 1954). The result was that some subjects tended to solve symbolic problems when they were unable to solve the same problem in JTPT. In fact, this test effort was trying to improve on this possible shortcoming of the tab tests. Before this pictorial type of symbolic troubleshooting test can be used successfully with FPJPAs, the troubleshooting strategies of the FPJPA must be studied and the missing displays required by the FPJPA must be added to the bank of test equipment pictorials.

To ascertain if the test equipment displays in these original troubleshooting symbolic tests are adequate for experienced technicians would require a tryout making use of such personnel using standard TO. This has never been accomplished. When arrangements were made for Tactical Air Command (TAC) subjects for such a tryout, the troubleshooting symbolic tests were modified. Instead of attempting to overcome the administrative and content difficulties of presenting a test equipment pictorial for each test point required by the test subject, the symbolic tests for troubleshooting were modified to eliminate this important pictorial feature. These modifications are described in Section IV. Whether or not this was the proper decision, will be discussed in Section V.

IV. DESCRIPTION OF REVISED SYMBOLIC TROUBLESHOOTING TESTS

Background

What was actually required instead of or in addition to the limited validation of the symbolic tests at Altus AFB was a full scale validation using a sufficient number of experienced electronic technicians as test subjects to evaluate the effectiveness of all the symbolic substitute tests. At the time, the Air Force Human Resources' Laboratory did not have such exploratory development money and MAC could not furnish sufficient experienced subjects for the testing time required. When a small amount of money did become available in FY73, it was not sufficient for the required large scale validation even if sufficient experienced subjects could be found. It therefore was necessary to limit the scope of the follow-on effort. Since the symbolic substitute tests for troubleshooting had presented the most problems at both Norton and Altus Air Force Bases, it was decided to concentrate the limited available resources on that area. The objective was to reduce the TA requirements contained in the original design of the troubleshooting tests while still providing a wide range of potential information about system parameters to the test subject.

The initial symbolic troubleshooting tests were based on the following premises:

1. Maximum pictorial fidelity with "live" troubleshooting.
2. Maximum simulation of "live" troubleshooting procedure.
3. Integrated testing of component skills.

While these premises were (and are) highly defensible as guiding principles for symbolic test construction, their implementation presented several problems. For example, the *first premise* (pictorial fidelity) meant that test point readouts are shown as drawings of meter needle position or scope waveforms. This approach resulted in voluminous numbers of drawings of meter faces for all reasonable readout values.

The *second premise* (procedural simulation) involved the test subject "asking questions" (e.g., "What reading do I get at this point?") in the symbolic test just as he would with the "live" equipment. As the tests were developed, this meant a one-to-one ratio between test subjects and TA, because the TA would have to show the test subject the appropriate drawings in answer to his questions.

The *third premise* (integrated testing) meant that all component skills in troubleshooting (e.g., test equipment control settings, meter reading, strategy of attack, logical conditions from test readouts, use of documentation, etc.) were being addressed simultaneously. Moreover, each troubleshooting problem incorporated analysis at the system level, at the chassis level, at a stage, and within a stage. Thus, whereas success on a problem was easy enough to interpret, failure to solve a problem could not be laid directly on a *particular* skill component or ascribed to a *particular* level of troubleshooting analysis.

Since all parameters were documented in the form of meter and other equipment readouts, this presented a formidable amount of paper. To organize this and expect a test subject to readily learn how to sort through it proved infeasible. Therefore, a "most likely" subset was developed. This, however, generated a need for the TA to be able to scan a test subject's request rapidly, and to determine whether he had that parameter documented appropriately with a standard display, or whether it was outside the bounds of the problem and should be answered with a standard reply (e.g., "in tolerance"). In addition, the TA served to reflect the dynamic effects of the subject's actions on the equipment. If a subject replaced a faulty component and then requested new readings or symptom information, the TA would present different displays than had been shown previously.

This procedure for symbolically testing troubleshooting is very realistic and provides a high degree of overlap with the information flow that actually transpires from the equipment and documentation to the technician in the course of a real-world problem. The need for equipment, both prime and test, is eliminated and the time to solve troubleshooting problems is reduced since the equipment interface tasks are eliminated. However, the need for an expert TA operating on a one-to-one basis, or at least on a very low subject-to-TA ratio, is introduced. Therefore, an approach was sought that would retain as many of the desirable features as possible while reducing the complexity and TA requirements of the symbolic tests.

To provide all of the test point and symptom information via equipment readings posed the prospect of volumes of displays to support each troubleshooting problem. While the paper costs and development costs were well within reason (when compared to the equipment replaced thereby), a possible unacceptable cost was that imposed on the test subject. He would have to spend considerable time learning and using the necessary indexing system to the materials as well as that required to actually retrieve a piece of information. If this indexing system were too complex, the learning and executing of the test mechanics could become a rather difficult separate skill requirement that could possibly contribute to test failure.

One solution to the problem was suggested earlier; that of using a rapid access *projector*, rather than a book for the presentation of the test point and symptom information. This approach would, of course, call for a simple indexing system for taping the information bank. In addition, a sufficient number of rapid access projectors would have to be added to the test administrator's kit. As an alternative to numerous displays it was decided to provide the readings in a more compact format that would provide better access to more information. While this was a giant step away from the goal of realistic information display, it was felt to be worth trying in order to achieve an administratively viable troubleshooting test.

Approach

The redesign of the symbolic troubleshooting tests was aimed at retaining a high degree of similarity with actual equipment troubleshooting. The approach retained the features of presenting the data in such a way as to allow the test subject to establish his own troubleshooting strategy; the ability to monitor or record his strategy; and providing no more self-correction than would normally occur. Administratively, the approach was to permit the administration to large groups of test subjects, with minimum interface by the TA, yet provide the data that a technician would normally require while keeping the volume of data to a manageable size.

To accomplish this and to provide a breakdown of the ability to troubleshoot at the various system levels, each of the original troubleshooting problems were divided into three levels: (1) isolation to a faulty unit, (2) isolation to a faulty circuit, and (3) isolation to a faulty piece/part. The levels of each problem are coordinated in that the faulty circuit group, for example, Level 2 is within the faulty unit of Level 1 and likewise the faulty piece/part of Level 3 is within the faulty circuit group of Level 2. However, each level is designed to be administered independently of the companion levels. This provides a degree of flexibility in testing fault isolation at particular system *levels.*

The materials required for each problem part are provided to the test subject including the applicable equipment TO. The materials provided are used to depict various equipment modes and conditions. The test subject is required to use this information, the TO, and his own knowledge of the equipment and electronics to isolate the fault. A detailed discussion of the design of each problem part is provided in the following paragraphs:

Part I – Isolation to a Major Unit (Black Box) Level. In this part the test subject is required to use the TO troubleshooting procedure for unit isolation. The materials provided depict multiple equipment set-ups for each step in the procedure. The test subject is asked to select the correct equipment set-up and then observe the corresponding visual indications. He must then decide whether the indication is normal or abnormal and proceed to the corresponding step (see Appendix A). The approach is structured in the sense that the fault isolation strategy is dictated by TO procedure. However, the problem allows the test subject to make a mistake and to continue until he corrects himself or isolates the wrong unit.

Part II – Isolation to a Circuit Group (Stage) Level. In this part the test subject is again required to use the TO. However, he establishes his own troubleshooting strategy. He is told what major unit contains the problem and is also given a set of data sheets which provide voltage and waveform data at key points in the equipment. Based upon the given symptoms, he selects points to measure. The data sheets provide the voltage or waveform at the selected point. The test subject must then determine whether this data is normal or abnormal and select his next point accordingly (see Appendix B). Thus, the test subject uses his TO as he would in an actual troubleshooting problem with the measurements being simulated by the data sheets. He continues this process until he has isolated as far as he can with the data provided which will be from one to three stages. In addition to listing the suspect stages, the test subject is also required to log each point he measured on the data sheet. Again, the problem is structured in such a manner as to allow the test subject to make some mistakes which he might make troubleshooting on the actual equipment.

Part III – Isolation to Piece/Part Level. This part is identical in approach to Part II. The materials provided include all of the data provided in Part II plus a piece/part data sheet covering those piece/parts in the faulty circuit group (see Appendix C). The test subject continues to make measurements as he did in Part II to isolate to a small circuit in which he can now check individual components. He selects a component to check and refers to the piece/part data for its condition. In order to prevent merely scanning the piece/part data sheet, all of the piece/part values are covered through a special printing process somewhat similar to tab test. The test subject must uncover these values in order to determine their value providing an unchangeable record of those components he checked. Once he has located the bad component it is logged on his answer sheet.

V. VALIDATION OF REVISED TROUBLESHOOTING TESTS

Test Validation Procedures

The Tactical Air Command (TAC) agreed to provide experienced subjects and the necessary support for the validation of these revised symbolic tests for troubleshooting. For this validation, the symbolic *troubleshooting* tests and their companion criterion referenced JTPT were administered to several groups of experienced technicians to ascertain the empirical relationship between the two types of tests. The results obtained from each symbolic substitute test was validated against the results obtained from its companion JTPT.

Fifteen subjects were tested at two installations. Eight subjects were available at Langley AFB, and seven were tested at Little Rock AFB. Considerable difficulty was encountered in finding the type of subject desired for this evaluation. It was necessary to have a pool of experienced technicians since inexperienced personnel cannot troubleshoot sufficiently well to provide useful data as to the tests' effectiveness. Further, it was necessary that the technicians be experienced specifically on the AN/APN-147 Doppler Radar. Due to the general manpower shortage that was being experienced by the Air Force at the same time as the test tryout, many of the personnel that were needed for testing were on extended TDY as a means of overcoming the effects of the manpower problems. A further restricting factor on the number of subjects was the length of the time required for testing. Actual troubleshooting problems require several hours for an individual to solve and also require the use of an operational test bench in the shop. The symbolic tests required almost the same amount of time, so that for a man to take two problems via both the JTPT and symbolic tests required a complete shift. Typically, men were made available for testing at the rate of one per shift. The total time required to test the 15 men was approximately 100 hours.

Each test subject was given two troubleshooting problems to solve. In the JTPT test, a faulted component was placed into the radar and the technician was instructed to find the problem. One problem consisted of two parts and the second one consisted of three parts. The parts were:

1. Isolation of the chassis or black box which contained the fault.
2. Isolation of the stage or module in which the fault was located.
3. Identification of the piece/part that was faulty.

Problems that were based on faulty tubes were graded as two-part problems, since a tube is considered to be part of a stage of an electronic circuit. The test subjects were instructed to work in each level until they could identify the location of the problem at that level. That is, in Part I they were told to identify the chassis in which they suspected the problem to be. For each subsequent Part of the problem they were started at the correct point. This was done to facilitate testing troubleshooting ability at each level. Previous efforts in which this was not done resulted in much lost time as test subjects pursued faulty assumptions.

The symbolic tests were administered in the same fashion. The test subject was instructed to identify the location of the fault at a particular level and stop. He was then started on the next part at the proper chassis or stage. *The problems presented to the test subjects in the symbolic tests were the same ones that he received in the performance test.* This was not made known to the technicians, however, and none showed any recognition that they were working on the same problems in both tests.

In administering the tests at Langley AFB, it was possible to counterbalance the test administration so that half of the test subjects took the performance version of the problem first, while the other half took the symbolic version first. At Little Rock AFB, however, this was not possible since access to the bench equipment for the JTPT could not be programmed as readily as at Langley AFB.

While all test subjects were experienced in their primary AFSC, the range of experience on the AN/APN-147 was quite wide. Since the doppler radar is only one of several major electronic systems covered under AFSC 328X4, an individual can be quite experienced in some other systems of the AFSC without having experience on the AN/APN-147. Table 11 shows the breakdown by test subject of the months of service and the months of experience on the doppler system. Even this does not reflect the fact that some people with adequate length of experience may have been doing only flightline maintenance, which means that they only replace black boxes in the aircraft and have not been involved in the shop level of maintenance. This means they have had their total experience in solving only the first level of the problems contained in these tests.

The two forms of the test were graded in the same manner. For each level, the technician was given a plus (+) if he correctly identified the suspect component, or a minus (–) if he did not. For the total problem he was given a plus only if he correctly completed each level of the problem. While a record was kept of the parts he checked and the sequence in which he checked them, as well as the test equipment that he used, this information was not used for scoring purposes.

Due to the time each subject was available for testing, the number of problems per test subject had to be restricted to two. Since considerable testing was conducted within each shop and there was no control possible over the nature and extent of contact among test subjects, it was necessary to give different problems to guard against compromise of the problem situations. Further, no feedback was given to the test subjects as to whether their solutions were correct until all testing had been completed. Naturally, when a performance test was correctly solved the technician had a strong idea that he had correctly identified the fault. There was also such inherent confirmation available for Part 3 of the symbolic tests. This part made it important that the testing strategy not be obvious to the test subjects.

Table 11. **Description of Test Subjects**

Subject	Rank	Months Service	Months of AN/APN-147 Radar Experience
1	SSgt	78	36
2	Sgt	44	28
3	SSgt	116	24
4	A1C	19	8
5	SSgt	66	66
6	A1C	23	10
7	AB	22	9
8	TSgt	209	28
9	SSgt	47	36
10	SSgt	69	21
11	A1C	23	8
12	Sgt	43	24
13	A1C	20	6
14	SSgt	85	7
15	TSgt	220	None

Since the objective was to compare test forms, the fact that different subjects were taking different problems is considered to have minimal effect on the comparison results. But the fact that Problem 4 was apparently more difficult than Problem 1 would be of concern for comparing the *abilities* of the subjects. In that case, all subjects would have to have taken the same or demonstrably equivalent test problems. In this study, however, the symbolic test validity was being verified, so that each problem pair is an independent set. The reasons fo[illegible]ng different problems, as stated above, were considered, therefore, to outweigh the reasons for giving th[illegible]e problems to all subjects.

Results

To determine the extent to which the symbolic tests produced the same results as the criterion JTPT, two types of statistical comparisons have been made between the number of times the two testing formats produced the same results. The first comparisons are made in terms of the tetachoric r statistic (r_t) and the second, in terms of the phi coefficient statistic (ϕ). The ϕ statistic was used in presenting the results of the Altus validations reported in Section III of this document. In the Altus validation, all of the categories of symbolic substitute tests including checkout, soldering, remove/replace, use of test equipment, alignment and troubleshooting were considered. The ϕ was used with the Altus results because the number of comparisons for each category of tests was, in most cases, very small.

The TAC validation, on the other hand, was concerned only with the troubleshooting category and the number of comparisons between the symbolic and criterion performance tests was greater. The r_t

statistic was chosen as the primary vehicle for presenting the results because it is a somewhat more sensititive statistic and the table used for its calculation (Table 12) provides a much better basis for discussing the results. This table shows passed and failed as well as matched and unmatched results. The ϕ presentation, however, has been included so that the results of this follow-on TAC validation can be compared with the Altus validation in terms of the same statistic. The comparison of the results of TAC validation in terms of the two statistics also is of some interest.

Tetachoric r Analyses. Table 12 indicates the number of problems in which the results were the same on both forms of the tests and the number in which the results were different. The numbers in this table reflect the troubleshooting tests for all three levels of troubleshooting – chassis (black box), stage, and piece/part.

Table 12. **Comparison of Overall Troubleshooting Test Results – TAC Validation (r_t = .68)**

		Symbolic Test		
		+	–	Total
Performance	+	11 (a)	5 (b)	16
Test	–	3 (c)	11 (d)	14
	Total	14	16	30

These data represent the 60 tests taken by the 15 subjects, 30 performance and 30 symbolics. Comparing the two tests taken by the subjects on the same problem results in 30 pairs of scores. In 11 cases, the technicians tested correctly solved the troubleshooting problem on both. In 11 other cases, the technicians failed to solve the problem on either test. For purposes of this study, the ability or inability to solve the problems was not of concern. The goal was to produce symbolic tests that would yield the same results as performance tests. Thus, there were 22 pairs (a + d) out of 30, in which matched results were achieved or in 73 percent of the cases. A total of 16 performance tests (a + b) and 14 symbolic tests (a + c) were solved correctly. There were 3 cases in which technicians solved the symbolic version of the tests but not the performance, and 5 in which they solved the performance version but not the symbolic.

An r_t value of .68 was obtained with a standard error (σ_{r_t}) of .288 so that the r_t value is 2.36 times the standard error. For complete confidence in the correlation, r_t should be 2.6 times σ_{r_t}. Ideally, also, N should be larger to satisfy the conditions for use of r_t, however, this was not possible due to the limited pool of subjects.

Given these restrictions, the results still indicate a positive relationship between the parameters of performance being measured by the criterion performance tests and those being measured by corresponding symbolic tests.

Table 13 shows the number of correct problem solutions by test type and test problem. This table indicates that while problem difficulty did in fact apparently vary (although the item difficulty versus ability interaction cannot be separated) the pattern of results was stable from problem to problem. As discussed previously, the degree of agreement between results of the two tests is the primary concern rather than the relative difficulty of the individual problems.

Table 13. Number of Correct Solutions by Test Type and Problem
Troubleshooting Problems

	1 (n=4)	2 (n=4)	3 (n=4)	4 (n=4)	5 (n=4)	6 (n=4)	7 (n=3)	8 (n=3)
Performance	4	3	1	0	4	2	0	2
Symbolic	3	2	2	0	3	2	1	1

Note. — n = number of subjects taking each problem.

As a means of assessing the influence of each part or level of the symbolic tests on the overall results, the results of technician performance on each part is presented. For the *first* level in the troubleshooting procedure, location of the faulty chassis or black box (i.e., identification of the Receiver Transmitter, Frequency Tracker Antenna or indicator as the location of the problem), the contingency table of results is given in Table 14.

Table 14. Results of Chassis (or Black box) Isolation
(r_t = .81)

		Symbolic Tests		
		+	—	Total
Performance	+	24 (a)	3 (b)	27
Tests	—	1 (c)	2 (d)	3
	Total	25	5	30

(The data in Tables 14, 15, and 16 are not cumulative but independent. That is, a person failing Part I still took Part II. Failing I and/or II, the technician still took Part III. In computing the total test scores previously presented in Table 12, all required parts had to be correct to get a correct score on the total problem.)

This yields an r_t of .81. The symbolic test results matched the criterion performance test results in 26 out of 30 times or in 87 percent of the cases. However, as can be seen from inspection of Table 12, considerably more technicians successfully performed this level than passed the complete test. Twenty-seven out of the 30 times, subjects were able to pass the criterion JTPT. Much of the flight line or organizational maintenance work is concerned only with this level in troubleshooting process — that of finding and replacing the defective chassis or blackbox (organizational maintenance). As would be expected, success in locating the faulty chassis is a necessary but not sufficient condition for problem solution in the Field Shop (intermediate maintenance). Similarly, one's ability to locate the chassis containing the problem cannot be used as an index of ability to ultimately solve the problem.

The *second* level of the problem was to locate the stage, within the chassis, that contains the fault. The contingency table for these results is in Table 15. The symbolic test results matched the criterion performance test results in 20 out of 30 times or in 67 percent of the cases resulting in a r_t of .46. (For this level of troubleshooting in 20 out of 30 attempts, the subjects were able to identify the defective stage; that is, pass the criterion JTPT.)

Table 15. **Results of Stage Isolation – TAC Validation**

		Symbolic Tests		
		+	–	Total
Performance	+	14 (a)	6 (b)	20
Tests	–	4 (c)	6 (d)	10
	Total	18	12	30

The *third* piece/part fault isolation, was contained in only half (30) of the troubleshooting problems, which gives an N of 15 matched pairs rather than 30 as in the previous test portions. Table 16 shows the results obtained. The r_t value is .16. The symbolic test results matched the criterion test results in 8 out of 15 times or in 53 percent of the cases. (In only 5 out of 15 attempts were the subjects able to isolate the defective piece/part; that is, pass the criterion JTPT.)

Table 16. **Results of Piece Part Isolation – TAC Validation**

		Symbolic Tests		
		+	–	Total
Performance	+	3	2	5
Tests	–	5	5	10
	Total	8	7	15

It is apparent, then, that the third portion of the symbolic troubleshooting tests operated to reduce the overall test correlation results. This was also the only part of the test in which more test subjects solved the symbolic test than the criterion JTPT. Refinement efforts focusing on this portion of the symbolic tests are indicated, therefore, and could possibly increase overall test correlation to a higher level.

Comparison of Results of Altus and TAC Validations *(ϕ Analyses).* As stated earlier, the Altus validation used novice subjects and was concerned with all the categories of symbolic and criterion JTPT, whereas the TAC validation used experienced subjects and was limited to the troubleshooting category of the JTPT and their symbolics substitutes. The symbolic troubleshooting tests had been modified between the Altus and TAC validations. Table 10 in Section III summarizes the results of the Altus validation in terms of χ^2 and ϕ statistics. The formulas and procedures for obtaining these statistics also are presented in Section III and are not repeated here. The necessary contingency tables for determining the χ^2 and ϕ statistics for the TAC validation are presented in Tables Tables 17 through 20.

Table 21 repeats the information found in Table 10, Section III concerning the Altus validation. But, it also includes the χ^2 and ϕ results for the TAC validation calculated from the data presented in Tables 17 through 20. It will be noted that there is a decided improvement in the correlation obtained in TAC for the overall troubleshooting category (.47) and the ϕ correlation previously obtained for the same category at Altus (–.33). This improvement could be attributed to several variables, such as the difference in type of subjects, a larger number of subjects and modification of the symbolic tests for troubleshooting. The criterion JTPT, as well as the original forms and modified forms of the symbolics, were developed for personnel trained to use standard technical orders. The TAC subjects were trained and experienced in the use of such technical orders. The Altus subjects were trained to perform troubleshooting using the step-by-step procedures provided in their FPJPA. The symbolic tests did not contain pictorial displays for all the test information called for by the FPJPA. The TAC subjects were experienced in the maintenance of the Doppler Radar System – the AN/APN-147 and the AN/ASN-35. The Altus subjects were novices with the limited training described earlier. There were only nine pairs of tests tried at Altus whereas there were 30 in TAC. Considering these variables, it is impossible to ascertain how much of the improvement can be attributed to the modification of the symbolics. *But it definitely can be concluded that symbolic troubleshooting tests show promise and their development should be continued.*

Table 17. **Overall Troubleshooting (ϕ = .47)**

	Results Matched	Results Differed
Expected Frequency	15	15
Observed Frequency	22	8

Table 18. **Troubleshooting Chassis Level (Black Box) (ϕ = .73)**

	Results Matched	Results Differed
Expected Frequency	15	15
Observed Frequency	26	4

Table 19. **Troubleshooting Stage Level (ϕ = .33)**

	Results Matched	Results Differed
Expected Frequency	15	15
Observed Frequency	20	10

Table 20. **Troubleshooting Piece Part Level (ϕ = .07)**

	Results Matched	Results Differed
Expected Frequency	7.5	7.5
Observed Frequency	8	7

Table 21. **Indicating Combined Results of Altus and TAC Validations**

Test Area	N Pairs	Results Matched	Results Differ	x^2	ϕ	r_t
Novice Subjects (Altus)						
Checkout	4	4	0	4.00	1.00	-
Remove & Replace	14	10	4	2.57	.43	-
Soldering Tests	4	2	2	0	0	-
General Test Equip	6	5	1	2.67	.67	-
Special Test Equip	6	4	2	.67	.33	-
Alignment/Adjustment	19	15	4	6.37	.58	-
Troubleshooting	9	3	6	1.00	–.33[a]	-
Experienced Subjects (TAC)						
Overall Troubleshooting	30	22	8	6.53	.47	.68
Chassis (Black box) Isolation	30	26	4	16.33	.73	.81
Stage Isolation	30	20	10	3.33	.33	.46
Piece/Part Isolation	15	8	7	.07	.07	.16

[a]This negative correlation was probably due to a number of deficiencies such as (1) deficiencies in the Fully Proceduralized Job Performance Aids provided the subjects, (2) deficiencies in the sequencing of the troubleshooting JTPT in relation to the sub-tests in the JTPT battery, (3) maintenance difficulties with the AN/APN-147 – AN/ASN-35 system, and (4) difficulties with the content and administration of test equipment pictorials provided in the original troubleshooting symbolic tests.

The r_t correlations for the TAC validation have also been included in Table 21. They indicate the same pattern of relationship between the symbolic and performance tests. However, the r_t figures are larger than the ϕ figures. This should be expected since the r_t is a more sensitive statistic. Both statistics indicate that symbolic tests for the piece/part level are in need of further refinement.

Symbolic Test Clarity. There was a great difference in the ability of the technicians to grasp the testing concepts used in the symbolic troubleshooting tests. The majority followed the instructions with no difficulty once the nature of the test was reviewed with them. Additional explanation was provided in several cases so that instructional misunderstanding is not considered to have been a factor influencing test results. Several, however, were not able to conceptualize the fact that all of the information they needed was present in the materials just as it would be in a faulty radar. They could not construct a search question or select a reasonable starting point for isolating the problem. In other words, these subjects did not demonstrate that they had an effective troubleshooting strategy at their command. All they could resort to was a linear search of the system parameters given.

This analytical approach is not always used in actual field performance where the system is available for immediate feedback. In some cases these subjects could solve the performance version of the problem based upon experience history or by replacing components until the fault was located. The history approach is sometimes very effective. However, as the realiability of replaceable components is improved in any system, the history approach becomes less and less effective. *Replacing components until a fault is located is an extremely undesirable form of troubleshooting.* It loads the maintenance system with good components that must be checked out. It generates unnecessary equipment handling, paperwork, and benchwork. And experience has indicated that many times these good components are discarded as faulty. As a result, an extremely good case can be made for every maintenance technician being proficient in the use of an effective analytical troubleshooting strategy; such a strategy is required by the symbolic tests.

VI. EVALUATIVE COMMENTS

Considerations for Future Development and Implementation

The efforts reported in AFHRL-TR-74-57(II), as well as in this volume for the development and tryout of criterion referenced JTPT and accompanying symbolic substitutes have been plagued by the limited availability of experienced subjects. The criterion referenced JTPT described in Volume II are worthy of administration in their present form, but further polish would probably improve them. This can only be accomplished by many more administrations of these JTPT under the guidance of experienced test developers. In spite of the limited number and *inexperience of the Altus subjects, the symbolic substitutes already developed for checkout, remove/replace, and use of general and special test equipment have shown a high degree of promise, but require more extensive validations and refinements. The alignment and troubleshooting symbolic tests have shown promise but both categories require a great deal more refinement before they should be validated again. No further work is recommended on symbolic substitutes for soldering. The exploratory work has identified major and minor problems of concern for future work. It has also provided a basis for planning of future work.*

The success of any future developments or refinements of either criterion referenced JTPT, or their symbolic substitutes, will depend on the availability of sufficient funds, expert test development personnel, and qualified subjects. All of these have been in short supply. Although all of the necessary development and refinement work is considered important, it would be impossible to accomplish all of this work at the same time considering the available resources. The recommendations made in Volume II, for an orderly development and implementation program for JTPT, must also be considered for any future development of symbolic substitutes. Empirically valid symbolic substitute tests cannot be produced for any job activity until good, administrable criterion referenced JTPT are available.

The Volume II recommendations suggest that JTPT refinement and implementation should start with general test equipment. Since all electronic technicians use general test equipment, the proper implementation of this action should result in the greatest gain to the Air Force for the least amount of effort and money. So logically, any future work in symbolic tests should start with this same area. As JTPT are refined and become available for other maintenance activities, appropriate work on companion symbolic tests can be pursued. The comments that follow are made for the purpose of helping concerned and interested people or agencies to structure future work on symbolic substitute tests concerning: (1) the use of general test equipment, (2) other straightline tasks (checkout, remove/replace and use of special test equipment), (3) troubleshooting, and (4) alignment.

Symbolic Tests for General Test Equipment. *In addition to the operational considerations for choosing the use of general test equipment for initial follow-on work concerning symbolic tests, such equipment is a very fertile area for symbolic presentation for training as well as testing.* This is especially true of the voltohmmeter and the oscilloscope. Most of the difficult activities concerning their use are performed on their front panels. And panels can be very easily represented by pictures. Their adjustments require the manipulation of switches and knobs; behaviors which are within the normal repertoire of most

Americans. The difficult part is learning the proper sequence in which these manipulations should be performed. They all require the ability to read displays. All of these behaviors, with the exception of the actual manipulations, can be simulated by pictures. In addition to the development of symbolic substitutes, for JTPT, extensive use of symbolic representatives should be considered for practice exercises for training purposes. Their use may greatly reduce the requirement for actual equipment for both personnel testing and training purposes.

The Altus validation of symbolic tests for general test equipment was extremely limited. Only six test equipment symbolic tests were administered and the results were lumped for analytical purposes. After another refinement, the symbolic tests for each test equipment should be validated in its own right using a sufficient number of subjects for each validation. Such validations are necessary to ascertain the degree of empirical validity for each test. The validation exercise, if properly structured, will probably provide a great many insights for the use of symbolic techniques in the training process.

Symbolic Tests for Other Basic Straightline Tasks. Whatever is learned from the proposed work on general test equipment can probably be applied directly to symbolic tests for special test equipment. Much of what is learned can probably be applied to checkout and remove and replace activities. For safety reasons, checkout is an extremely important activity concerning any system. We should have means to determine how effectively these checkout tasks are performed. Both criterion referenced JTPT and companion symbolic tests should be developed for several key equipments for an AFSC such as 328X4, and should be validated on a large scale.

Symbolic Tests for Troubleshooting. The original attempt to validate symbolic tests for troubleshooting at Altus was unsuccessful. There were several reasons for this which have been discussed earlier in Section III. As explained earlier for the TAC validation, the symbolic troubleshooting tests were modified to remove the pictorial presentations of test equipment information. Volt and ohm information were furnished in printed form in tables and waveforms were given. *But* the subject was not required to obtain any of this information by interpreting a picture of the test equipment front panel display. This modification made these troubleshooting symbolic tests very similar to the tab tests (Crowder et al., 1954).

The TAC validation indicated that these modified symbolic tests for troubleshooting did have a high degree of empirical validity for measuring a subject's ability to identify faults at the chassis or black box level. *But* the symbolic tests did not do as well for fault isolation to the stage level (within a black box). *And* at the piece/part level of fault identification with the modified tests, the validation indicated that the symbolic tests had a very low empirical relationship with the criterion JTPT. The piece/part level is the most difficult and expensive level of maintenance in terms of spare parts consumption. These weaknesses must be corrected before symbolic tests for troubleshooting can be considered successful.

In the opinion of the writers any future refinement work concerning troubleshooting symbolic substitutes should reflect the following considerations:

1. The original rationale for the development of symbolic tests was formed after a study of the results of the tryout of tab tests for measuring ability to troubleshooting (Crowder et al., 1954). The study of the tab test data indicated two possible weaknesses. *First,* the Crowder tryout assumed that a subject taking the criterion performance tests could set up his test equipment correctly and obtain correct test equipment readings. The readings were given to the subject upon request. After a review of the Crowder study, the writers were of the considered opinion (based on Crowder's and other research) that the subjects probably could not use their test equipment too well. As a result, even though a subject could find the fault correctly on the tab test, he was not able to find the same fault in his actual equipment because he could not use his test equipment.

Second, approved or desired troubleshooting is usually based on a strategy or cognitive process. The tab test (as well as most other paper and pencil tests of its kind) also requires the use of such a strategy to successfully identify the fault. But in the tab test, the subject was not faced with the problem of interrupting his strategy to obtain test point information. He received it instantly in printed form and proceeded with his strategy, whereas, the requirement to set up and use test equipment to obtain test point information during the criterion performance test (actual equipment) provided many distracting interruptions or "clutter" in his strategy.

2. A proposed solution to the problem that a subject might not be able to use his test equipment was presented in Volume II. Each subject can be given a performance test on the use of his test equipment

before he receives his troubleshooting tests. And, if the subject cannot pass his test equipment test, he would not be permitted to take the troubleshooting test. Due to the lack of money, time pressures, and the limited number of available subjects, this was not done during the TAC validation.

One hypothesis as to the cause of some of the different results for symbolic tests for the chassis, stage, and piece/part levels of troubleshooting is that some subjects were not able to use their test equipments properly. The *chassis level* of troubleshooting requires little use of test equipment. The criterion referenced JTPT and their symbolic substitutes thus call for very similar behaviors. The *stage level* of troubleshooting requires some very common uses of test equipment. In this case, the criterion JTPT and their symbolic substitutes are reasonably close. The subject is required to make limited use of test equipment in the criterion test, but no use of test equipment in the symbolic test. The piece/part level of troubleshooting requires a great use of test equipment. In this case, the criterion JTPT and the modified symbolic tests are far apart in respect to the test equipment behaviors required. The subject is required to make great use of test equipment in the criterion JTPT but *no* use of test equipment in the symbolic test. This difference, of course, makes the symbolic test easier than the criterion. It should be noted that 8 out of the 15 subjects passed the symbolic test and only 5 passed the criterion (see Table 16).

The above hypothesis should be further explored in future work on symbolic tests. A sufficient number of subjects should be given the test equipment JTPT, and those who pass the test equipment tests should be assigned to one category; those who do not, to another category. Both categories should be given the criterion JTPT and the symbolic tests for troubleshooting. If the hypothesis is true, the correlations for the stage and piece/part levels should be improved for the category of subjects who are able to use their test equipment correctly. The correlations for the category of subjects who cannot use their test equipments could be even lower than those obtained in the TAC validation.

3. The above hypothesis may account for part of the variance obtained between the criterion JTPT and the symbolic tests during the TAC validation. But it may not account for all of it, if the distraction or "clutter" factor is of importance. As discussed earlier, the troubleshooting symbolic tests developed earlier which were used in the Altus validation contained displays of test equipment front panels. The book presentation of this information to the test subject by the test administrator proved difficult. As stated earlier, these were eliminated when the symbolic tests were modified for the TAC validation. As a result, no data concerning the effect of this type of "clutter" for troubleshooting has been obtained. The modified symbolic tests did require the subject to search his technical order which is one type of realistic clutter.

In Section II of this document, the suggestion was made that a random access projector might possibly be used in place of the book of displays. The authors are of the opinion that this suggestion should still be tried. The displays could easily be placed in a random access projector but the problem is the requirement for a simple indexing system. But the test point information formats developed for the modified symbolic tests may provide the answer. The test point information (such as 150v or 80Ω) found in the cells of these forms could be replaced by the call out numbers to be punched on the control panel of the random access projector.

The use of such a random access projector program is strongly suggested for any future exploratory work on symbolic substitutes for troubleshooting. The development should, also, include further work on just what displays are required. There is reason to believe that there were not enough in the original effort. It is certainly better to have too many available than too few.

It is hypothesized that symbolic tests that include this type of clutter will result in high correlations between the criterion referenced JTPT and the symbolic tests for the piece/part level of troubleshooting. It is suggested that subjects used in the validation of the test also be divided into two categories; namely, those who have previously passed the performance tests on the use of test equipment and those who have not.

Symbolic Tests for Alignment Tasks. Although alignment, adjustment and calibrating tasks are as important as troubleshooting, it requires less time to measure such activity with JTPT using actual equipment than it does to measure troubleshooting activities. In addition, what is learned about symbolizing "clutter" for troubleshooting may help in the development of symbolic tests for alignment activities. It is therefore suggested that further work on symbolic tests for alignment tasks be delayed until after the troubleshooting symbolic test problems are solved.

Maintenance Quality Consideration

Although the primary purpose of the TAC efforts were to validate the effectiveness of symbolic substitutes, a secondary finding on quality of troubleshooting is worthy of comment. It is very difficult to find hard data concerning the true quality of maintenance in the Air Force. Some studies concerning ability of technicians to use test equipment were reviewed in Volume II. But all available data do indicate that the ability of technicians to perform troubleshooting could be greatly improved. The results of the TAC validation certainly support this contention. Table 16 indicates that the experienced technicians used as subjects could isolate defective piece/parts only 5 out of 15 times, or only 33 percent of the time. The same subjects were able to identify faulty stages only 20 out of 30 times, or 67 percent of the time (Table 15). They could identify black boxes in 27 out of 30 times, or 90 percent of the time (Table 14).

This performance for black box fault isolation is fairly good. However, black box isolation is the easiest level of fault identification. *And,* it is very deceptive because if there is a large enough supply of black boxes, the planes still fly, and it appears to the pilots that maintenance is fairly good. This supports the contention made in Volume II that activities having the greatest visibility get the most attention. *And* shop maintenance does not have near the same visibility as flightline.

But the "sleeper" in this situation is that once the black boxes are identified, they are sent to the field shop for repair. And the ability of the technicians to find the trouble in the black boxes would appear to be very weak, resulting in very expensive repair for the Air Force. Findings such as these further support the contention that good criterion referenced JTPT should be available for the purpose of gathering extensive hard data concerning the ability of technicians to perform maintenance activities. The known presence of such JTPT in the field and the possibility of technicians being tested, would probably motivate many technicians to learn to perform their key maintenance activities more efficiently.

VII. SUMMARY AND CONCLUSIONS

In this effort, graphic symbolic substitutes were developed for each type of electronic maintenance activity for which criterion referenced JTPT had already been developed. The JTPT are described in AFHRL-TR-74-57(II) Part I. The job activities include: (a) checkout, (b) remove/replace, (c) soldering, (d) use of general and special test equipment, (e) align/adjust/calibrate, and (f) troubleshooting.

The hardware utilized as a vehicle for the development of all these tests was the Doppler Radar AN/APN-147 and its Computer AN/ASN-35.

In the development of each of the symbolic substitutes, an attempt was made to require the test subject to demonstrate as nearly as possible, the same behaviors as he would be required to perform while taking its companion JTPT.

The first drafts of these symbolic tests were given a limited administrative tryout in a maintenance squadron of the Military Airlift Command (MAC) at Norton AFB, CA. The subjects were technicians who had maintenance experience on the AN/APN-147 and the AN/ASN-35. This tryout indicated that all the tests as developed were administratively feasible with the exception of the troubleshooting tests.

After this administrative tryout, all of the symbolic tests were refined based on the experience gained during the tryout. A full scale controlled validation was planned to ascertain the empirical validity of each type of symbolic substitute. Due to schedule changes and unavailability of experienced subjects, such a validation exercise was not possible in MAC.

A more limited validation was substituted making use of available novices with limited training at Altus AFB, OK. These subjects had been given a four-week training program on how to use test equipment, how to use hand tools and how to perform the maintenance tasks on the AN/APN-147 and AN/ASN-35 using special step-by-step maintenance instructions called Fully Proceduralized Job Performance Aids.

During this extremely limited validation, both the criterion JTPT and their companion symbolic substitutes were administered to the same novice subjects. The symbolic tests for checkout, remove/replace, general and special test equipment, and align/adjust/calibrate showed promise. The troubleshooting tests as structured were still not administratively feasible. The soldering symbolic tests, although administratively feasible, showed no empirical relationship with the criterion soldering test.

The chief administrative difficulty experienced with the symbolic troubleshooting tests used at Norton and Altus was caused by the technique used to realistically simulate the use of test equipment. An attempt was made to present all necessary test point information as it would appear on the actual test equipment. This required one test equipment pictorial for each test point called for by a subject taking the symbolic test. A book of pictorials was developed. When the test subject indicated a requirement for test point information, the TA would show him the appropriate picture in the book if it was available. The TA functioned both as an index to the data bank and as a searching device. This proved a difficult if not impossible task.

The use of a random access projector was suggested in lieu of the book, but there was insufficient time and money remaining in the project. In addition, the effective use of a random access projector would require the development of a simple but effective indexing system.

With the limited available funds, an attempt was made to modify the troubleshooting symbolic tests by compressing test point information. Several forms were developed for presenting printed voltage and resistance values and simple wave form displays. This was a retreat from the realism of the original symbolic tests, making them somewhat similar to the tab tests.

Arrangements were made to validate these modified troubleshooting symbolic tests in the Tactical Air Command using experienced technicians. Fifteen subjects were obtained by administrating the symbolic tests and their criterion JTPT at Langley AFB, VA, and Little Rock AFB, AR.

The results of this validation indicated an improvement in the administrability of the tests. The empirical relationship between the symbolic tests and the criterion JTPT at the "black box" or chassis level of troubleshooting was excellent; at stage level the relationship was fair; but at the piece/part level the relationship was extremely low. This validation indicated that symbolic troubleshooting tests have promise, but more exploratory development is required.

One hypothesis offered for these results is that at the black box level of fault isolation little use is made of test equipment; as a result the realism of the symbolic tests is high. At the stage level of fault isolation, a limited use of test equipment is made, and the realism of the symbolic test is fair. At the piece/part level, extensive use of test equipment is made. As a result, the printed presentation of test equipment information results in a large deviation from the job realism. A return to the original pictorial presentation of test equipment information, therefore, is suggested.

As stated earlier, one suggestion for presenting test point information in pictorial form was the use of a random access projector, provided a simple indexing system could be developed. The forms developed for compacting test point information for the troubleshooting symbolic tests used for the TAC validation provide a possible solution to the indexing problem. The substitution of access code numbers for the resistance and voltage values now found in the cells of these forms may provide the simple indexing system for obtaining the desired test equipment pictorials rapidly.

A second hypothesis is that the modified troubleshooting symbolic tests used in TAC may be viable tests, provided the test subject is required to demonstrate his ability to use his test equipment before he is permitted to take these troubleshooting tests. This procedure was not used in the TAC validation of the modified troubleshooting symbolic tests.

Although promising, the symbolic tests for align/adjust/calibrate activities require more refinement. One special area that has not been explored adequately is the tuning skill required in some alignment tasks.

The results from the soldering symbolic tests would indicate that no further work should be done on these tests. An JTPT on soldering is not too difficult to administer – so, very little would be gained even if an empirically valid symbolic test could be developed.

A secondary finding of the TAC validation was that the experienced technicians used as subjects could not troubleshoot very well to the piece/part level. Only 33 percent of the defective piece parts were identified. This finding supports other available hard data in the contention that, in general, electronic technicians do not troubleshoot very efficiently.

VIII. RECOMMENDATIONS

The future development, refinement and implementation of symbolic tests are dependent on the availability of criterion referenced JTPT. Empirically valid symbolic substitutes cannot be developed and validated without JTPT. The validation process also is dependent on the availability of a sufficient number of trained and experienced subjects. Unless *sufficient money* is provided for test development and the *availability of subjects ensured*, the development of symbolic substitute tests should not be attempted and is not recommended.

All of the promising symbolic substitute tests for straightline tasks should be given a full scale validation. But due to probable fund and subject limitations, the following priority is recommended: (1) general test equipment, (2) checkout, (3) remove/replace, (4) special test equipment, and (5) align/adjust/calibrate.

The modified troubleshooting symbolic tests used in the TAC validation should be revalidated using a larger number of subjects, who have demonstrated their proficiency in the use of test equipment by successfully passing the test equipment JTPT.

A random access projector presentation of pictorial test point information should be developed. An indexing system is suggested, which makes use of the information forms developed for the modified tests used in the TAC validation. Such an index would be obtained by substituting an access number (for the random access device) in each cell of these forms for the printed test point information now found in each cell. When the test subject punches the access number, he will obtain a pictorial display of the appropriate test equipment which he must interpret.

After such troubleshooting symbolic tests are developed, they should be validated and their empirical validity compared to the results obtained in the previous paragraphs.

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APPENDIX A

PART I. SYMBOLIC TROUBLESHOOTING TEST MATERIALS

Isolation to a Major Unit or Black Box Level

PART IB

TEST SUBJECT TEST INSTRUCTIONS

Part IB: Isolation to Unit.

INSTRUCTIONS:

a. Ensure that you have the Radar Set AN/UPM-147(V) TM and the following information sheets:

   (1) Part IB Test Performance Sheet

   (2) Part IB Answer Sheets.

b. Enter your assigned identification number on the Test Performance Sheet.

c. Follow the instructions given on the Test Performance Sheet. You may use any and all parts of the TM to answer the questions.

d. When you have completed all questions turn in Test Performance Sheet to the Test Administrator.

PART IB

TEST PERFORMANCE SHEET

Technician ID No. ____

A. Read step 1 of the troubleshooting table. Examine step 1 answer sheets and record the number of the answer sheet which corresponds to indicated switch settings. Note associated digital counter indication and proceed to step B if indication is normal and to step F if indication is abnormal.

   1. Answer Sheet ____.

B. Read step 2 of the troubleshooting table. Examine step 2 answer sheets and record the number of the answer sheet which corresponds to indicated switch settings. Note associated digital counter indication and proceed to step C if indication is normal and to step F if indication is abnormal.

   1. Answer Sheet ____.

C. Read step 3 of the troubleshooting table. Examine step 3 answer sheets and record the number of the answer sheet which corresponds to indicated switch settings. Note position of associated Drift-Angle pointer and proceed to step D if indication is normal and to step H if indication is abnormal.

   1. Answer Sheet ____.

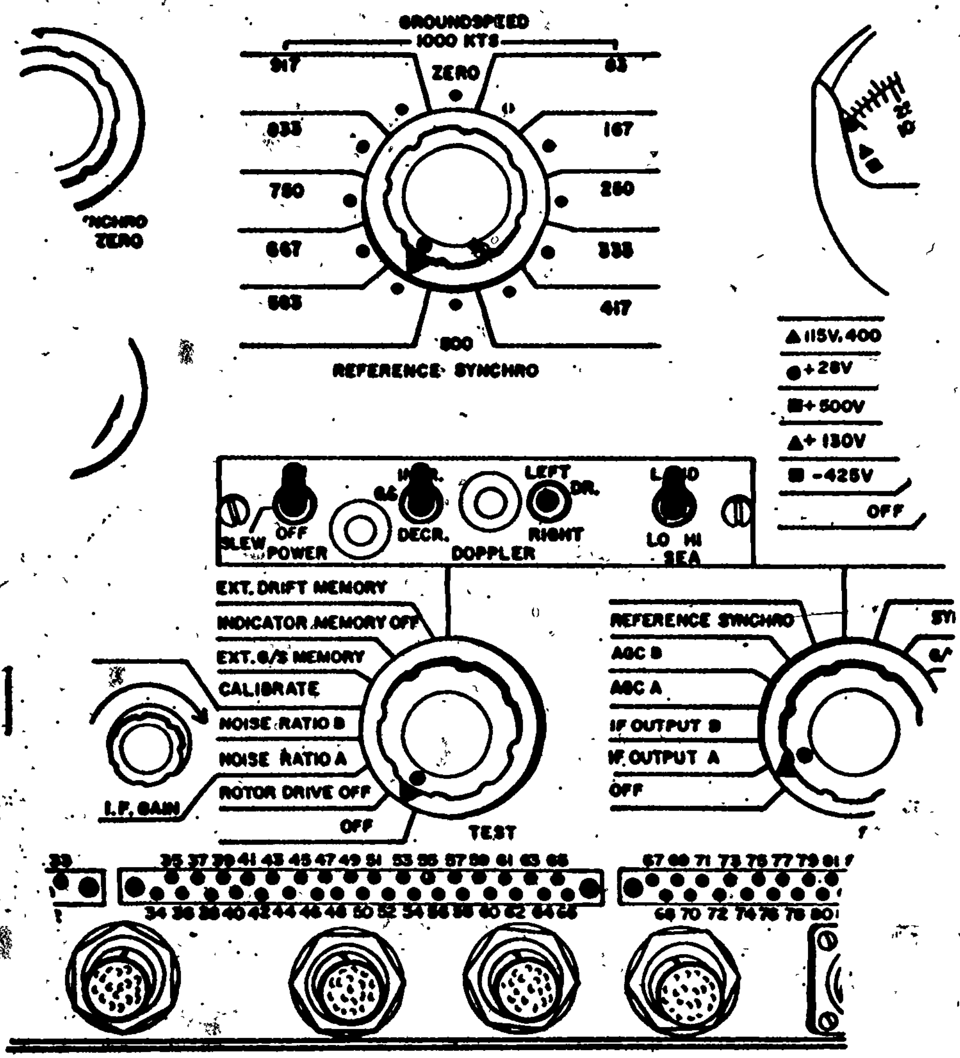
D. Read step 4 of the troubleshooting table. Examine step 4 answer sheets and record the number of the answer sheet which corresponds to indicated switch settings. Note position of associated Drift-Angle pointer and proceed to step E if indication is normal and to step H if indication is abnormal.

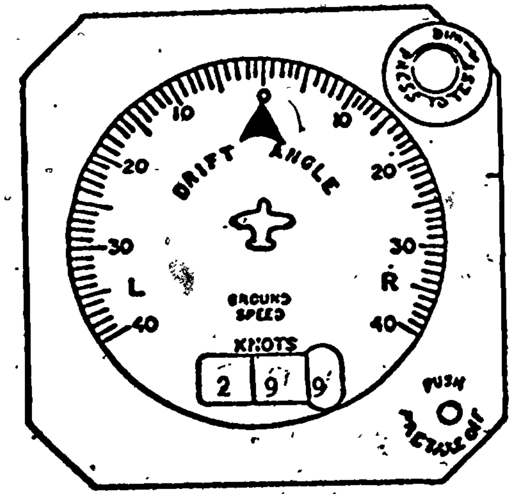
   1. Answer Sheet ____.

Step	Test Point	Test Equipment	Control Settings and Instructions	Normal Indication	If Indication Is Normal	If Indication Is Abnormal
1	Drift angle - ground-speed indicator	Visual	On the radar set control located in the test harness, set the power switch to SLEW and the G/S switch to INCR.	Digital counter of the indicator increases its count.	Proceed with step 2.	Proceed with step 6.
2	Indicator	Visual	As in step 1 except place G/S switch to DECR.	Digital counter of the indicator decreases its count.	Proceed with step 3.	Proceed with step 6.
3	Indicator	Visual	On the radar set control, set power switch to SLEW, and set DR switch to LEFT position.	Drift angle pointer should rotate to left.	Proceed with step 4.	Proceed with step 8.
4	Indicator	Visual	As in step 3, except set DR switch to RIGHT position.	Drift angle pointer should rotate to right.	Proceed with step 5.	Proceed with step 8.
5	Indicator	Visual	As in step 4 but without slewing.	Memory warning light should be on.	Indicator is satisfactory. Proceed with step 10.	Operate the PRESS TO TEST switch; if light comes on, fault is not in indicator; proceed with step 10.
6	TP24 of radar test harness	Vacuum-tube voltmeter (vtvm)	As detailed in step 1. Connect vtvm to TP24.	115 volts ac, 400 cps.	Proceed with step 7.	Check F7103 of the frequency tracker.

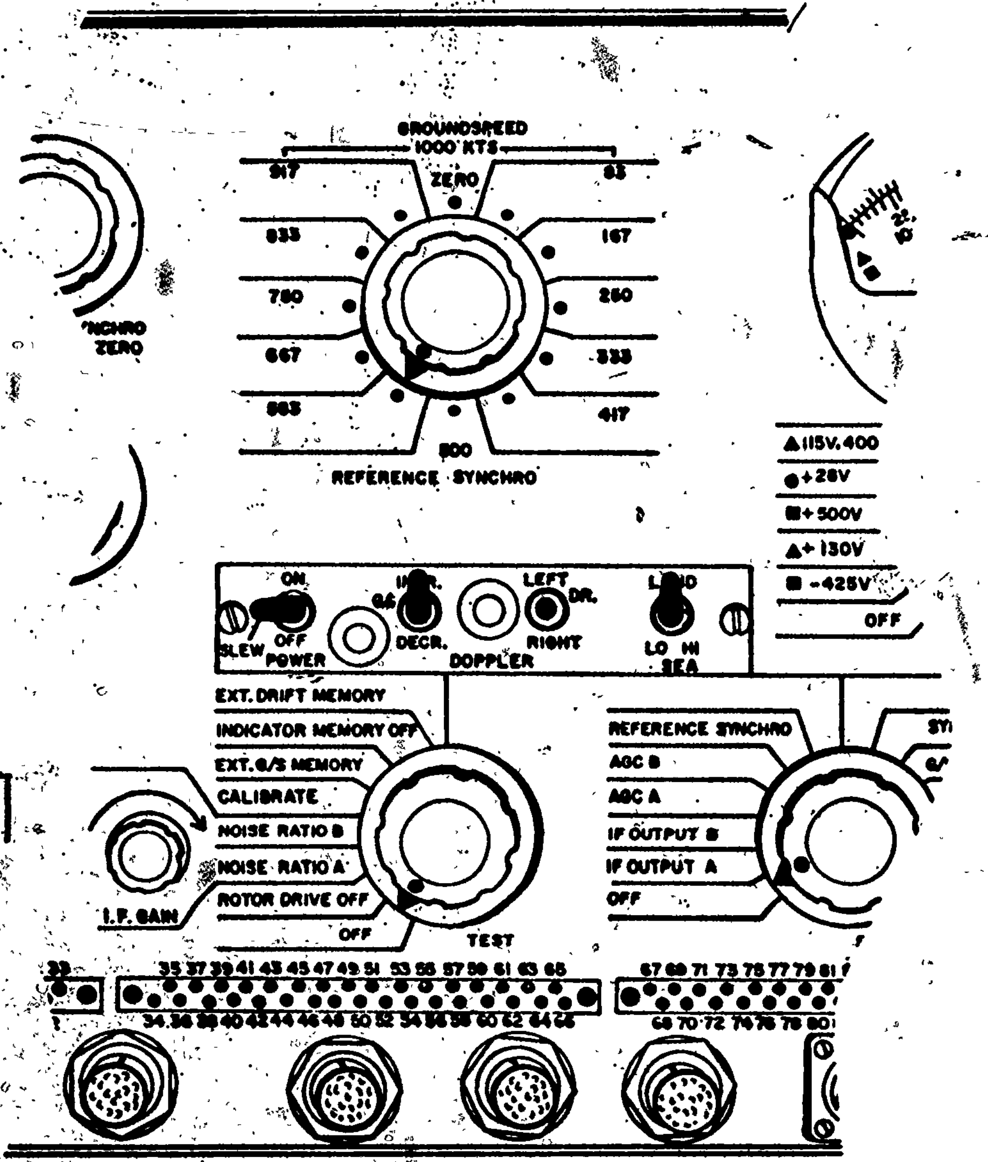
Table A-1. Table of Radar Set Trouble Analysis

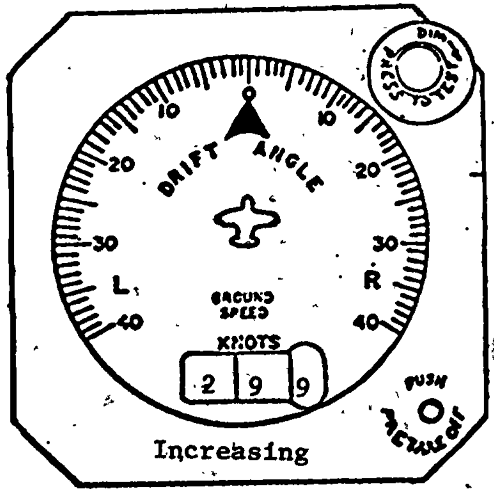
STEP 1, ANSWER SHEET 1



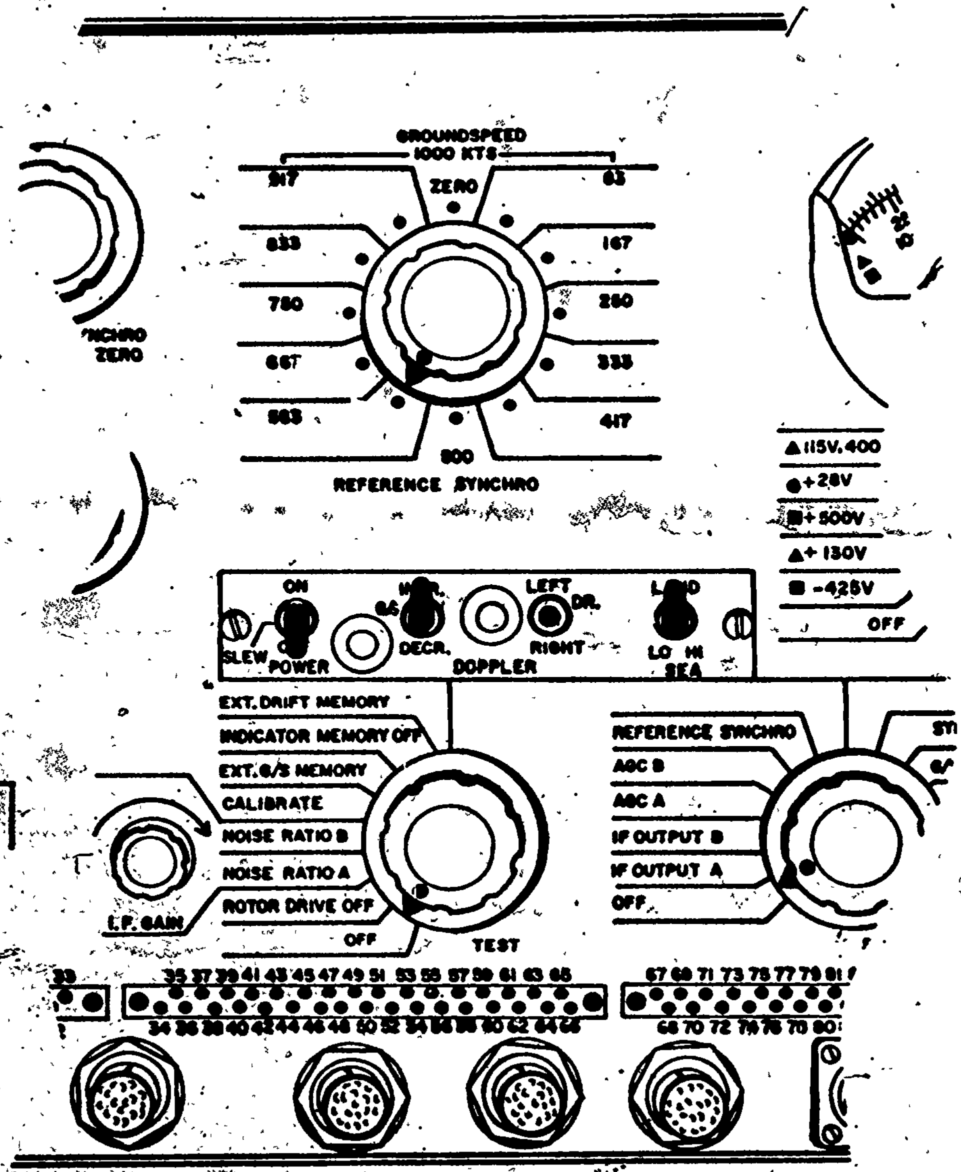


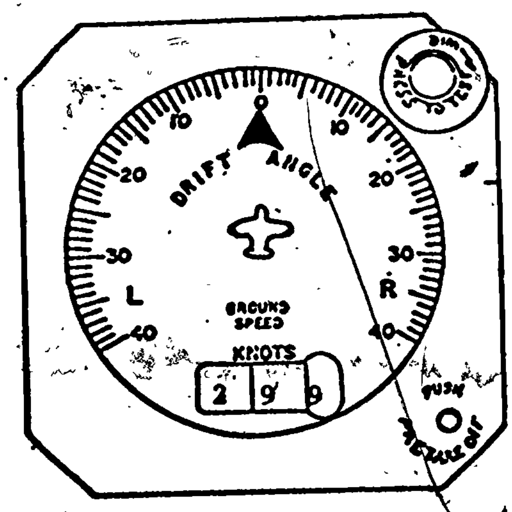
STEP 1, ANSWER SHEET 2





STEP 1, ANSWER SHEET 3





APPENDIX B

PART II. SYMBOLIC TROUBLESHOOTING TEST MATERIALS

Isolation to Stage Level

PART II

TEST SUBJECT TEST INSTRUCTIONS

Problem No. 1

INSTRUCTIONS

a. Ensure that you have a TM and the following information sheets.

(1) Equipment Visual Indications

(2) Equipment Test Point Data Sheets

(3) Equipment Tube Pin Data

(4) Part II Technician Performance Sheet

b. Enter your assigned identification and problem number on the Test Performance Sheet.

c. A problem has been isolated to the Indicator unit. Your job is to isolate this problem to a stage or small group of stages.

d. You will be simulating measurements on the equipments as follows:

(1) Use visual indications and TO to decide where you want to make a measurement.

(2) Log this point and test equipment you would use on the Test Performance Sheet.

(3) Examine Equipment Test Point and Tube Pin Data Sheet for point you have selected and observe data given. Determine whether the reading given is normal or abnormal and log on Test Performance Sheet.

(4) With this new information repeat the process until you feel you can isolate no further with the information given.

(5) Now log the suspected stage or stages and the tubes you wish to check next.

(6) Turn in Test Performance Sheet to Test Administrator.

PART II

TEST PERFORMANCE SHEET

Problem No.: ____________ Technician ID No.: ____________

Point Measured	Test Equipment You Would Use	Is Reading Normal or Abnormal

Suspect Stage or Stages ____________________________

____

Tubes you wish to check ____________________________

____

PART II

Problem No.

VISUAL INDICATIONS

DOPPLER TEST HARNESS METER SWITCH READINGS

Position	Reading
115,400 CPS	Normal
+28V	Normal
+500V	Normal
+130V	Normal
-425V	Normal

FREQUENCY TRACKER TEST PANEL METER SWITCH READINGS

Position	Reading
XTAL A	Normal
XTAL B	Normal
IF A	Normal
IF B	Normal
COMP	Abnormal

DRIFT ANGLE/GROUNDSPEED INDICATOR

Drift Angle Indicator	Groundspeed Counter
Normal, but may be slewed	Abnormal, but may be slewed

Memory Light

Remains on

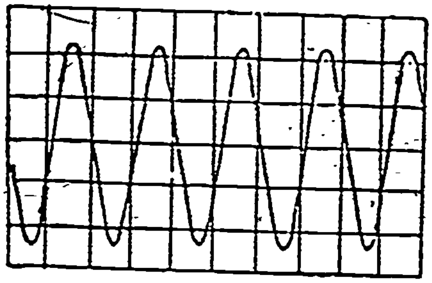
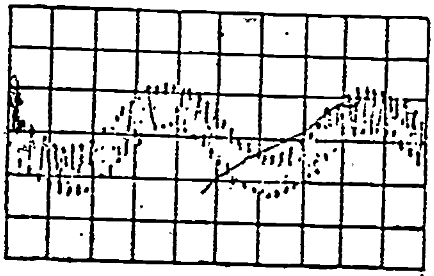
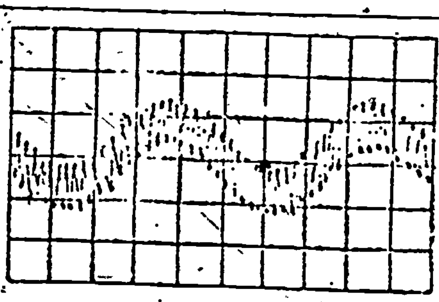
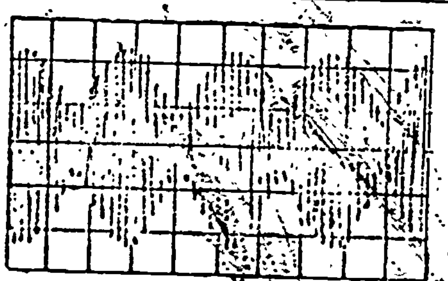
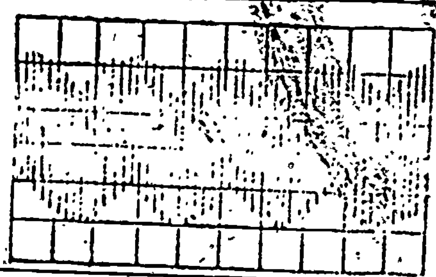
FREQUENCY TRACKER TUBE PIN READINGS

TUBE	TUBE PIN 1	2	3	4	5	6	7	8	9	10
V6701(V)	3.15VAC	1.4VAC	3.1VAC	7.2VAC	---	120VDC 11.3VAC	2.65VAC	4.3VDC	3.15VAC	---
(R)	150	13	470K	47K	0	15	100K	1.5K	150	---
V6702(V)	102VDC 2.3VAC	3.0VAC	21.1VDC 2.6VAC	3.15VAC	3.15VAC	75VDC 1.8VAC	0.18VAC	1.1VDC	3.15VAC	---
(R)	4.7K	475K	5.2K	150	150	10K	430K	220	150	---
V6703(V)	102VDC 2.2VAC	3.0VAC	21.1VDC 2.6VAC	3.15VAC	3.15VAC	75VDC 1.7VAC	0.16VAC	1.1VDC	3.15VAC	---
(R)	4.7K	475K	5.2K	150	150	10K	430K	220	150	---
V6704(V)	120VDC 2.5VAC	2.4VAC	5.8VDC	3.15VAC	3.15VAC	120VDC 2.5VAC	2.35VAC	5.8VDC	3.15VAC	---
(R)	6	100K	1.5K	150	150	6	100K	1.5K	150	
V6705(V)	120VDC 2.7VAC	2.2VAC	5.8VDC	3.15VAC	3.15VAC	120VDC 2.7VAC	2.35VAC	5.8VDC	3.15VAC	---
(R)	6	100K	1.5K	150	150	6	100K	1.5K	150	---
V6706(V)	---	-143VDC	-147VDC	---	---	---	0.95VAC	-143VDC	---	---
(R)	---	2.2K	0-10K	0	0	330K	1MEG*	2.2K	---	---
V6707(V)	---	-143VDC	-147VDC	---	---	---	0.95VAC	-143VDC	---	---
(R)	---	2.2K	0-10K	0	0	330K	1MEG*	2.2K	---	---
V6708(V)	94VDC 2.4VAC	1.6VAC	4.4VDC	3.15VAC	3.15VAC	94VDC 2.4VAC	1.6VAC	4.4VDC	3.15VAC	---
(R)	10K	24	1.5K	150	150	10K	24	1.5K	150	---
V6709(V)	120VDC 0.84VAC	1.6VAC	5.8VDC	3.15VAC	3.15VAC	120VDC 0.84VAC	1.65VAC	6.1VDC	3.15VAC	---
(R)	15	24	3.3-4.3K	150	150	15	24	4.3-3.3K	150	---
V6710(V)	120VDC	1.65VAC	50VDC 1.5VAC	3.15VAC	3.15VAC	120VDC	1.65VAC	50VDC 1.5VAC	3.15VAC	---
(R)	0	57K	10.5K	150	150	0	57K	10.5K	150	

NOTES:
1. To obtain the ac voltages feed a 3.0 kc, 0.18 rms to channel A (pin 7-V6702) and a 3.0 kc, 0.16 volts mc signal to channel B (pin 7-V6703)
2. All voltages measured with respect to ground
3. All voltages measured with tubes in place and POWER ON.
4. All resistance measured in ohms with respect to ground and tubes removed.
5. Resistance measurements are made with pins 2 and 6 of P6701 shorted to ground.

* It may be necessary to reverse the ohmeter leads to obtain these readings.

FREQUENCY TRACKER TEST POINT READINGS

TEST POINT	READING		
	VTVM	OSCILLOSCOPE	
TP6701			AMPLITUDE: 5V/DIV TIME BASE: 5µs/DIV
TP6702			AMPLITUDE: 2V/DIV TIME BASE: 0.1MS/DIV
TP6703			AMPLITUDE: 2V/DIV TIME BASE: 0.1MS/DIV
TP6704			AMPLITUDE: 2V/DIV TIME BASE: 0.1MS/DIV
TP6705			AMPLITUDE: 2V/DIV TIME BASE: 0.1MS/DIV

APPENDIX C

PART III. TEST MATERIALS

Isolation to Piece/Part Level

PART III

TEST SUBJECT TEST INSTRUCTIONS

Part III: Isolation to the Piece/Part.

INSTRUCTIONS:

a. Ensure that you have a TM and the following information sheets.

(1) Equipment Visual Indications

(2) Equipment Test Point Data Sheets

(3) Equipment Tube Pin Data

(4) Part III Test Performance Sheet

(5) Piece/Part Data

b. Enter your assigned identification and problem number on the Test Performance Sheet.

c. A problem has been isolated to a faulty module. Your job is to isolate this problem to a faulty part. Piece/part data is provided on the faulty module.

d. You will be simulating measurements on the equipments as follows:

(1) Use visual indications and TO to decide where or what part you wish to measure. Assume all vacuum tubes are good.

(2) Log this point or part and the test equipment you would use on the Test Performance Sheet.

(3) Examine corresponding Data Sheets and observe data given. Determine whether the reading given is normal or abnormal and log on Test Performance Sheet.

(4) With this new information repeat the process until you have isolated to the faulty part.

(5) Now log the suspected part on the Test Performance Sheet.

(6) Turn in Test Performance Sheet to Test Administrator.

PART III

TEST PERFORMANCE SHEET

Problem No.: ________ Technician ID No.: ________

Point Measured or Part Checked	Test Equipment You Would Use	Is Reading Normal or Abnormal

Suspect Part ____________________

PART III

FREQUENCY TRACKER

Piece/Part Data,
Problem No. 2.

PART	READING
C7901	
C7902	
C7903	
C7905	
C7908	
C7913	
C7914	
C7917	
C7919	
C7920	
CR7901	
CR7902	
K7901-13/12	
K7901-13/14	
K7901-1/2	
R7901	
R7902	
R7903	
R7904	
R7905	
R7906	
R7907	

PART	READING
R7908	
R7909	
R7910	
R7911	
R7912	
R7913	
R7925	
R7926	
R7928	
R7929	
R7930	
R7936	
R7937	
R7938	
R7939	
R7940	
R7941	
T7901-1/2	
T7901-3/4	
T7901-5/6	
T7901-7/8	
T7901-9/10	