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FUNCTIONAL FUNDAMENTALS TRAINING FOR ELECTRONIC MAINTENANCE PERSONNEL

JOHN P. FOLEY, JR.

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FOR
ELECTRONIC MAINTENANCE PERSONNEL**

JOHN P. FOLEY, JR.

FOREWORD

This report is published as a portion of the applied research program conducted under Project 1710, "Training, Personnel and Psychological Stress Aspects of Bioastronautics," Task 171004, "Techniques for Training, Aiding and Evaluating the Performance of Technical Tasks." Dr. Gordon A. Eckstrand was project scientist. Dr. Ross L. Morgan was task scientist.

The reported experiment was conducted by the author while a member of the Training Analysis and Development Division (TA&D), Air Training Command, Scott Air Force Base, Illinois. The experimental design and the training procedures were developed in 1953 and 1954. The actual experiment was conducted in 1954 and 1955. The final TA&D report was prepared in 1956. Mr. Walter W. Van Skiver was chief of the Scott AFB TA&D during this effort. The project was approved by Colonel Channing E. Beasley, Commander of the 3310th Technical Training Group. Mr. George Lenny, Scott AFB, designed the training equipment. The author used the data from this experiment as the basis of a master's dissertation which was published in 1959 by Our Lady of the Lake College, San Antonio, Texas. The present report represents a revision and expansion of the earlier reports.

The author wishes to express his appreciation to Dr. Henry J. Duel who suggested the experiment and whose advice was most valuable during the development of the experimental design and training procedures; to Mr. James Newman and Mr. George Roberts who developed most of the training materials and taught or supervised the teaching of the revised program; to Dr. Harold A. Wren and Dr. Michael A. Zaccaria who carefully edited his master's dissertation.

The author also wishes to express his appreciation to Dr. Ross L. Morgan for his critical review of the draft. His suggestions are greatly appreciated. The comments and suggestions of Dr. Gordon A. Eckstrand were also most helpful.

This technical report has been reviewed and is approved.

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ABSTRACT

A majority of the experiments reported in the literature concerning functional electronic fundamentals have applied the functional principles to training for a very limited and specific area of maintenance--in some cases to only one electronic equipment. The present experiment was designed to include the fundamental tasks and concepts applicable to all of the electronic communications specialties at the time of the study. The course was organized around specially designed trainers that incorporated the desired circuits and task requirements. Considerable well spaced maintenance practice was given using common test equipment, such as, vacuum tube voltohmmeter, signal generator, and oscilloscope. The curriculum development principles and procedures as well as the results of controlled experiments are found in the report. The findings indicated that the traditional and experimental courses were equally successful in training high aptitude students (7, 8, and 9 stanines). The experimental course was much more successful, however, than the traditional course in training average aptitude students (4, 5, and 6 stanines). The job success of the average aptitude graduates who completed the experimental course was equivalent to that of the higher aptitude graduates.

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SECTION I

INTRODUCTION AND STATEMENT OF PROBLEM

Introduction

Prior to World War II, the applications of electronics were few and were confined mostly to the field of radio communications. Although a considerable amount of research had been accomplished regarding the transmission of video or picture information, and scientists had developed rather successful radar devices, the actual use of such devices was rather limited.

During and since World War II, the complexity and uses of electronic devices have mushroomed. The use of electronics in the parent application of radio communications has expanded to the extent that microwave relays are used in place of telephone trunk lines by commercial telephone companies, the military services, railroads, pipelines, city fire companies, and many others. These systems not only transmit voice, but also video, teletype, IBM card data, instrumentation, and facsimile. Western Union has developed a completely automatic teletype message center controlled, of course, electronically. The radar, originally a military application, is now found on all ocean-going vessels, river boats, trains, and practically all commercial as well as military aircraft. Control of the ever-increasing air traffic is accomplished wholly by electronic means. Electronic devices are used to control practically every manufacturing process and in some applications without human assistance. Automation becomes possible only with highly complex electronics. The devices used to control the flight of modern aircraft and missiles have opened an entirely new avenue for the use of electronics.

With these developments and expansions there has been an evolution of an individual called the electronic technician. The early developments of electrical and electronic devices which were simple in design were accomplished, for the most part, by relatively untrained people. As more of these devices were refined and put into use, a trained individual--the electrical engineer and later the electronic engineer--was needed to design, develop, and to supervise the installation of the many and increasingly complex devices. In addition, the electrician, the man who did the actual installation and later the maintenance and repair of these devices, appeared on the scene. At first, his was a relatively simple job, but as electronic devices began to become more prevalent, there was a definite need for a highly trained maintenance and repairman of almost engineering caliber.

In the United States, large numbers of these people were not required until early in World War II, although the Army Air Corps did start a school for such individuals as early as 1935. Until that time, personnel with engineering training were sufficient in number to carry on this function. Since that time, more and more of these technicians have been required to install and maintain the ever-increasing number of electronic devices.

Early in World War II, the training programs designed to develop the electronic technician required a select type of individual. At first, it was not too difficult to obtain these individuals in the required numbers, but as the electronic field expanded it became more and more difficult to obtain such individuals in the numbers required especially for the military services. In order to produce the numbers of such personnel, standards were lowered in these training programs. The lowering of such standards invariably resulted in complaints from the supervisors that the graduates could not perform.

Proposed Actions

As a result of much discussion of these situations, it was decided to take the following actions at Scott Air Force Base, Illinois:

(1) To evaluate the traditional procedure for teaching electronic fundamentals in the light of recognized educational and psychological principles as well as applicable research results. This would be done to ascertain if such procedures could be improved.

(2) If the results of this evaluation indicated that profitable improvements could be accomplished in the training procedures for electronic technicians, they would be incorporated into a course of instruction and service-tested.

SECTION II

DESCRIPTION OF THE TRADITIONAL ELECTRONIC FUNDAMENTALS COURSE

The traditional electronic technician program, being very similar to engineering courses, is usually started with an extensive study of electronic fundamentals beginning with the electron and atom itself. In this program, the student builds his knowledge of theory background through an abstract study of the nature of electricity, direct current, alternating current, electron tubes, and later design problems in radio transmitters, receivers, and other electronic equipment. The emphasis in this part of the electronic technician training was, of course, on building and designing.

This part of the course, which required from 20 to 25 weeks, was followed by a study of actual military electronic equipment, including their operation, maintenance, and repair. These procedures had been used in the successful training of thousands of electronic technicians during and since World War II.

A Typical Electronic Fundamentals Course Outline

A more comprehensive picture of such a course can be obtained by an examination of the following subject outline. This outline not only gives the topics taught, but also the order in which these subjects usually are presented.

- I. Direct current concepts and circuits
 - A. Electrostatics, including the electron and the construction of the atom, and the interaction of charged bodies
 - B. Ohm's law
 - C. Voltage
 - D. Current
 - E. Resistance
 - F. Series resistive circuits
 - G. Parallel resistive circuits
 - H. Series parallel resistive circuits
 - I. Resistive bridge circuits
 - J. Principles of magnetism
 - K. Direct-current generators and motors
 - L. Direct-current measuring instruments
- II. Alternating current
 - A. Generation of alternating current
 - B. Inductance
 - C. Capacitance
 - D. Reactance and impedance
 - E. Transformers
 - F. Series resistive and capacitive (RC) circuits
 - G. Series resistive inductive (RL) and resistive inductive capacitive (RLC) circuits
 - H. Series resonance
 - I. Parallel resistive and capacitive (RC) and resistive inductive (RL) circuits
 - J. Series-parallel resistive inductive capacitive (RLC) circuits
 - K. Parallel resonance

transients L. Resistive and capacitive (RC) and resistive inductive (RL)

III. Electron tubes and associated circuits

- A. Diodes
- B. Half-wave and full-wave rectifiers
- C. Power supplies
- D. Filter circuits
- E. Triodes, tetrodes, and pentodes
- F. Cathode Ray Tubes
- G. Multi-purpose tubes
- H. Voltage regulators
- I. Classes of Operation
- J. Bias
- K. Audio frequency amplifiers
- L. Radio frequency amplifiers
- M. Video amplifiers
- N. Inductive capacitive (LC) oscillator and buffer amplifiers
- O. Types of coupling
- P. Modulation
- Q. Detection

IV. Transmitters

- A. Radio waves and propagation
- B. Continuous wave (CW) transmitters
- C. Voice transmitters
- D. Phase inverters
- E. Microphones
- F. Transmitter troubleshooting

- V. Receivers
 - A. Tuned radio frequency (TRF) receivers
 - B. Superheterodyne receivers
 - C. Mixing
 - D. Intermediate frequency (IF) circuits
 - E. Receiver Alignment
 - F. Speakers
 - G. Receiver troubleshooting
 - H. Volume control
 - I. Automatic volume control (AVC)
 - J. Delay automatic volume control (DAVC)
- VI. Electron control circuits
 - A. Tuned circuit oscillators
 - B. Multivibrators
 - C. Clampers
 - D. Sweep generators
 - E. Electronic counters
 - F. Frequency modulation and dissemination
 - G. Limiters
 - H. Wave guides
 - I. Cavity resonators
 - J. Synchros systems
- VII. Fundamentals of radar

SECTION III

OVERVIEW OF RELEVANT INFORMATION

A brief overview of available information on the following topics will be useful as a frame of reference in evaluating the traditional fundamentals course described in section II.

- (1) General educational and psychological information on curriculum design and methods of teaching.
- (2) Transfer of training.
- (3) Methodology of equipment maintenance.
- (4) Training aids, including training equipment.
- (5) Student selection procedures.

General Educational and Psychological Information

Until relatively recent times, the learning of skills and trades was accomplished through apprenticeship. Formal lectures were a very small part of such training. However, with the development of trade schools, lectures and various practical exercises became major instructional devices in teaching trade skills and knowledges. Lectures probably were used more because of an inadequate number of job-like experiences available to the trade school than because of their special contribution to learning trades and skills. Likewise, lectures alone were considered unsuitable for instruction in the expanding fields of engineering and physical science. Education in these areas, as well as training in modern trade schools, has given rise to laboratory exercises and workbooks used in conjunction with lectures and textbooks.

A 1924 experiment by Thorndike (ref 15) contributed much to current educational psychology. Until the conclusive experiment of Thorndike, the learning of the various disciplines was believed to train the mind. The so-called formal discipline value of various high school and college subjects was the principal reason given for their inclusion in the curriculum. Thorndike's experiment proved the formal discipline theory of transfer of training to be in error. However, through the force of tradition much of the traditional practice of teaching methodology continued in many high school and college courses.

Hartman (ref 9) has indicated that educators look to psychology to provide working principles. This is much the same as the engineer looking to the basic physicist for his working formulæ. Hartman makes the comment that in actual practice psychological research has less influence on what teachers and administrators do than the psychologist would like to believe.

Transfer of Training

Bode (ref 2) believed that schools have a problem of transfer because the

schools had failed to develop concepts in such a manner as to give them usefulness outside the classroom. This is another way of saying that the school does not supply the student with a realistic frame of reference. According to Bode, this lack of carrying over is due to a cleavage between the school and real life. He indicated that the problem of transfer does not appear in everyday living. If school can be properly related to real life, the problem of transfer would largely disappear. This would require a reorganization of curricula.

Hartman (ref 9) believed that if the Gestalt principles were consciously applied to the reorganization of the curriculum that teaching procedures would become more effective. Gestalt principles are usually applied by presenting the student with the whole. To be effective, in keeping with Bode, this whole must be related to real life, that is within the experience or comprehension of the student. The whole radio receiver is within the experience of most American boys and, as such, makes a meaningful whole or Gestalt. The same radio receiver would be beyond the comprehension of an African boy who has never seen or heard one. It would not be part of his everyday life.

Thorndike (ref 12) considered transfer of training from another point of view, that of identical elements. His concept was that there was transfer of training between two wholes only insofar as the two wholes had identical elements. For example, a child might first become acquainted with the color blue when playing with a blue block. As he has more experience, he sees this color blue associated with other objects (blue suit, blue ball, blue boat). As a result, he learns to identify blue in all situations. Applied to electronics, resistors, capacitors, coils, and electron tubes might be considered identical elements found in all electronic equipment.

Woodworth (ref 16) expanded Thorndike's identical elements to identical components. There may be complexity of function of components that gives them identity or likeness. For example, an amplifier (a complexity made up of wire, resistors, capacitors, coils, and tubes) performs the same function in a radio receiver, a radio transmitter, or as a booster in a telephone line. As such it is an identical component.

Methodology of Equipment Maintenance

The principal job of the electronic technician is the accomplishment of preventive and corrective maintenance. The difficulty of this job has increased as the complexity of the equipment has increased. Berkshire (ref 1), who states this situation very well, indicates that in the electronic equipment of an earlier day trouble symptoms could be related to a single faulty component rather easily. However, with the development of ever more complex equipment, the maintenance job has become more and more difficult. The training of the electronic technician has been accomplished by giving training only to airmen with high intellectual and technical aptitudes through a rather lengthy course of instruction. The problem is further complicated by the short enlistment time remaining after the completion of this lengthy training. He suggests three approaches to the solution of this problem:

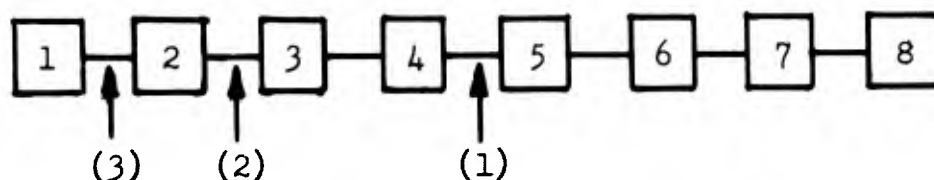
- (1) Equipment should be designed to simplify maintenance procedures.

(2) Efforts should be made to improve the training of electronic equipment maintenance technicians.

(3) Efforts should be made to revise maintenance procedures.

Several rather important studies have been conducted on this maintenance problem. Miller, Folley and Smith (ref 11) describe two general methods of attacking the troubleshooting problem. The first is troubleshooting from probability or historical data; the second, by logical elimination of alternatives. The first method was used quite extensively during World War II in field practice. It is very effective when large numbers of identical or similar equipment are used for long periods of time, providing the equipment is not too complex. It was the method used to repair many home radios during the 1930's. It is not very effective on new complex electronic equipment for which no history has been developed, nor is it practical for locating unusual troubles in any equipment. In these cases, the second method must be used which requires that the technician have a good logical trouble-shooting procedure, and that he be trained in the effective use of test equipment.

In the study of systematic troubleshooting, the problem is considered from the point of view of signal tracing of information flow through an electronic equipment. The technician's first step is to determine the particular data chain in which the difficulty is located. This is usually done by attempting to pass a simulated signal through each of the data chains in the equipment being tested. Second, after the particular defective data chain is located, the malfunctioning component or stage can be isolated by means of a half-split technique by consulting only a block diagram of the equipment. For example, in a straight series with eight stages:



The first test would be to check the data flow at point (1). If it is normal here, then it can be assumed that the malfunction is in one of the last four stages. If abnormal at this point, it can be assumed that the malfunction is in one of the first four stages. If the latter were the case, the next check would be made at point (2). If abnormal at this point, the next check would be found in the least number of tests on the average.

The final step in this procedure would be to isolate the defective element or part of the defective stage, usually by voltage and resistance checks.

Saltz and Moore (ref 12) in another study investigated the characteristics of good troubleshooters as opposed to poor troubleshooters. Their findings were as follows:

(1) Poor troubleshooters knew less about the functional relations between components than good troubleshooters.

(2) Good troubleshooters have participated in more different kinds of activities of all sorts than have the poor troubleshooters.

(3) Good troubleshooters know more about the use of test equipment than poor troubleshooters.

(4) There is no significant difference in intelligence between good and poor troubleshooters.

(5) The good troubleshooters did not form abstract concepts any better than poor troubleshooters.

The last of these findings has a great deal of significance since the learning of traditional fundamentals requires the forming of abstract concepts. Some poor troubleshooters learned abstract fundamentals better than some good troubleshooters. The findings as to the importance of test equipment were also important. Since the same or similar test equipment was used to test, adjust and repair many different types of electronic equipment, its use should be emphasized in any type of electronic fundamentals course.

Trainers and Training Aids

Since all electronic fundamentals courses make use of trainers and training aids, three studies of such devices are pertinent. Two of these experiments deal with teaching personnel with established, realistic frames of reference, not with teaching personnel such as are found in basic electronic courses.

Donenberg (ref 6) found that students could learn the procedures for operating a tank better by use of an inexpensive mockup of the instrument panel and driver's controls than by use of an expensive tank hull trainer costing \$10,000. Swanson (ref 13) found that for the instruction of skilled technicians, well-prepared lectures and less expensive, simple devices are just as effective as more complex, expensive devices.

Students in both Donenberg's and Swanson's experiments had a realistic frame of reference for the subject matter being taught. Donenberg's subjects had developed many of the skills required from the operation of automobiles and trucks. Undoubtedly Swanson's subjects had developed a realistic frame of reference in their previous assignments.

In a study of training aids format, Berkshire (ref 1) found that the use of color-coded schematics for each of five or six subsystems helped the technician in his circuit analysis.

Student Selection Procedures

The requirement for valid instruments for the selection of trainees for complex training became very apparent during World War II. The United States Army Air Force developed the "stanine" or standard nine index for the prediction of student success in pilot and navigator training. The Navy developed the "Eddy Test" for predicting success in the Navy Electronic Technician Program.

After World War II, the Airman Classification Test Battery was developed (ref 5). This particular battery was in use at the time students were selected for

the test and control groups. Aptitude indices were developed to predict school success in the following training areas: mechanical, clerical, equipment operator, radio operator, instructor, services, crafts, and electronics. Table I indicates the spread of these scores in terms of Standard Deviation and Theoretical Percent of the population. It also shows percentile and Army Standard score equivalents. Later Gragg and Gordon (ref 8) made a validity study

TABLE I

COMPARISON OF AIR FORCE APTITUDE INDICES WITH STANDARD DEVIATION, THEORETICAL PERCENT OF THE POPULATION, PERCENTILE, AND ARMY STANDARD SCORE

Aptitude Index	Standard Deviation	Theoretical Percent of Population	Percentile	Army Standard Score
9	2.0	4	95 thru 99	140
8	1.5	7	88 thru 94	130
7	1.0	13	76 thru 87	120
6	0.5	17	58 thru 74	110
5	0	20	38 thru 57	100
4	-0.5	17	21 thru 37	90
3	-1.0	12	10 thru 20	80
2	-1.5	7	4 thru 10	70
1	-2.0	4	0 thru 3	60

of this classification battery. Their study indicated that the correlation between the electronic aptitude index and school success was approximately .60 and the estimated reliability coefficient for the electronic index was .93. This study also indicated that the aptitude indices for most of the training areas, including the electronic index, were very successful. The Air Force, at times, has found it difficult to obtain a sufficient number of high aptitude students for all schools. Brokaw and Burgess (ref 3) state that the Electronic Aptitude Index "is essentially an engineering aptitude measure" and that engineering students would fall in the upper 10 percent of the population using this measure. The aptitude scores predict success in the traditional school situation. How well they predict actual job success is not known.

SECTION IV

CRITICAL ANALYSIS OF THE TRADITIONAL FUNDAMENTALS COURSE

At least for a point of departure it is appropriate to examine any existing educational procedure critically in the light of recognized principles. If the educational procedures in question meet the test of such a critical examination, then we can assume that we are doing the best possible job within the limits of the present stage of development of the art and science of teaching, and we should continue to operate as before. If, however, this examination shows apparent weaknesses in the educational procedures, the procedures should be modified accordingly and evaluated.

With this in mind, the following questions are posed with regard to the traditional procedures for teaching electronic fundamentals described in Section II:

- (1) Does the traditional course have correct objectives?
- (2) Are the curriculum and methodology used the most desirable for the accomplishment of the desired objectives?
- (3) Are the training aids and training equipment, presently used, designed to meet the objectives of electronic technician training?

Does the Traditional Course Have Correct Objectives?

The main objective for teaching electronic fundamentals is to train personnel to perform preventive and corrective maintenance on the various electronic devices used in the Air Force. To answer this question in a very general way, some form of the traditional course of instruction has been used to train the many thousands of electronic technicians now in the field. Therefore, it must be accomplishing its objectives.

A closer examination of the question, in the light of the historical development of the traditional course, might result in a somewhat different answer. When schools were developed for radio and electronic technician training, engineers, not educators, were called on to develop these courses. The courses developed were similar to those used to train engineers. The engineer is trained to design and build equipment from component parts, that is, by synthesis. In the engineering school tradition, the majority of electronic fundamentals courses start with the electron and atom. The student builds his knowledge of theory through an abstract study of direct current, alternating current, electron tubes, and later design problems in radio transmitters, receivers, and other electronic equipment. The emphasis in these courses is on building and designing. In such courses, the student learns a body of fundamental facts and later ties these all together to develop a complete picture of a radio or other electronic equipment. This may be satisfactory for the objectives of engineer training, but it fails to give sufficient attention to training technicians. We have assumed that a student trained to design a system can break it down and perform the analysis necessary for

troubleshooting. Little practice is given in actual analysis and troubleshooting. Thus, the true objectives of the courses for Air Force electronic technicians are accomplished by an indirect means rather than by direct attack. From an educational point of view, this is at least questionable.

Another facet of this question is the type of student that has been successfully trained by these traditional procedures. Experience with these procedures has indicated that, on the average, only students with 7, 8, and 9 aptitude indices pursue these traditional procedures with a considerable degree of success. Students with these aptitudes are in the upper 23 percent of the population. According to Brokaw (ref 2) these are the same type of students found in engineering schools. This suggests the possibility that a course of instruction aimed directly at the electronic technician might successfully train **average** aptitude personnel.

Further support of this possibility is obtained by examining the characteristics of good troubleshooters, since this process is probably the most difficult aspect of the electronic technician's job. Saltz and Moore (ref 12) indicated that a good troubleshooter does not necessarily have superior intelligence to the poor troubleshooter and he does not have better ability to form abstract concepts than the poor troubleshooter. In fact, there is evidence that he has less of this ability. The man of **average** intelligence who is able to assimilate with difficulty the abstract ideas or concepts of electronics may be able to do a better job of troubleshooting and repairing the electronic equipment than a man of higher intelligence for whom the job of assimilating the abstract ideas is much less difficult.

Saltz and Moore also found that good troubleshooters had more skill in the use of test equipment than did poor troubleshooters. In traditional courses much emphasis is placed on the design and theory of operation of test equipment, but students get little actual practice in the use of these test equipments.

An examination of the objectives of traditional electronic fundamentals courses seems to indicate that, although many electronic technicians have been produced, the course objectives may be more appropriate for training engineers than training Air Force electronic technicians.

Are the Curriculum and Methodology Used the Most Effective for the Accomplishment of the Desired Objectives?

An examination of electronic fundamentals courses in the light of the accepted principles and theories of learning and curriculum development seems to indicate that little or no consideration had been given to such principles as transfer of training in their design. An example of the failure to apply these psychological principles is demonstrated by the fact that many times similar circuits are explained from different points of view with no reference to previous explanations; as a result, some students do not recognize the identical elements and do not understand relationships.

Another example is the failure to provide extensive practice in the use of test equipment. Common test equipment are used in maintaining practically all electronic equipment. If the graduate possesses proficiency in their use, he has skills that can be easily transferred from one maintenance situation to another.

Further evidence of the failure to obtain transfer of training is implicit in the frequent charge that the traditional fundamentals course is not "practical" -- the word "practical" in this case not being too well defined. In general, the individuals making this statement probably could not make the transfer between the concepts learned in fundamentals and the real job situation. Some other people say, "I have never been able to use most of the stuff I learned in radio school." This may mean that the content of radio school actually was not relevant to their post-school duties, but more probably it means that the training was not presented in a way to facilitate transfer of learning from the school situation to the work situation.

Principles that seem applicable to developing curricula that will achieve greater transfer to the work situation should be explored. Both Hartman (ref 9) and Bode (ref 2) indicate that a great deal would be gained by deliberately planning our curriculum in keeping with Gestalt psychological theory. Bode (ref 2) further indicates that there is little difficulty in the transfer of training in the everyday pursuits of people, but that the difficulty in transfer of training appears only in the school situation. It would appear, therefore, that developing the curriculum around a realistic frame of reference, tied to concepts or materials within the experience and understanding of the student, would aid in the transfer of training. The job of the electronic technician can be analyzed very easily in terms of Gestalt psychology as well as Thorndike's (ref 14) identical elements and Woodworth's (ref 16) identical components.

(1) In the electronic technician's process of locating troubles, he begins with the whole equipment -- the Gestalt. He must determine what the particular equipment is supposed to do when it is operating normally.

(2) When he analyzes the equipment in the process of determining a trouble, he will find many identical or similar components. From his point of view, for example, all amplifier circuits and oscillator circuits perform similar functions although found in many varied and different equipment.

(3) When he isolates a trouble to a particular element, he finds many similar elements, such as resistors, capacitors, and inductors, which are found in many and varied components.

If examined from the point of view of the training of personnel with aptitude for assimilating and applying abstract principles to the building and designing of electronic equipment, the methodology used in traditional courses probably is adequate. If examined from the point of view of training average aptitude electronic technicians for the accomplishment of preventive and corrective maintenance of electronic equipment, the curriculum and methodology used probably could be improved.

Are the Training Aids and Training Equipment Presently Used Designed to Meet the Objectives of Electronic Technician Training?

An examination of the training aids utilized with the traditional teaching procedures indicates that they usually are of a bread-board type which present circuits and their components, such as resistors, capacitors, coils and tubes, on flat surfaces much as they appear in textbook schematic diagrams. Again, the presentation seems more appropriate to designing circuits than to maintaining them. The result is that, when these same circuits are used in their realistic equipment environment, the student or graduate is unable to recognize them. Circuits should therefore be presented and studied as they actually appear in equipment.

Conclusion

An analysis of the traditional fundamentals courses reveals some serious deficiencies and raise some important questions. These deficiencies and questions seem to justify developing and evaluating new curricula and instructional procedures for teaching electronic fundamentals.

SECTION V

DESCRIPTION OF THE REVISED ELECTRONIC FUNDAMENTALS COURSE

As a result of the analysis of traditional courses in the previous chapter, a hypothesis was formulated that a more effective curriculum for teaching electronic fundamentals can be designed around actual electronic devices making use of recognized psychological principles for teaching maintenance skills and knowledges.

Ground Rules for the Development of the Fundamentals Course

The following ground rules or considerations were applied in the development of such a course of electronic fundamentals.

(1) Each student would be presented with a complete or whole electronic system -- a Gestalt. This would be done in the very beginning of the course. This system would be simplified enough for him to operate; ie, within his realm of easy comprehension. In this way, he could discover that he could communicate from one room to another without wires. He would later analyze each circuit and component to learn how this overall operation was accomplished.

(2) An attempt would be made to develop many job-like situations throughout the course. Standard test equipment (the tools of the electronic repairman) would be used by the student from the very beginning of the course to analyze the circuits of the electronic system. Such test equipment would include "voltohmmist," vacuum tube voltmeter, oscilloscope, tube tester, and signal generator. These test equipments would only be used as tools. The student would, therefore, not be expected to understand the details of their design.

(3) No electronic circuit theory or principles would be presented until after it had been used and tested in actual equipment. In this way, the student first discovers what a circuit does and what can be expected of it after which he learns why and how it accomplishes its function. For example, in the study of the amplifier circuit, the student would first pass a signal through the amplifier. He would listen to the volume of the signal before it was passed through the amplifier and after it was passed through the amplifier to demonstrate just what the amplifier does and where its input and output can be measured. He would later analyze the operation of the circuit from an electronic troubleshooting point of view.

(4) The course would, as near as possible, be designed so that the student would start with easy material and progress to more difficult material. For example, if we would trace one thread of information such as vacuum tubes through the course, we would find that we start with the diode and progress through the triode, tetrode and pentode, and finally into multi-purpose tubes of various types.

(5) Once a circuit had been presented and explained, it would not be presented as something new when found in different equipment but would be presented as a similar circuit to that found in the previous equipment. This procedure would emphasize the existence of the many identical elements or components that are common to all types of electronic equipment.

Equipment Designed for the Course

The revised procedures were planned around pre-wired radio equipment. This equipment was designed so that it not only contained all basic radio circuits, but, also, so that these circuits appeared to the student in their general order of difficulty. For example, the first piece of equipment used by the student contained simple diode and triode electron tubes. Later pieces of equipment contained more complex tetrode, pentode, and multipurpose tubes. The last piece of equipment contained high powered, high voltage tubes. Stages and components were identified by color to emphasize that many common or identical elements and components are found in all electronic equipment. The sequence of instruction followed this progression of equipment. The planning, designing, developing and producing of this equipment was a formidable engineering undertaking. The items of equipment are listed below: (figures 1 through 5 and table II gives additional descriptive information concerning the major items).

(1) Vacuum Tube Power Supply - This is a plug-in type power supply that is used to furnish high voltage for all of the training equipment described below except the transistor receiver and 1000 V transmitter. The use of this design emphasized the fact that most vacuum tube rectifier power supplies are similar. (See figures 1, 2, 3 and 4.)

(2) Other Power Supplies - To demonstrate that other power sources are sometimes used, a battery power supply, a dynamotor power supply and a selenium rectifier power supply also were developed. These units could be substituted for the vacuum tube power supply.

(3) Simple Radio Transmitter - This is a very low power transmitter made up of a triode oscillator with a triode amplifier as a modulator. (See figure 1.)

(4) Simple Radio Receiver - This receiver contains a diode detector and a triode audio amplifier. (See figure 1.)

(5) TRF Receiver - This receiver contains a pentode RF amplifier, a diode detector, and a pentode audio amplifier. (See figure 2.)

(6) Superheterodyne Receiver - This receiver contains a pentode RF amplifier as a preselector; a separate mixer and HFO; a pentode IF amplifier; a diode detector, an audio voltage amplifier; and an audio power amplifier. (See figure 3.)

(7) Superheterodyne Receiver with Push-Pull Output - The RF, IF, and detector circuits are similar to those in the previous receiver. The audio section is made up of a phase inverter and push-pull output stages. In addition, a BFO section is added. Multi-purpose tubes are used where applicable. (See figure 4.)

(8) Transistor Receiver - A transistor receiver was developed to demonstrate that all receiver equipment did not necessarily use vacuum tubes.

(9) 1000 Volt Transmitter - This transmitter contained similar circuits to that found in the previously described equipment, except that high power transmitter tubes were used requiring voltage of approximately 1000 volts. (See figure 5.)

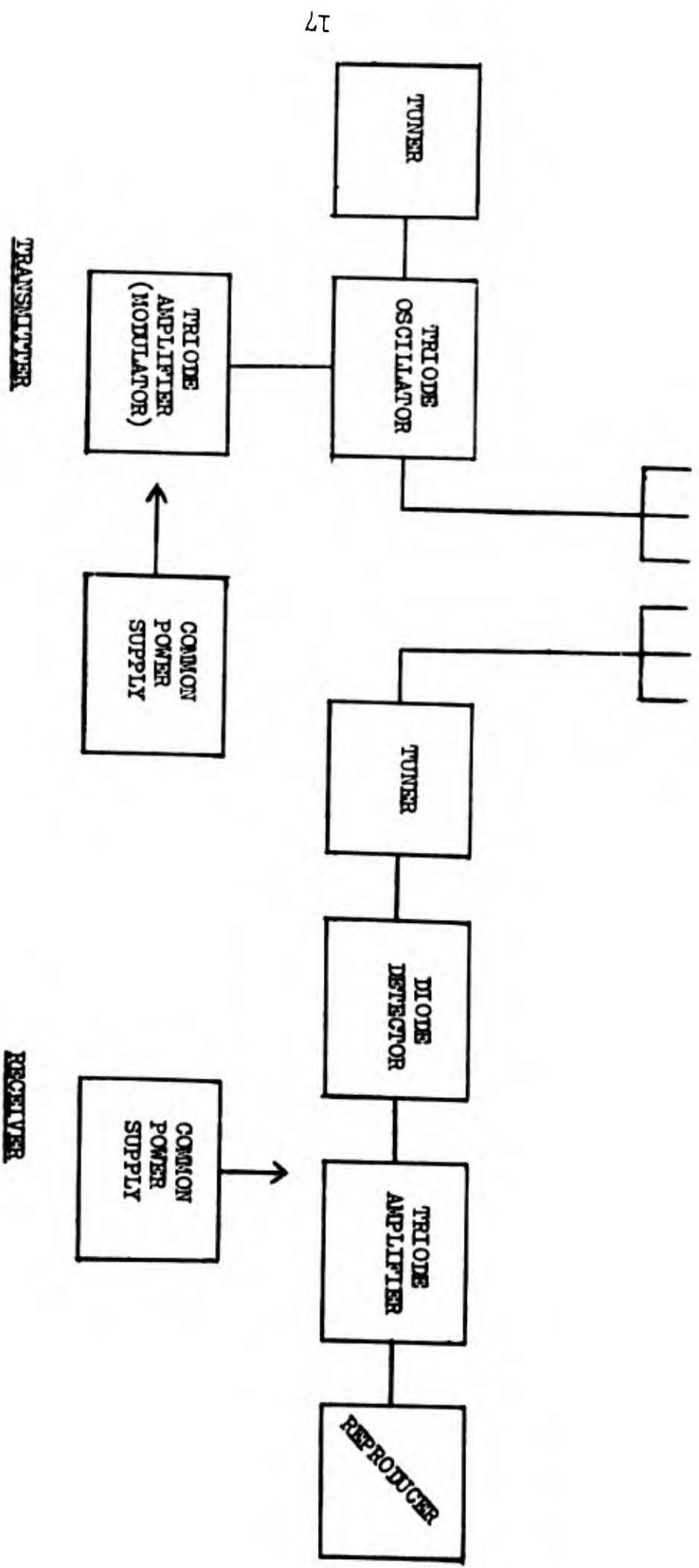


Figure 1. Block Diagram of Simple Electronic Communications System

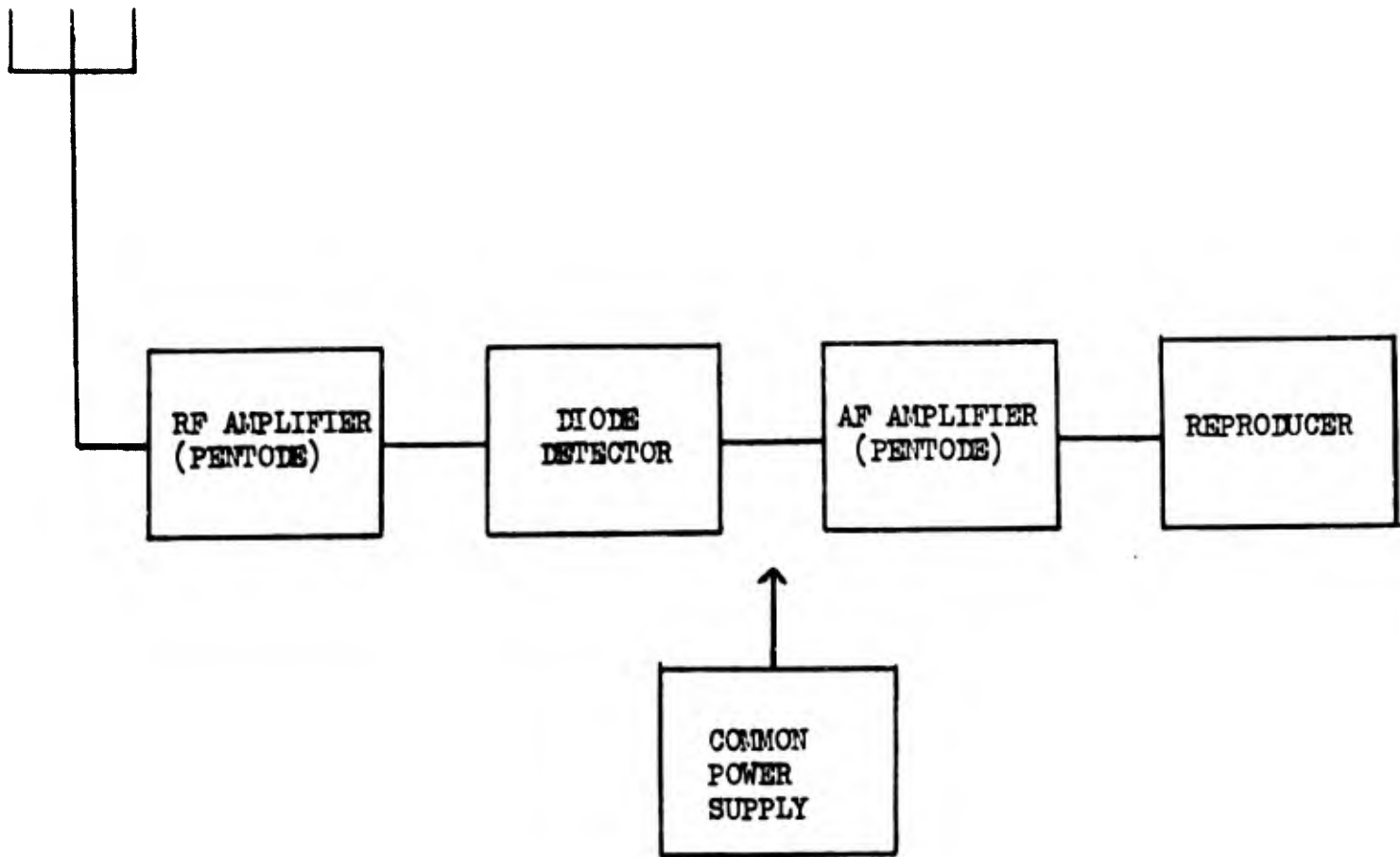


Figure 2. Block Diagram of Tuned Radio Frequency (TRF) Receiver

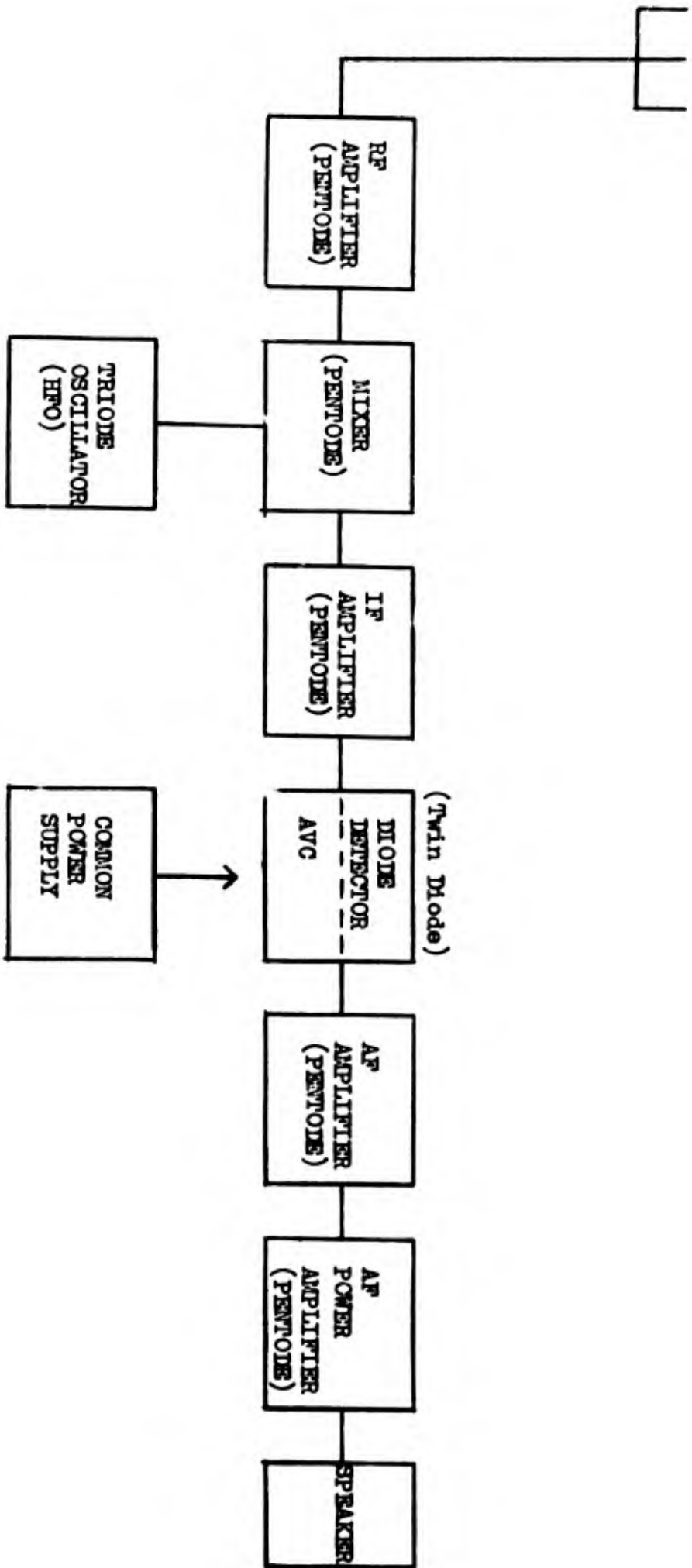


Figure 3. Block Diagram of Simple Superheterodyne Receiver

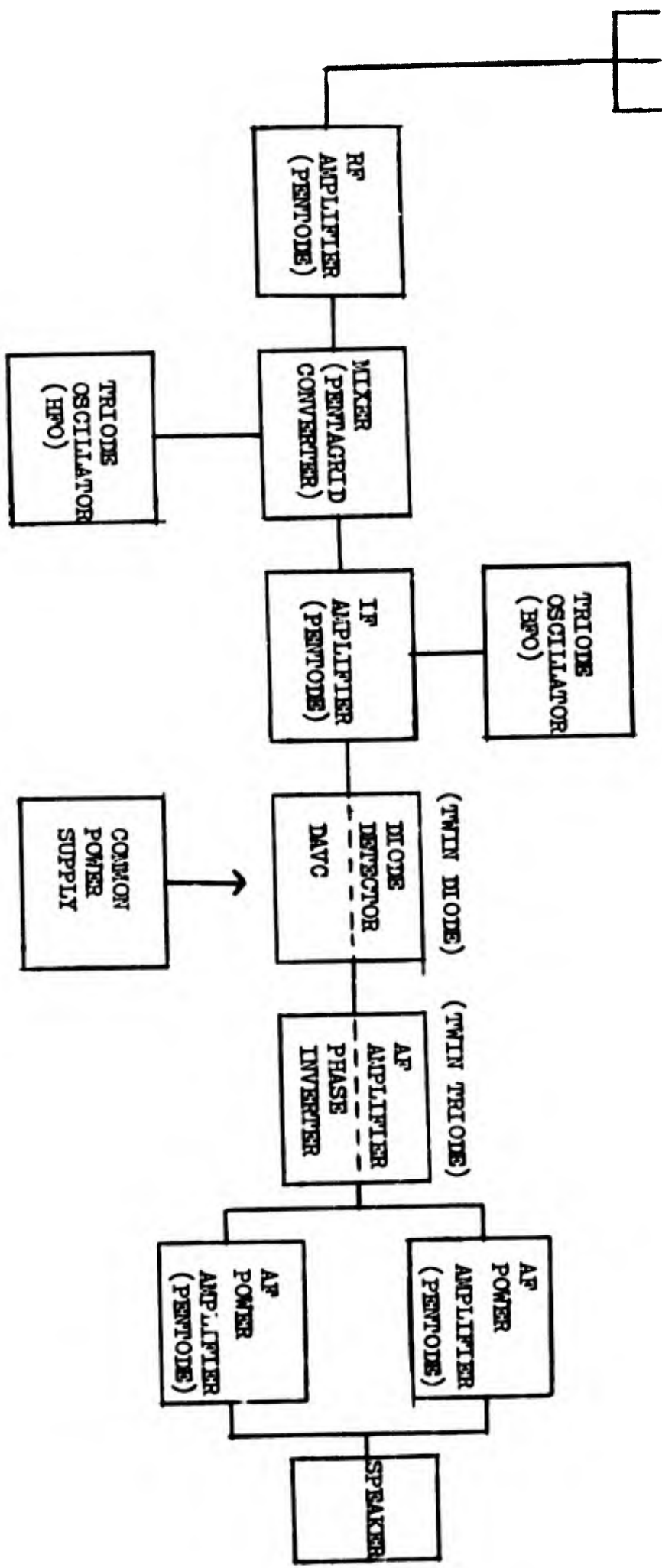


Figure 4. Block Diagram of Superheterodyne Receiver
(with BFO and Push-Pull Output)

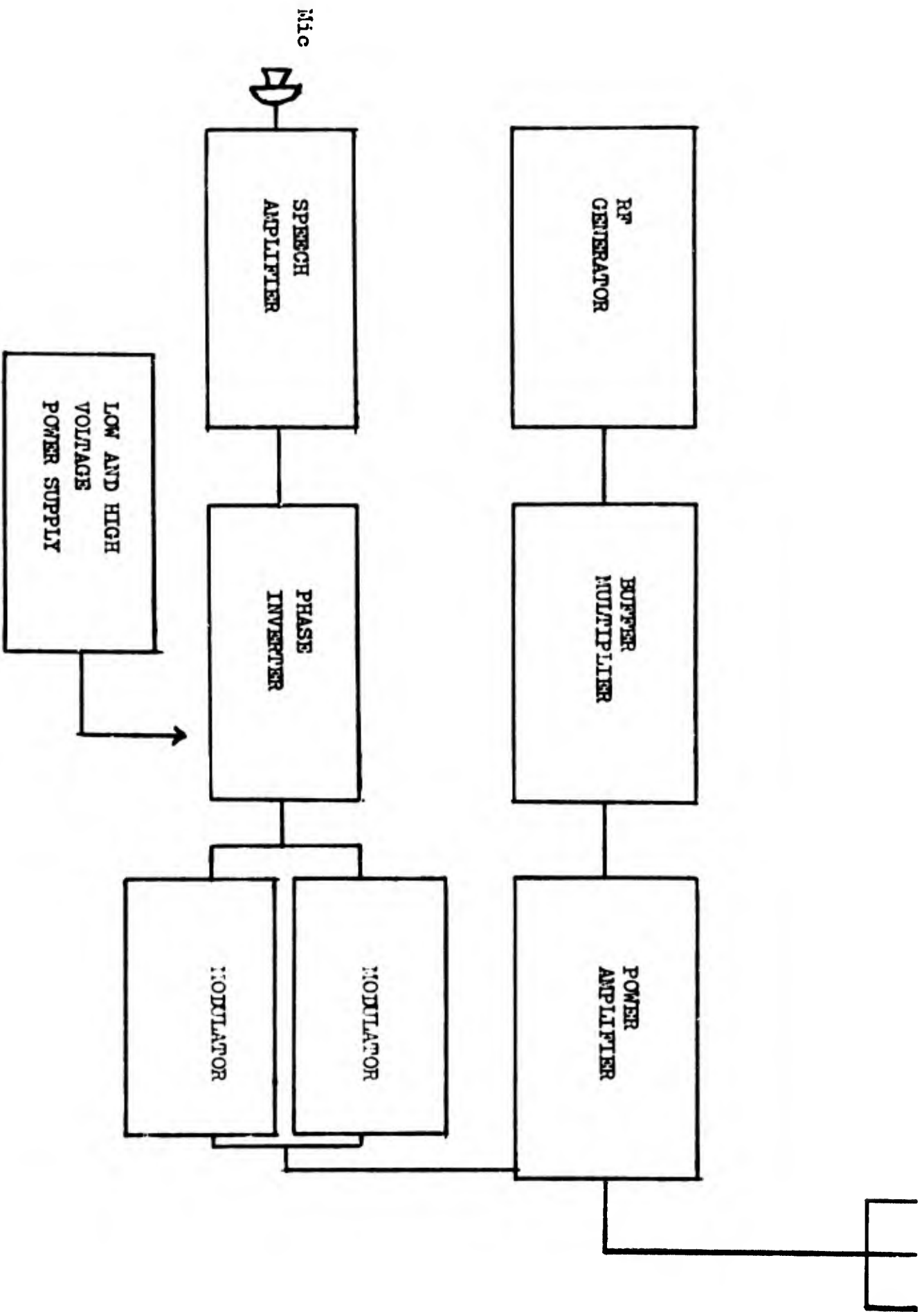


Figure 5. Block Diagram of 1000 Volt Transmitter

TABLE II

STAGES, TUBE TYPES, AND TUBE NOMENCLATURE ON MAJOR ITEMS OF TRAINING EQUIPMENT DESIGNED FOR USE IN STUDY

<u>EQUIPMENT</u>	<u>STAGES</u>	<u>TUBE TYPE</u>	<u>TUBE NOMENCLATURE</u>
I Simple Electronic Communication System (See figure 1.)			
*A. Power Supply	Rectifier	Diode	5W4
B. Simple Transmitter	Oscillator	Triode	6J5
	Modulator	Triode	6J5
C. Simple Receiver	Detector	Diode	6H6
	AF Amplifier	Triode	6SF5
II Tuned Radio Frequency Receiver (See figure 2.)	RF Amplifier	Pentode	6SK7
	Detector	Diode	6H6
	AF Amplifier	Pentode	6SH7
III Simple Superheterodyne Receiver (See figure 3.)	RF Amplifier	Pentode	6SK7
	Mixer	Pentode	6SK7
	HFO	Triode	6J5
	IF Amplifier	Pentode	6SK7
	Detector-AVC	Twin diode	6H6
	Audio Amp	Triode	6J5
	Power Amp	Pentode	6V6
IV Superheterodyne Receiver with Push-Pull Output (See figure 4.)	RF Amplifier	Pentode	
	1st Detector	Pentagrid converter	
	IF Amplifier	Pentode	6SK7
	Best Frequency Oscillator (BFO)	Triode	6J5
	2nd Detector)	Twin Diode	6SQ7
	DAVC)	High Mu	
	1st Audio Amplifier)	Triode	
	2nd Audio and Phase Inverter	Twin-Triode	6SN7
	Push-pull Power Amplifier	2 Pentodes	2-6V6
V 1000 V Transmitter (See figure 5.)	RF Generator		6AG7
	Buffer - Multiplier		6L6
	RF Power Amplifier		809
	Speech Amplifier)	Twin-triode	$\frac{1}{2}$ 6SN7
	Phase Inverter)		$\frac{1}{2}$ 6SN7
	Modulator (push-pull)	2 Power Pentode	2-6L6's
	Low Voltage	Full-wave Rectifier	5Z3
	Power Supply High Voltage	Full-wave Rectifier	
	Power Supply	Used as Half-Wave	

*This same power supply unit was used with all other equipment except the 1000V Transmitter.

TABLE III
DISTRIBUTION OF DIRECT CURRENT
CONCEPTS AND CIRCUITS IN THE
FUNCTIONAL PROGRAM

I - Introduction and Application
R&E - Review, Expansion and Application
R - Review & Application
A - Application only

I. Simple Electronic Communication System		Electrostatics														
I.	A. Power Supply	I														
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		I	R&E	R	A											
		II.	B. Simple Transmitter													
III.	C. Simple Receiver															
		IV.	Tuned Radio Frequency Receiver (TRF)													
V.	Simple Superhetrodyne Receiver															
		VI.	Superhetrodyne Receiver with Push-Pull Output													
VII.	1000 Volt Transmitter															

TABLE IV

DISTRIBUTION OF ALTERNATING CURRENT CONCEPTS AND CIRCUITS IN THE FUNCTIONAL PROGRAM

I - Introduction and Application
 R&E - Review, Expansion and Application
 R - Review and Application
 A - Application Only

Alternating Current Concept and Circuits

FUNCTIONAL SEQUENCE											
I. Simple Electronic Communication System	A. Power Supply	Generation of AC									
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	I								
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
		R&E	R&E	I							
II. Tuned Radio Frequency Receiver (TRF)											
		A									
		A									
		A									
		A									
III. Simple Superheterodyne Receiver											
		A									
		A									
		R&E									
		R&E									
IV. Superheterodyne Receiver with Push-Pull Output											
		A									
		R&E									
		R&E									
		A									
V. 1000 Volt Transmitter											
		A									
		A									
		A									
		A									

TABLE VI
DISTRIBUTION OF TRANSMITTER
CONCEPTS AND CIRCUITS IN THE
FUNCTIONAL PROGRAM

I - Introduction and Application
R&E - Review, Expansion and
Application
R - Review and Application
A - Application Only

I. Simple Electronic Communication System		Radio Waves and Propagation																		
A. Power Supply																				
B. Simple Transmitter		I		I		I	I													
C. Simple Receiver		R&E						A												
II. Tuned Radio Frequency Receiver (TRF)		A						A												
III. Simple Superheterodyne Receiver		A						A												
IV. Superheterodyne Receiver with Push-Pull Output		A			I			A												
V. 1000 Volt Transmitter		R&E	I	R&E	R&E	R&E	R&E	R&E												

TABLE VIII
DISTRIBUTION OF COMMON
MAINTENANCE TASKS AND
CONCEPTS IN THE FUNCTIONAL
PROGRAM

FUNCTIONAL SEQUENCE		COMMON MAINTENANCE TASKS AND CONCEPTS																		
		Use of Multimeter	Use of Vacuum Tube Voltmeter	Use of Tube Tester	Use of Signal Generator	Use of Oscilloscope	Use of Neon Bulb	Fault Localization to Stage	Identification of Defective Circuit Components	Systems Concept	Safety Practices									
I. Simple Electronic Communication System	A. Power Supply	I	I	I		I	I	I	I	I										
	B. Simple Transmitter	R&E	R&E	R&E	I	R&E	R&E	R&E	R&E	R&E										
	C. Simple Receiver	R&E	R&E	R&E	R&E	R&E	A	R&E	R&E	R&E										
	II. Tuned Radio Frequency Receiver (TRF)	A	A	A	A	A	A	R&E	R&E	A	A									
	III. Simple Superheterodyne Receiver	A	A	A	A	R&E	A	R&E	R&E	A	A									
IV. Superheterodyne Receiver with Push-Pull Output		A	A	A	A	R&E	A	R&E	R&E	A	A									
	V. 1000 Volt Transmitter	R&E	R&E	R&E	A	R&E	A	R&E	R&E		R&E									

Quantity of Training Equipment Available

Sufficient items of most of the training equipment listed above were produced so that each subject had his own equipment during class hours. Each student, therefore, was required to accomplish all of the performance exercises. Only one transistor receiver, selenium rectifier power supply, battery power supply and dynamotor power supply were produced. These were used for demonstration.

Test Equipment

The following items of test equipment were selected for use with the revised procedures. These test equipment items were used throughout the course in conjunction with all of the equipment described above. The students learned to use them with much the same facility as they drive automobiles.

- (1) Multimeter
- (2) Vacuum Tube Voltmeter
- (3) Tube Tester
- (4) Signal Generator
- (5) Oscilloscope
- (6) Neon Bulb

Course Development Procedure

As outlined in Section II, the traditional electronic fundamentals course is usually sequenced in blocks of instruction as follows:

Direct Current
Alternating Current
Electron tubes and associated circuits
Transmitters
Receivers

As stated above, this functional course was developed around specially designed equipment. The electrical and electronic concepts and circuits were taught in conjunction with these equipment items which became progressively more difficult. Each of the concepts found in the traditional curriculum are also found in the functional curriculum. Figure 6 is a graphic representation of the course development plan. Tables III through VI show how the major concepts in each of the tradition blocks of instruction were distributed in the functional course. It is emphasized that these tables do not show the complete list of concepts taught in either the traditional or functional courses. They are, however, inclusive enough to present the course development procedure used. Although a correspondence is shown as to items taught, the electronic theory taught in the experimental course emphasized maintenance rather than design.

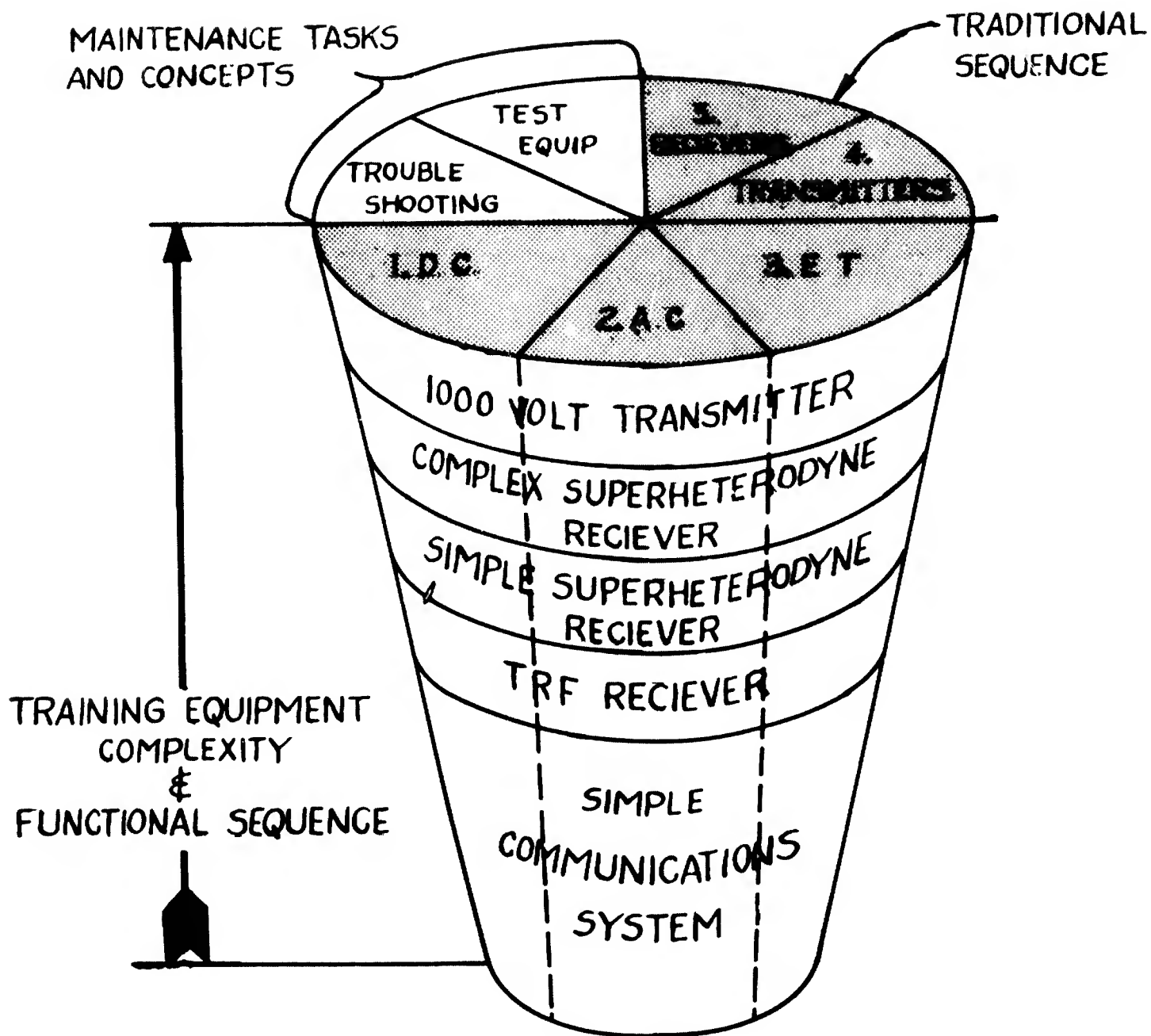


FIGURE 6. COURSE DEVELOPMENT CONCEPT FOR THE FUNCTIONAL ELECTRONIC FUNDAMENTALS

Training Materials

Text materials that reflect the principles of the study were not available. Reading assignments were made from standard texts and Air Force manuals.¹ Laboratory worksheets were developed for each project or unit of work.² Since no facilities were available for printing colored materials, no use was made of the recommendation by Berkshire (ref 1) that schematics be color-coded.

¹Since these publications were organized and sequenced in traditional fashion, they were not too satisfactory. If the revised procedures were adopted new text materials would have to be developed.

²One copy of each of the Laboratory worksheets developed for use in the experimental course is on file at the Technical Training Branch (MRPTM), Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio 45433.

SECTION VI
DESCRIPTION OF EXPERIMENTAL PROCEDURES

After the development of the revised course of instruction as described in Section V, a controlled experiment was conducted for the purpose of ascertaining whether the revised instructional procedures were actually better in practice than the traditional course procedures for the teaching of electronic fundamentals. The hypotheses offered for testing in this experiment were that:

(1) The revised curriculum and procedures, when used under controlled conditions, will successfully train more trainees with average electronic aptitudes (4, 5, and 6) than the traditional course.

(2) Students taught with the revised procedures will master more knowledge of electronic principles than those taught with the traditional procedures.

(3) Students taught with the revised procedures will be more skilled in troubleshooting procedures than those students taught with the traditional procedures.

Operational Procedures for Conducting Experiment

Experimental and control groups were selected and matched on the basis of the electronic aptitude indices. Every effort was made to keep all variables constant with the exception of the curriculum and methodology. The students slept in the same type barracks, attended school on equivalent shifts and were given instruction by instructors of equivalent ability. Every effort was made to conduct as unbiased an evaluation of the two courses as humanly possible.

Four test sections and four control sections were selected as experimental and control groups. These groups were matched by pairs on the basis of the electronic aptitude index. In addition, one section of 21 students with electronic aptitudes of 4, 5, and 6 was also entered in training. The four experimental sections and the one average aptitude section received instruction under the revised procedures described in Section V. Table IX indicates the distribution of students by aptitude in the experimental, the control and the special average aptitude groups. The four control sections received instruction in the regular course described in Section II.

The first experimental section and the first control section began training on 20 January 1954. The other experimental sections and the average aptitude sections were entered in training at approximately 7-week intervals. The first three experimental sections and the average aptitude section completed fundamentals training in the normal 22 weeks. The last experimental section completed training in 18 weeks. All four control sections were given the standard 22 week course.

The last experimental section completed fundamentals training on 11 January 1955. The last control section was scheduled to complete fundamentals training on 8 February 1955. Due to washbacks, the last control student completed this training on 21 February 1955.

TABLE IX

DISTRIBUTION OF STUDENTS BY ELECTRONIC
APTITUDE IN THE EXPERIMENTAL, CONTROL
AND SPECIAL AVERAGE APTITUDE GROUPS

Aptitude		Experimental Group	Control Group	Special Average Aptitude Section
High	9	11	11	
	8	14	14	
	7	20	20	
Average	6	13	13	6
	5	7	7	8
	4	6	6	7
Total Students		72	72	21
Total High Aptitude		45	45	
Total Average Aptitude		27	27	21
Total Students		72	72	21

The first experimental section was taught by two experienced civilian instructors who had assisted in the course development. The other experimental sections were taught, for the most part, by regular enlisted instructors. These instructors received their training in the new concepts by observing only those blocks of instruction to which they were assigned to teach.

Evaluation Procedures

Both written and performance examinations were given to both groups at about five points during their fundamentals training. Since the experimental and control groups received electronic fundamentals materials in entirely different sequences, these internal examinations were different in content. It was, therefore, necessary to use other measures of effectiveness for comparison purposes.

(1) The number of students who successfully completed both the fundamentals training and equipment training was an important factor to be measured, provided such graduates could perform successfully in the field.

(2) Although the examinations given during the fundamentals training could not be equated, a comprehensive examination could be administered to both groups upon completion of fundamentals. Two such examinations were administered. An examination had been used from time to time at the end of the regular fundamentals course. This examination contained only theory questions. Another examination was developed specifically for this purpose containing both theory and troubleshooting questions.

(3) After both the experimental and control groups completed their fundamentals course, they attended ten weeks of equipment training in which actual Air Force electronic communication equipments were studied. These courses consisted of analyzing, testing and troubleshooting equipments. Written and performance examinations were given after the study of each equipment. A T-Score was given for each of these examinations and a final T-Score was awarded at the end of this course. This final T-Score was used as another measure of the success of the experimental and control groups.

(4) If objective measures were available, the results of a field evaluation of graduates on the job would be the most desirable measure of success of a technical course. Due to the many uncontrolled variables in the field, an acceptable objective measure of field success has not yet been devised. However, a graduate evaluation questionnaire was sent to the supervisor of each experimental and control group graduate. The results of this evaluation, although subjective, were utilized as another measure of student success.

SECTION VII

PRESENTATION AND ANALYSIS OF DATA OBTAINED

Information Obtained and Analyzed

The information concerning the experimental group, control group, and the special average aptitude section was analyzed and the results were organized in the following manner.

(1) The number of students in the experimental group, control group and average aptitude section who successfully completed training.

(2) The results of two comprehensive examinations given at the end of the fundamentals training.

(3) The results of written and performance examinations given after each equipment phase of the basic radio courses.

(4) The results of field evaluation of graduates on the job.

Graduation Success

An analysis of the graduation success of the students in the experimental group, control group, and the special average aptitude section indicates that considerable success was experienced especially with the average aptitude students.

(1) Twenty-seven students with electronic aptitude indices of 4, 5, and 6 were entered with the experimental groups and a like number with the control groups. None of the average aptitude students were eliminated from the experimental group, while six average aptitude students (22.2%) were eliminated for academic reasons from the control groups. No experimental group students were washed back during the fundamentals portion of the service test. Two were washed back in the equipment phases. Nine of the control group students received academic washbacks before graduation. Table X gives a summary of the graduation success of students with 4, 5, and 6 aptitudes in the experimental and control groups.

(2) In addition to the average aptitude students in the experimental group, 21 students were entered in the special average aptitude section. Table XI gives a summary of the graduation success of these 21 average aptitude students receiving the revised instructional procedures. Of these 21 students only one was eliminated for academic reasons. There is some evidence, however, to show that the average aptitude students in this special section did not progress as well as the average aptitude students mixed in with the higher aptitude students in the regular experimental classes. Another study (ref 7) also indicated that average aptitude students do better when mixed with high aptitude students than when only average aptitude students are trained together.

(3) An analysis of the graduation success of high aptitude students (7, 8 and 9) indicates little difference between the graduation success of the experimental and control groups. (See table XII.) Forty-two (93%) of the experimental group graduated as compared with 40 (89%) of the control group. When considered from time spent in training however, there is a reasonable difference favoring the experimental group. Forty-two (93%) of the experimental group graduated without washback compared with 32 (71%) for the control group. Three students (7%) of each group were eliminated for nonacademic reasons.

Results of Comprehensive Examinations

Two comprehensive examinations were used to measure the effectiveness of training. The first examination has been used from time to time to measure the overall effectiveness of the traditional radio fundamentals training. This examination was designed in keeping with the objectives of the traditional electronics fundamentals training. It contains, for the most part, theory questions. The second examination, designed in keeping with the objectives of the experiment, contained questions on troubleshooting of radio circuits as well as radio theory. Table XIII shows that the experimental group received significantly better scores on both examinations. This indicates that although the prime objective of the experiment was to teach students to analyze and troubleshoot radio circuits, the experimental group not only learned to analyze and troubleshoot but also learned more theory in the process. The control group received fairly good scores on the theory questions but very poor scores on the troubleshooting questions. It appears, therefore, that the revised instruction gave the average student a more realistic and lasting frame of reference for electronic theory than the traditional instruction. It is also probable that the continued application given in the revised procedures motivated the students in terms of sub-goals and success as well as feedback from knowledge of successful troubleshooting results.

T-Scores Obtained in Common Equipment Phases

After the experimental and control groups completed fundamentals training, both groups received equivalent training in the equipment phases. Information

TABLE X
GRADUATION SUCCESS OF 27 EXPERIMENTAL GROUP STUDENTS
COMPARED WITH THE SUCCESS OF 27 CONTROL
GROUP STUDENTS HAVING ELECTRONIC APTITUDES
OF 4, 5, AND 6

Electronic Aptitude Index	Experimental				Control			
	6	5	4	Total	6	5	4	Total
Number entered	14	7	6	27	14	7	6	27
Number graduated without academic washback	13	6	6	25	5	4	1	10
Number graduated after academic washback	1	1	0	2	6	2	1	9
Number eliminated for academic reasons	0	0	0	0	2	1	3	6
Number eliminated for non-academic reasons	0	0	0	0	1	0	1	2

TABLE XI

GRADUATION SUCCESS OF 21 STUDENTS HAVING ELECTRONIC APTITUDES OF 4, 5, AND 6 ENTERED AS A SPECIAL SECTION IN ADDITION TO THE EXPERIMENTAL GROUP RECEIVING THE REVISED INSTRUCTIONAL PROCEDURES

Electronic Aptitude Index	6	5	4	Total
Number entered	6	8	7	21
Number graduated	6	7	4	17
Number eliminated for academic reasons	0	0	1	1
Number eliminated for non-academic reasons	0	1	2	3

TABLE XII

GRADUATION SUCCESS OF 45 EXPERIMENTAL GROUP STUDENTS COMPARED WITH THE SUCCESS OF 45 CONTROL GROUP STUDENTS HAVING ELECTRONIC APTITUDES OF 7, 8, AND 9

Electronic Aptitude Index	Experimental				Control			
	9	8	7	Total	9	8	7	Total
Number entered	11	14	20	45	11	14	20	45
Number graduated without academic washback	11	11	20	42	10	9	13	32
Number graduated after academic washback	0	0	0	0	1	2	5	8
Number eliminated for academic reasons	0	0	0	0	0	1	1	2
Number eliminated for non-academic reasons	0	3	0	3	0	2	1	3

TABLE XIII

RESULTS FROM THE ADMINISTRATION OF TWO
COMPREHENSIVE EXAMINATIONS TO 60 MATCHED
PAIRS OF STUDENTS FROM THE EXPERIMENTAL AND
CONTROL GROUPS

	Experimental Group	Standard Deviation	Control Group	Standard Deviation	Differences	No. Pairs	Critical Ratio
Fundamentals Course Compre- hensive Exam (Ave. No. right out of 100 ques- tions)	53.61	13.47	50.95	14.24	2.66	60	3.06*
Experimental Comprehensive Exam (Ave. No. right out of 100 questions)	66.78	13.37	51.06	11.60	15.72	60	7.07*

*.01 level of significance

concerning student success in the equipment phases of the basic radio courses for experimental and control group students is presented in table XIV.

(1) The results of an analysis of the T-Scores received by both groups is given in table XV. This indicates that the experimental group students received a significantly higher final average T-Score than the control group students.* The experimental group students received a significantly higher T-Score average on performance examinations. This group of students also received a significantly higher written average T-Score.

(2) A further analysis of these T-Scores is given in Table XVI. This indicates that, for 7, 8, and 9 aptitude levels experimental students received a higher, but not significantly higher, average T-Score than did those in the control group. However, for the 4, 5, and 6 aptitude levels, experimental students received a significantly higher final average T-Score and performance T-Score than did those in the control group. For these average aptitude students, the score on the written test was also significantly higher.

*One tailed test of significance.

TABLE XIV

AVERAGE T-SCORED RECEIVED BY MATCHED PAIRS OF EXPERIMENTAL AND CONTROL GROUP GRADUATES BY APTITUDE IN FOUR WRITTEN AND FOUR PERFORMANCE EXAMINATIONS AND FINAL GRADE--ALL OBTAINED IN THE COMMON EQUIPMENT PHASES RECEIVED BY BOTH THE EXPERIMENTAL AND CONTROL GROUPS AFTER COMPLETING FUNDAMENTALS TRAINING

Electronic Aptitude Index	Number of Matched Pairs	Average T-Score Written Examinations			Average T-Score Performance Examinations			Average T-Score Final Equipment Grade		
		Experimental Group	Control Group	Difference	Experimental Group	Control Group	Difference	Experimental Group	Control Group	Difference
9	11	57.36	<u>58.36</u>	-1.00	53.82	<u>55.18</u>	-1.36	55.73	<u>56.73</u>	-1.00
8	11	<u>50.00</u>	48.45	1.55	<u>52.45</u>	50.82	1.69	<u>51.64</u>	50.09	1.55
7	19	<u>49.63</u>	49.16	.47	<u>49.47</u>	48.89	.58	<u>49.63</u>	49.32	.31
6	11	<u>48.82</u>	43.82	5.00	<u>51.91</u>	47.27	.64	<u>50.39</u>	45.73	4.66
5	6	42.67	<u>43.50</u>	-.83	<u>48.67</u>	47.17	1.64	<u>46.33</u>	45.83	.50
4	2	43.50	<u>46.00</u>	-2.50	<u>48.50</u>	41.50	7.00	<u>46.00</u>	43.50	2.50
Total	60	<u>50.07</u>	49.07	1.00	<u>51.00</u>	49.83	1.17	<u>50.80</u>	49.63	1.17

TABLE XV

RESULTS OF AN ANALYSIS OF THE FINAL AVERAGE
T-SCORES FOR EXPERIMENTAL AND CONTROL GROUP STUDENTS
IN THE EQUIPMENT PHASES OF THE BASIC RADIO COURSES

	Experimental Group	Standard Deviation	Control Group	Standard Deviation	Differences	Nr. Pairs	Critical Ratio
Final Average T-Score	<u>50.80</u>	5.92	49.63	6.20	1.17	60	2.68**
Average Perform- ance T-Score	<u>51.00</u>	5.74	49.83	5.88	1.17	60	2.54**
Average Written T-Score	<u>50.07</u>	7.90	49.07	8.01	1.00	60	1.89*

*.05 level of significance

** .01 level of significance

TABLE XVI

RESULTS OF AN ANALYSIS OF THE FINAL AVERAGE
T-SCORES OF EXPERIMENTAL AND CONTROL GROUP STUDENTS
BY HIGH AND LOW APTITUDE IN THE EQUIPMENT
PHASES OF THE BASIC RADIO COURSES

		Experimental Group	Standard Deviation	Control Group	Standard Deviation	Differences	Nr. Pairs	Critical Ratio
Final	All Students	<u>50.80</u>	5.92	49.63	6.20	1.17	60	2.68**
Average	7,8,9 Aptitude	<u>51.80</u>	6.45	51.51	5.97	.29	41	.69
T-Score	4,5,6 Aptitude	<u>48.63</u>	3.76	45.53	4.49	3.10	19	2.99**
Average	All Students	<u>51.00</u>	5.74	49.83	5.88	1.17	60	2.54**
Perf.	7,8,9 Aptitude	<u>51.44</u>	6.10	51.10	5.99	.34	41	.81
T-Score	4,5,6 Aptitude	<u>50.05</u>	4.73	47.11	4.55	2.94	19	2.61**
Average	All Students	<u>50.07</u>	7.90	49.07	8.01	1.00	60	1.89*
Written	7,8,9 Aptitude	<u>51.80</u>	8.30	51.44	7.76	.36	41	.71
T-Score	4,5,6 Aptitude	<u>46.32</u>	5.27	43.95	5.87	2.37	19	1.88*

*.05 level of significance

** .01 level of significance

Results of Field Evaluation of Graduates

The success of the graduates in both the experimental and control groups was measured by means of graduate evaluation questionnaires. The rated items on each student's questionnaire were averaged to obtain an overall rating for that student. The rating scale used in the graduate evaluation was the job training standard six-point scale, modified for questionnaire purposes.

(1) The results of an analysis of these ratings are shown in Table XVII. This indicates that the average student performance of graduates working in the field from the experimental group was not higher than the control group. However, when the average aptitude graduates (4, 5, and 6 aptitude) are considered separately, the experimental group graduates received a statistically significantly higher average than the control graduates. This gives additional evidence to the superiority of the experimental course as compared with the traditional course for the average aptitude personnel.

TABLE XVII

FIELD SUCCESS OF 25 MATCHED PAIRS OF EXPERIMENTAL AND CONTROL GROUP GRADUATES AS MEASURED BY A FIELD EVALUATION QUESTIONNAIRE

	Experimental Group	Standard Deviation	Control Group	Standard Deviation	Differences	Nr. Pairs	Critical Ratio
Average Questionnaire Rating on all Aptitudes	4.28	.76	4.05	.85	.23	25	1.10
Average Questionnaire Rating (4, 5, 6 Aptitude)	4.45	.86	3.51	.62	.94	9	1.91*

*.05 level of significance

(2) The graduation success of the average aptitude students receiving the revised instructional procedures was discussed previously. Forty-four such students graduated. Questionnaires were returned on 25 of these graduates. Of these, only one student was considered undesirable. This student had an aptitude of 4. With this one exception, these students' performance in the field was higher than average. One of these students returned as an instructor and performed very effectively. The overall field satisfaction with the 4, 5, and 6 aptitude graduates was about the same as for the 7, 8, and 9 aptitude graduates.

SECTION VIII

CONCLUSIONS AND APPLICATIONS

Conclusions

The revised instructional procedures were more effective for average aptitude (4, 5, and 6 indices) than the conventional procedures because:

- (1) More average aptitude students graduated when the revised instructional procedures were used.
- (2) The students in the experimental group received significantly higher scores in two end-of-course comprehensive examinations than the students in the control groups.
- (3) The average aptitude students in the experimental group received a significantly higher average final T-Score in the equipment phases than the average aptitude students in the control group.
- (4) The average aptitude students in the experimental group received a higher average rating on a graduate field evaluation questionnaire than the average aptitude student in the control group.
- (5) The field success of the average aptitude students trained by the revised procedures compared favorably with students having 7, 8, and 9 aptitude indices. In fact, the average aptitude personnel received slightly higher ratings than those of high aptitude. If the average aptitude students can be trained, they perform just as effectively as high aptitude students. This would seem to confirm the finding of Saltz and Moore (ref 12) that good troubleshooters did not form abstract concepts any better than poor troubleshooters.

For the high aptitude students (7, 8, and 9 indices) the superiority of the revised procedures was not as great as for the average aptitude students. There was, however, a reasonable difference favoring the revised procedures. Although the graduation success of both the experimental and control groups were about the same, only 71% of the control group graduated without washback while 93% of the experimental group graduated without washback.

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Military Applications

This study has taken recognized psychological and educational principles and applied them directly to the teaching of general electronic fundamentals in a military situation. The study has also given definite indications that average aptitude personnel can be trained to perform satisfactorily on the job. These findings should have great significance in assisting the military establishments in training the large numbers of electronic personnel required to maintain the ever increasing numbers of electronic equipments. Since the training procedures used in this study give a broad or general background of electronic maintenance fundamentals, it has a very definite application if it is necessary to train an electronic technician who can be cross-trained from one equipment to another. This is an important consideration in our present day of rapid development of new equipment.

Rather than train men of general background as was done in this study, both the Army and Air Force have at times trained technicians for only one equipment or a small number of similar equipments. In such training only the specific fundamental concepts of that equipment were taught. This approach was used by Hitchcock, Mager, and Whipple (ref 10) in their Army experiment on electronic fire control equipment. This procedure worked very well when the graduate was assigned to the equipment on which he had been trained. The criticism that has been made concerning this approach is that personnel given such limited fundamentals cannot be easily cross-trained to perform maintenance on dissimilar equipments.

The general principles used in my study, therefore, can either be applied to a general fundamentals course or to a specific fundamentals course designed for only one equipment. Under either condition, it is possible to train average aptitude individuals more successfully than by the traditional procedures. Specific fundamentals may however limit the cross-training capabilities of the trainee whereas general fundamentals will not.

General Educational Applications

The normal aptitude indices (7, 8, and 9) used for selection into the Air Force electronic courses include the top 23 percent of the population. The average aptitude indices (4, 5, and 6) include the middle 54 percent of the population. The normal high school class in physics will include more of the average type as represented by this study than the high aptitude indices.

High School Physics Courses

The findings of this study would indicate that to teach physics most effectively to the normal high school class, the subject matter should be related to objects within the experience of the students. In teaching mechanics, the students should be presented with the whole automobile engine or the whole automobile for that matter. In teaching electricity and electronics, the student could be presented with the whole radio system as was done in this study. The student could develop a realistic frame of reference on which to base abstract principles.

Once this realistic frame of reference is established, the abstract principles will be retained much longer. If this approach were used in high school physics, basic college courses could be much more meaningful and not just a repetition of the high school subject matter.

High School and Vocational School Radio and TV Repair Courses

If the object of a particular course is to train the students to actually repair equipment, the procedures developed for this study should prove much more effective than the presently used quasiengineering approach. The type of student attracted to these courses comes from the general population and is not limited to the top 33 percent as are the 7, 8, and 9 aptitude students found in the Air Force courses. As a result, the engineering approach is usually over the heads of most of these students. A procedure similar to those used in this experiment would actually train the man to repair equipment.

Commercial Applications

With the installation of electronic equipment replacing electromechanical equipment, many industries have been faced with the problem of cross-training electricians with no electronic backgrounds into the maintenance and repair of newer electronic equipments. The proper application of the principles presented in this study should result in the conversion of more of these employees into satisfactory electronic repairmen.

SECTION IX

A SIMILAR EXPERIMENT

One of the recognized proofs of experimental results is the replication of results by a similar independent experiment. In 1958 Hitchcock, Mager and Wipple (ref 10) reported such an experiment in revised procedures for teaching electronic fundamentals to Army Fire Control Technicians.*

The Army fundamentals was limited to concepts required for one equipment specialty. The Scott program was designed to include the fundamentals concepts required of all the Air Force electronic communications specialties. The Army experiment utilized actual electronic fire control equipment rather than training equipment designed specifically for teaching general electronic fundamentals. The overall course development ground rules were similar, however.

(1) The trainees were given a formal orientation at the beginning of the course followed by successive informal orientation throughout the course directing them toward the objective of the course, namely, the successful performance of equipment maintenance and repair.

*Their experiment was conducted at least one year after the present study.

(2) The students were presented with the whole operational and repair picture--the Gestalt--in the beginning by a one-week subcourse on systems operations and elementary systems troubleshooting techniques.

(3) This was followed by basic electronics instruction. In this subcourse, the amount of theory taught was reduced and emphasis was placed on analysis of circuits and their functions, reducing the need for mathematics instruction.

(4) Test equipment operation was taught in the laboratory rather than by lecture.

(5) In the equipment subcourse, emphasis was placed on function of various stages and chassis. The instruction stressed input-output voltages and wave forms and test points. This emphasis of necessity required the use of test equipment in a job-like manner.

(6) Written and practical examinations were developed to emphasize the analysis, troubleshooting and repair of equipment.

Two experimental classes were used in the Army experiment. One received a completely revised curriculum; the other received only a part of the revised curriculum. Both experimental classes obtained much higher scores on their proficiency test than any standard class tested at graduation. The average score of the first class was equivalent to the proficiency level of standard course graduates after eighteen months on the job. The other class received an average score equivalent to standard course graduates after 6 months on the job. This experiment verifies the findings of the Scott experiment indicating a functional approach to teaching electronic concepts is superior to the traditional approach.

REFERENCES

1. Berkshire, J.R., Field Evaluation of a Trouble-Shooting Aid, Air Force Personnel and Training Research Center, Technical Report AFPTRC-TR-54-24 (AD 53724), Lackland Air Force Base, Texas, pp 1-2, June 1954.
2. Bode, B.H., Modern Educational Theories, D. C. Heath & Co, pp 202-204, 1928.
3. Brokaw, L.D. and Burgess, G.G., Development of Airman Classification Battery AC-2A, Personnel and Training Research Center, Technical Report AFPTRC-57-1 (AD 131422), Lackland Air Force Base, Texas, p 7, June 1957.
4. Brubacher, J.S., A History of the Problems of Education, McGraw-Hill Book Company, Inc., New York, pp 170-193, 1948.
5. Dailey, J.T., Development of the Airman Classification Battery, Air Training Command, Research and Development Program (Research Bulletin 48-4), Barksdale Air Force Base, Louisiana, pp 1-13, November 1948.
6. Denenberg, V.H., The Training Effectiveness of a Tank Hull Trainer, Human Resources Research Office (HumRRO Technical Report 3), Department of the Army, pp 7-10, February 1954.
7. Foley, J.P., Service Test of Homogeneous Grouping, Training Analysis and Development, TA&D Project Nr: Scott 54-31 Scott Air Force Base, Illinois, pp 2-4, August 1955.
8. Gragg, D.B. and Gordon, M.A., Validity of the Airman Classification Battery AC-1, Human Resources Research Center, Research Bulletin 50-3 (ATI 93440), Lackland Air Force Base, Texas, pp 41-43, 163-164, September 1951.
9. Hartman, G.W., Gestalt Psychology--A Survey of Facts and Principles, The Ronald Press Company, pp 258-274, 1935.
10. Hitchcock, L., Mager, R.F. and Whipple, J.E., Development and Evaluation of an Experimental Program of Instruction for Fire Control Technicians, U.S. Army Air Defense Human Research Unit, Technical Report 46, Fort Bliss, Texas, pp 4-6, May 1958.
11. Miller, R.B., Folley, J.D., Jr. and Smith, P.R., Systematic Troubleshooting and the Half-Split Technique, Human Resources Research Center, Technical Report 53-21 (AD 19046), Lackland Air Force Base, Texas, pp 1-12, July 1953.
12. Saltz, E. and Moore, J.V., A Preliminary Investigation of Troubleshooting, Human Resources Research Center, Technical Report 53-2 (AD 14441), Lackland Air Force Base, Texas, pp 3-6, February 1953.
13. Swanson, R.A., The Relative Effectiveness of Training Aids Designed for Use in Mobile Training Detachments, Air Force Personnel and Training Research Center, Research Review 54-1, Lackland Air Force Base, Texas, p 6, March 1954.

REFERENCES (CONT'D)

14. Thorndike, E.L., Educational Psychology, Briefer Course, Bureau of Publications, Teachers College, Columbia University, New York, pp 268-269, 1916.
15. Thorndike, E.L., Mental Discipline in High School Studies, Journal of Educational Psychology, Nr. 15, p 98, January and February 1924.
16. Woodworth, R.S., Contemporary Schools of Psychology, The Roland Press, pp 221-224, 1948.

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13. ABSTRACT
A majority of the experiments reported in the literature concerning functional electronic fundamentals have applied the functional principles to training for a very limited and specific area of maintenance--in some cases to only one electronic equipment. The present experiment was designed to include the fundamental tasks and concepts applicable to all of the electronic communications specialties at the time of the study. The course was organized around specially designed trainers that incorporated the desired circuits and task requirements. Considerable well spaced maintenance practice was given using common test equipment, such as, vacuum tube voltohmmeter, signal generator, and oscilloscope. The curriculum development principles and procedures as well as the results of controlled experiments are found in the report. The findings indicated that the traditional and experimental courses were equally successful in training high aptitude students (7, 8, and 9 stanines). The experimental course was much more successful, however, than the traditional course in training average aptitude students (4, 5, and 6 stanines). The job success of the average aptitude graduates who completed the experimental course was equivalent to that of the higher aptitude graduates.

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