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ELECTRICAL AND ELECTRONIC TECHNOLOGIES, JOB DESCRIPTIONS AND SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS.

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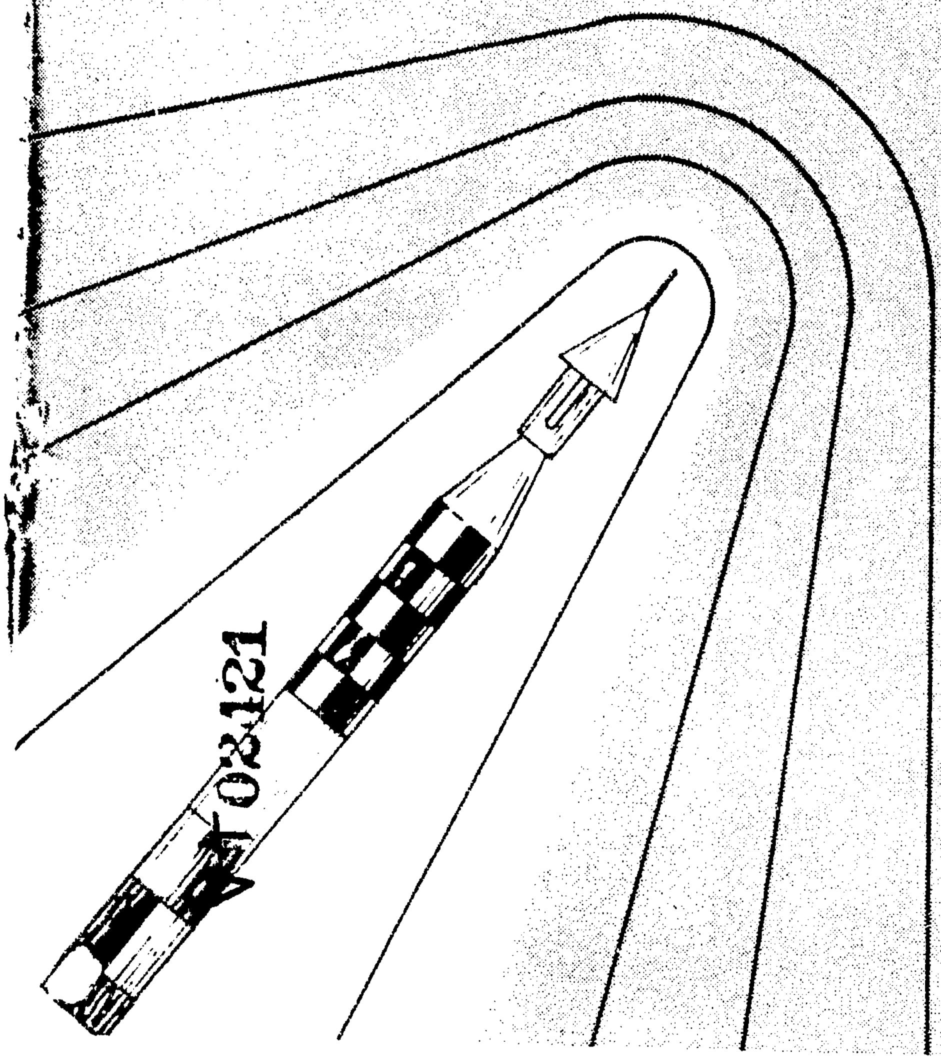
REPORT NUMBER OE-80004 PUB DATE 66
EDRS PRICE MF-$0.25 HC-$1.68 42P.

DESCRIPTORS- *JOB ANALYSIS, *CURRICULUM DEVELOPMENT, TECHNICAL EDUCATION, OCCUPATIONAL CLUSTERS, *OCCUPATIONAL INFORMATION, TRADE AND INDUSTRIAL EDUCATION, CURRICULUM PLANNING, ADULT VOCATIONAL EDUCATION, *ELECTRONIC TECHNICIANS, ELECTRONICS, ELECTRICITY, EDUCATIONAL NEEDS,

THE PURPOSE OF THIS REPORT IS TO HELP THE STATES ORGANIZE AND OPERATE PROGRAMS UNDER TITLE VIII OF THE NATIONAL DEFENSE EDUCATION ACT, P.L. 85-864. THE BASIC OCCUPATIONAL INFORMATION RESULTING FROM UP-TO-DATE JOB ANALYSIS STUDIES IS USED TO DETERMINE RELATIONSHIPS BETWEEN JOBS AND TO IDENTIFY THE SKILLS AND ABILITIES REQUIRED FOR SUCCESSFUL JOB PERFORMANCE IN THE ELECTRICAL AND ELECTRONIC TECHNICIAN OCCUPATIONS. THIS INFORMATION CAN BE USED TO ESTABLISH A WELL-BALANCED AND INTEGRATED COURSE OF STUDY TO PREPARE STUDENTS FOR A CLUSTER OF CLOSELY RELATED JOBS OR FOR A SPECIFIC OCCUPATION WITHIN THE CLUSTER. TOPICS INCLUDED ARE -- (1) THE FIELDS OF WORK, (2) JOB RELATIONSHIPS, (3) JOB DESCRIPTIONS, (4) TRAINING REQUIREMENTS, AND (5) DEVELOPING THE CURRICULUM. A TRAINING REQUIREMENTS ANALYSIS FORM ILLUSTRATES THE METHOD FOR RECORDING KNOWLEDGE AND ABILITY REQUIRED FOR EACH OCCUPATION. A LIST OF REFERENCE MATERIALS FOR DETERMINING JOB DESCRIPTIONS AND JOB RELATIONSHIPS IS PROVIDED. THIS DOCUMENT IS AVAILABLE AS GPO NUMBER FS 5.280--80004 FOR 30 CENTS FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (HC)

JOB DESCRIPTIONS AND SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS

Electrical and Electronic Technology



OE-80004

U. S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
Office of Education
Division of Vocational Education

OE - 80004
MISC. 3570-2

JOB DESCRIPTIONS AND SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS

ELECTRICAL AND ELECTRONIC TECHNOLOGIES

I The Fields of Work

II Job Relationships

III Job Descriptions

IV Training Requirements

V Developing the Curriculum

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education, Division of Vocational Education, Area Vocational Education Branch
Washington 25, D. C.

FOREWORD

Knowledge of jobs is fundamental to the planning of any occupational training program. Effective surveys aimed at determining the employment opportunities for highly skilled technicians in the labor market area served by the schools require some general understanding of the titles and duties of the jobs and the training required for job performance.

This publication, covering electrical and electronic technologies, is the second in a series of miscellanies designed to provide information to help the States organize and operate programs under Title VIII of the National Defense Education Act, P. L. 85-864.

Each publication indicates how the States can use composite job descriptions and job relationship techniques to facilitate the planning of training programs. Each publication will contain the following information and suggestions:

1. General information about a technology or broad field of work.
2. Composite job descriptions of representative occupations in a field of work.
3. A method for determining the courses of study required to prepare students for a cluster or group of closely related occupations or for a specific occupation within a group.

The individual job descriptions are illustrations of occupations found in this general field of work and are not meant to be all-inclusive. They are based upon source data resulting from occupational analysis studies made in a number of employer establishments in different parts of the nation. Therefore, they must be considered as composites which will not match exactly any single position in a specific establishment.

It should be recognized that these job descriptions represent typical areas of activity in which highly skilled technicians are engaged and should not be considered in all cases as entry jobs. Technicians who have received instruction in an organized training program for a specific technology are provided with the skills and knowledges of this field of work, but like the young medical doctor or graduate engineer, they serve a period of internship in order to learn how to apply their knowledge to technical problems likely to be encountered in the specific job to which they are assigned.

Technicians trained in electrical technology usually work in one or two major areas--the generation and distribution of electric power or the manufacture of electrical machinery, controls, and equipment. They may also work in a field of industrial electronics such as induction or dielectric heating, use of X-rays, diathermy, and ultrasonics. In such jobs their work may overlap that of the electronic technicians.

Graduates of a technical course in electronic technology may work in two broad areas--the field of communications, where they usually specialize in radio, radar, and television; or in manufacturing, where they become specialists in the design, modification, and installation of complex electronic units used in controlling and activating various mechanical systems such as analog and digital computers, servomechanisms, missile guidance systems, and machine tools; in evaluating the operating characteristics of electronic equipment; or in performing trouble shooting functions to locate and correct malfunctioning of electronic equipment. Some may be hired to work in a research laboratory engaged in experimental work for aircraft and missiles. At the outset, they may perform simple, functional tests on electronic units to become familiar with the conventions, techniques, terminology, and other factors peculiar to the industry and to the specific work assignment. They may soon test electronic units under simulated flight conditions, and later be assigned to rework, modify, or adapt electronic units to meet specific engineering and customer requirements.

Grateful acknowledgment is made to the Occupational Analysis Branch, Bureau of Employment Security, U. S. Department of Labor, for permission to publish the job descriptions contained in Section III. The job descriptions are taken in part or in whole from preliminary drafts which will be published in a more comprehensive study of technicians by the Department of Labor. The occupational information was developed from source data in the Dictionary of Occupational Titles and from occupational data developed in collaboration with the various State employment service offices which participated in the study of technician jobs sponsored jointly by the President's Committee on Scientists and Engineers and the National Science Foundation.

It should be clearly understood that these job descriptions are given as examples of closely related jobs for which vocational training can be provided and that no attempt has been made to classify them into a standard pattern which may be used for wage, hour, and skill level determinations or for jurisdictional matters.

This manuscript was prepared by Clarence E. Peterson, Occupational Analyst, Area Vocational Education Branch, who participated in the occupational analysis study of technician jobs referred to above when he was associated with the Department of Labor. In the preparation of this manuscript he was ably assisted by other members of the staff of the Area Vocational Education Branch. Special recognition is given to Lynn A. Emerson and Frank J. Coyle for their valuable suggestions and counsel.

W. M. Arnold, Director
Area Vocational Education Branch

January 1960

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INTRODUCTION

Accurate information about jobs is needed for many programs involved in the recruitment, employment, placement, training, and utilization of manpower. The nature of the job information required varies in type and approach according to the program contemplated. Regardless of its ultimate use, however, the data must be accurate, detailed, and presented in usable form.

Job analysis is the process of obtaining and reporting pertinent information relating to the nature of a specific job. It is the determination of those actions, skills, knowledges, abilities, and responsibilities which are required of the worker for successful job performance and which differentiate the job under study from all others.

Basically, there are three parts to the analysis of any job: (1) the job must be completely and accurately identified; (2) the tasks or job elements which describe the duties and worker actions required in performing the job must be complete and accurate; and (3) the knowledge and skills which are required for each job element must be specified.

There are several methods of making a job analysis. Probably the most widely used are those described in the <u>Training and Reference Manual for Job Analysis</u>, prepared by the U. S. Department of Labor (see addenda).

It is assumed that experienced personnel will be assigned to make the necessary job analyses to provide the basic data which can be translated into curriculums designed to prepare workers for a specific field of work. Therefore, it is not the purpose of this document to describe the methods and techniques for analyzing jobs. Rather, its purpose is to explain how the basic occupational information resulting from a job analysis study is used to determine the relationship between jobs and the skills and abilities required for successful job performance. Such information can be used to establish the courses of study required to prepare students for a cluster of closely related jobs or for a specific occupation within a group.

Because of the specialized nature of highly skilled technician jobs, it is essential that the data be as detailed and complete as possible. This is especially true of educational and training requirements where the skills and knowledges required for employment in these occupations should be clearly defined, for example: (1) <u>basic knowledge of physics with emphasis on</u>

mechanics, heat, sound, light, electricity and magnetism is more specific and meaningful than basic knowledge of physics; and (2) must have a working knowledge of algebra, trigonometry, analytical geometry, and vector analysis is more informative than uses mathematics in solving electrical problems.

Most of the information about technician jobs must be obtained through interviews, with little opportunity for observing the job. Some of these jobs are in classified areas or the end product being worked upon may be classified. In such cases, it may be necessary to interview the technician in a non-classified area under whatever security regulations may be in effect in the establishment where the study is being made.

A successful training program requires detailed information concerning the nature, duties, responsibilities, job elements, educational requirements, and related factors of each job for which training is contemplated. The content of the training curriculum, and the selection of trainees depend upon a thorough analysis of each job.

SECTION I

THE FIELDS OF WORK

Technicians trained in electrical and electronic technologies are employed in many industries considered necessary for national defense, such as aircraft, shipbuilding, missile research and production, automated machinery and equipment, power plants, and ordnance. Many of them are found in laboratories engaged in developmental, experimental, analytical, or testing work on equipment whose functional principles are primarily dependent upon phenomena associated with magnetism, electricity, and electrons.

While there are no statistics available as to the number of electrical and electronic technicians needed throughout the nation, all indications are that the demand for them is greater than for any other group of technicians. According to the latest figures released in the "Index of Professional Job Openings from States Agencies," issued by the Bureau of Employment Security, U. S. Department of Labor, in November 1959, 55 percent of the engineering vacancies are in the electrical and electronic field, while mechanical engineers are in second place with 32 percent. It is safe to assume that the demand for supporting personnel follows the same general pattern.

Technicians in the two fields of work described in this publication may develop and lay out electrical circuits for the production and transmission of electricity or electronic circuits used in radio, radar, and television. Some develop and fabricate jigs, fixtures, and special instruments for testing equipment; establish testing methods and procedures; test and modify or optimize prototypes of electrical, electronic, electromechanical, and hydromechanical devices and mechanisms.

Basically, the electrical technician and the electronic technician require similar educational backgrounds. Both need knowledge of the fundamentals of A-C and D-C circuits; mathematics including algebra, analytical geometry, trigonometry, and vector analysis; physics, including mechanics, heat, light and sound; drafting; strength of materials; and machine processes. Also, both should be able to use hand tools, as well as to set up, manipulate, calibrate, and interpret the readings of delicate laboratory testing equipment. The electrical technician uses galvanometers; kilowatt hour meters; voltmeters; integrating, power, power factor and phase meters; oscilloscopes; and potentometers. In addition to these, the electronic technician uses impedance bridges, vacuum tube voltmeters, signal generators, electroscopes, and "Q" meters. While the electrical technician requires only an introduction to, and general understanding of, electronic principles, the electronic technician must be thoroughly grounded in electronic theory and the application of its principles.

The Electrical Technician sometimes tests high voltage transformers and other power house or substation equipment to gather and interpret data required by electrical engineers for evaluating conformance to standards and specifications. He may also make electrical tests on solenoids, switches, relays, electric motors, generators, and other electrical devices and equipment and recommend modifications required to meet prescribed performance characteristics. He may design electrical equipment or component parts of such equipment to meet engineering specifications and customer requirements, or lay out complex electrical circuits and networks in accordance with rough sketches provided by an electrical engineer.

The Electronic Technician with specialized training in electronic theory including the purpose and use of vacuum tubes, transistors, transducers, and other electronic components, maintains, repairs, and optimizes complex devices and instruments such as digital and analog computers, photoelectric controls, fire control devices, automatic guidance equipment, and other devices used in automation. He may perform environmental and evaluation tests on complex, precision electronic systems such as airborne control and navigation systems, marine depth sounding (sonar) systems, machine tool controls, and gyroscopes. Also, he may design wired and printed circuitry to meet prescribed specifications, experimentally arranging and rearranging electrical and electronic components on breadboards and modifying circuits to obtain desired performance characteristics.

Listed below are typical occupations in defense industries where graduates of technical courses in these two fields of work are employed:

ELECTRICAL TECHNICIANS

Design Draftsman, Electrical
Development Technician, X-ray Equipment
Electrical Test and Development Technician
Electrical Experimental Technician (Aircraft)
Solenoid Technician
Test Technician (Electric Motors)

ELECTRONIC TECHNICIANS

Electronic Layout Technician
Electronic Technician, Multiplexing
Electronic Technician, Printed Circuits
Electronic Technician, Telemetering
Instrumentation Technician, Electronic
Research Technician, Electronic Systems
Test Technician, Guidance Systems
Transducer Development Technician

SECTION II

JOB RELATIONSHIPS

Before technical curriculums are established, the individual occupations for which training is needed should be identified. The next step would be to analyze each of these jobs and to prepare brief job descriptions covering the work activities, functions, and performance requirements for each occupation.

The occupations should then be arranged in homogeneous groups or clusters, and the kind and amount of basic and applied science, mathematics, etc., required to prepare workers to perform the duties of the job included in each grouping, should be specified.

The procedure used in determining the similarities in jobs and the common worker knowledges and abilities involved is called the job relationship technique. The criteria used by industry for establishing job relationships vary. However, all or most of the following factors are used in establishing the homogeneous groups or job clusters referred to in this bulletin:

a. The similarity of work performed.

b. The abilities and knowledges required of the worker for successful job performance.

c. The pattern of worker characteristics required by the job, such as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment.

d. The tools, machines, instruments, or other equipment used on the job. Also the reading and interpreting of blueprints, or the use of special measuring devices which may be involved.

e. The basic material worked on or with. Occupations may involve working with more than one material or working with the same material in different forms.

Not all of the factors are matched exactly nor found to be the same for all jobs being considered. However, most of the factors should be present and analagous in a cluster of related jobs. For example, in developing the relationships of jobs found in the broad field of drafting and design, it is readily apparent, when using the criteria shown above, that the electrical draftsman and the mechanical draftsman have only one factor in common--that of drawing. The abilities and knowledges required for successful job performance and the basic materials worked upon or with are totally dissimilar. The mechanical draftsman prepares drawings for mechanical devices. He must know how to calculate such engineering details as angles, strength-weight ratios, and how metals react under extreme temperature changes. He must be familiar with the working properties of metals, metal alloys, and other materials, as well as with machine shop operations and practices. On the other hand, the electrical draftsman prepares plans and wiring diagrams. His knowledge must encompass electricity and magnetism, circuitry, and other factors related to electrical engineering. Therefore, it is evident that these two jobs are not closely related and do not belong in the same cluster or major grouping.

At first glance, it would seem that the electrical technician occupations and the electronic technician occupations are closely related. Such worker characteristics as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment are common to both fields of work, but they also apply to most highly skilled technician jobs. It is true that they both require technical knowledge of electricity and a background in physics and mathematics. Yet a careful analysis of the two occupational categories indicates that some of the factors are not analagous and that there are two distinct fields of work.

A technician trained in electrical technology is usually involved in the production and distribution of electric power or in the manufacture of electrical machinery and equipment, such as motors, generators, convertors, regulators, switchgear, and welding equipment. He has to know the principles and theory of electricity. He also needs a background in applied mathematics and physics. He should have an introduction to electronic principles and their application to power systems and related control and protective devices. In the production and distribution of electric power, his work may include planning and supervising construction and operation of electric-power generating plants, high voltage transmission lines and distribution systems; and with construction and installation of illumination, wire communication, and electric transportation systems. In manufacturing, he may help to design and produce anything from huge generators which produce power for industrial establishments and communities to appliances that convert power into light, heat, sound, and mechanical power.

Electronic technology deals with the design and application of electron tubes, transistors, transducers, and related solid state devices. The electronic technician may be involved in communication (radio, radar, television, and telephony) or in the manufacture of electronic systems and components. Unlike the electrical technician who works with comparatively large machines and equipment, including high tension systems, the electronic technician works with high frequencies and microwaves, and low current power packs where miniaturization is the rule rather than the exception. In addition to the fundamental knowledge of electricity, these technicians must have knowledge of the theory and practical use of photo tubes, amplifiers, rectifiers, thyratron tubes, and voltage regulator tubes. Besides knowing how to use a voltmeter, ammeter, and wattmeter, these workers must be proficient in the use of the signal generator, multimeter, ohmmeter, and cathode ray oscillators. Since they are concerned with automation, they must work with equipment requiring extremely close precision in the regulation of voltage, current, frequency, speed, acceleration, and deceleration, utilizing selsyn motors and amplidyne generators. They must be able to read, understand, and interpret electrical circuit diagrams involving the use of electronic control tubes in order to diagnose and correct operational difficulties.

The following examples illustrate a procedure for comparing a number of electrical and electronic technician occupations in order to arrive at a cluster of related jobs.

After a preliminary study and careful analysis of a number of jobs in each of the two fields of work, the job of Electrical Test and Development Technician was selected as the key job in the field of electricity, and a comparison was made of the characteristics of other technician occupations to determine the interrelationship. The characteristics or job elements of all of the jobs being considered were identified by job analysis and those which were common to most of the jobs in the field of work were used. Form "A" provides a graphic illustration of the relationship between these various jobs. A close look at this form discloses that all of the elements from A through E are present in the key job and most of them are present in the related jobs. It will be noted that only five of the seven elements are present in the job of Solenoid Technician. Usually, if less than half of the elements are found to exist in a particular job, the relationship would not be close enough to warrant its inclusion in the cluster or major grouping.

Secondly, the job of Research Technician, Electronic Systems, was chosen as the key job in the electronic field and the characteristics of other technician occupations in this field were compared to determine their interrelationships. Another look at Form "A" shows that all of the elements from G through K are present in this key job and that most of them are found in the related jobs. The job factor or job element F is common in both fields of work.

Form "A" also reveals that most of the factors found in the electrical field are not present in the electronic occupations or vice versa. Therefore, it is evident that there are two distinct fields of work which should be treated as separate technologies.

It should be recognized that Form "A" is the result of a study in which a great number of occupations were compared to determine interrelationships. Only those found to be closely related in each of the two fields of work have been actually entered on the form.

Form A. - JOB RELATIONSHIPS

Symbols:

X - Requires full capability
S - Requires partial capability

Example: Electrical Technician may be required to read and understand simple electronic wiring diagrams and have some knowledge of electronic principles

	A Ability to read and understand complex electrical wiring diagrams	B Ability to design, modify, install or maintain electrical machinery and equipment	C Ability to apply mathematical and scientific principles toward the solution of electrical problems	D Ability to diagnose and correct malfunctioning of electrical machinery, equipment, and controls	E Ability to plan, set up, and/or conduct environmental and/or performance tests on electrical components or units	F Ability to interpret test results and to prepare technical drawings, charts, graphs and reports for use of engineers and scientists	G Ability to read and understand complex electronic wiring diagrams	H Ability to design, modify, install, construct, or maintain electronic apparatus and test equipment	I Ability to apply mathematical and scientific principles toward the solution of electronic problems	J Ability to diagnose and correct malfunctioning of electric systems and controls used in automation, communications and industrial equipment	K Ability to plan, set up or conduct experimental and/or performance tests on electronic components or units
KEY JOB: (Electrical)											
Electrical Test & Development Technician	X	X	X	X	X	X					
RELATED JOBS:											
Development Technician, X-ray Equipment	X	X	X	X	X	X	S				
Design Draftsman, Electrical	X	X	X	X			X				
Test Technician (Electric Motors)	X	X	X		X	X					
Experimental Technician (Aircraft)	X	X		X	X		S				
Solenoid Technician	X	X		X	X	X					
KEY JOB: (Electronics)											
Research Technician, Electronic Systems	X	X				X	X	X	X	X	X
RELATED JOBS:											
Electronic Technician, Printed Circuits						X	X	X		X	X
Electronic Technician, Multiplexing	X					X	X	X	X	X	X
Electronic Technician, Telemetering	X					X	X	X	X		X
Electronic Layout Technician	X				X	X	X	X	X	X	X
Transducer Development Technician	X				X	X	X	X	X	X	X
Test Technician, Guidance Systems	X				X	X	X	X	X	X	
Instrumentation Technician, Electronic	X				S	X	X	X		X	X

SECTION III

JOB DESCRIPTIONS

The job descriptions included in this section are representative of the occupations found in the two fields of work and are not meant to be all-inclusive. These descriptions are based on source data assembled from various parts of the country. Since they reflect the occupational situation as it exists in a variety of plants and localities, they must be considered as composites and may not coincide exactly with any single position in a specific employing establishment. However, these descriptions can be readily adapted to fit individual organizational patterns and needs.

Each job description identifies and describes the principle elements of the job and the training and experience required for successful job performance. The job duties and performance requirements for closely related occupations vary from plant to plant and from one industry to another. However, these job descriptions should be useful in identifying technician jobs in the two fields of work covered in this publication. Also they can be used for comparison purposes, which may eliminate the need for time-consuming job analyses of certain occupations. In many cases, the plant job may reveal only minor differences from those shown in one of these job descriptions. In this event, only the differences in job content need be considered. Even in the case of major differences, many of the technician jobs for which training is required will undoubtedly fit into the general framework of the job description.

DESIGN DRAFTSMAN, ELECTRICAL

Prepares detailed drawings and circuit diagrams, from rough sketches or verbal instructions furnished by engineers or designers, to be used in the erection, installation, and manufacture of various types of electrical machinery and equipment such as motors and generators; convertors and rectifiers; transformers and regulators; switchgear; and welding equipment for power plants, manufacturing establishments, or buildings. Makes modifications in drawings as required by engineering changes. Suggests design changes to be made to overcome difficulties encountered in the assembly or installation of the equipment or machinery, utilizing knowledge of machines, electrical and mechanical engineering principles, mathematics, and mechanics to make any adjustments or changes necessary or desired.

The job requires two years of post-high school training in electrical technology, which should include study of A-C and D-C circuits and electrial drafting and design; a working knowledge of the use of machine tools; a thorough knowledge of arithmetic, algebra, trigonometry, and use of the slide rule. Worker must be able to visualize relationship between component parts and relationship of parts to the completed structure, and he must have working knowledge of the strength of materials and machine design.

DEVELOPMENT TECHNICIAN, X-RAY EQUIPMENT

Performs experiments on engineering models of new or redesigned medical, dental, and industrial X-ray equipment to evaluate performance under normal or unusual operating conditions, and suggests design revisions to improve performance, durability, ease of assembly, and cost of manufacture of proposed equipment. Develops working procedures and sequence of operations to be followed in building an engineering model of new or revised X-ray unit or auxiliary equipment, such as milliamperage generators, full-wave transformers, control panels, high voltage supply units, and medical diagnostic units, working from general instructions from, and discussions with, a project engineer. Develops and expands rough engineering sketches into detailed sketches, schematics, and wiring diagrams, and designs new circuits to improve overall performance and ease of operation. Makes sketches and prepares specifications of parts to be built or modified by mechanics. Prepares sketches showing arrangement of parts within subassemblies or circuits to assure adherence to predetermined outside dimensions. Assembles or supervises assembly of parts and circuits, using electrician's or mechanic's hand tools. Develops test setup; installs test instruments such as ammeters, watt and volt meters, and oscilloscopes; and attaches completed model to standard X-ray machine or laboratory mockup. Converts instrument recordings, using algebraic equations and standard engineering formulas to determine heat storage and cooling capacity of X-ray tubes. Evaluates performance of models constructed and tested and sketches new parts, circuits, or layouts to improve performance and durability of product. Prepares written report of project including working procedures, sketches, diagrams, charts, graphs, and schematics used, test performed, and modifications made. May write technical description of new products, outlining basic mechanical and electrical specifications to be used in the preparation of product data sheets and technical bulletins.

Educational background for this job can be acquired through two years of technical institute type training in electrical technology. Worker must know electrical and electronic theories as applied to construction and operation of X-ray equipment. Mathematical background through trigonometry is required for making test data calculations concerning theoretical life expectancy of performance and materials. Knowledge of machine shop operations is also required. Several years of on-the-job training and experience are required to acquire sufficient knowledge of the design, construction, and application of X-ray equipment, related auxiliary controls, and components to evaluate new designs and to make modifications needed to improve operating characteristics.

ELECTRICAL TEST AND DEVELOPMENT TECHNICIAN

Tests high voltage transformers, substation grounding grids and tower footings, line components, and magnetic oscilloscopes to gather and interpret data required by engineers for conformance to standards and specifications. Performs tests on transformers following verbal instructions from engineer or schematic diagrams and procedures in the American Standards Association manual. Connects portable generators and instruments, such as voltmeters, ammeters, power factor test sets, and temperature recording devices, to transformer and regulates voltage and current of generator to specified level for testing. Records instrument readings and observes transformer for any sign of insulation, dielectric, or part failure as indicated by excessive noise or smoke. Computes impedance, turns ratio, and power factor, using engineering formulas and knowledge of algebra and trigonometry. Performs ground resistance tests at substations to determine adequacy of grounding grids and tower footing by hammering electrodes into ground at prescribed distance from installation and measuring ground resistance from each electrode to installation. Plots distance-resistance curve and computes difference of potential between installation and ground at each check point. Tests line components, such as power cable, cable connectors, and fittings, for conformity with specifications and to study effects of environmental conditions such as heat, dampness, and cold. Tests magnetic oscilloscopes for such characteristics as accuracy and frequency response, using generators, transformers, and recording instruments. Designs and draws rough schematic diagram of electrical circuits needed for tests following engineer's oral instructions. Prepares graphs and charts of all test procedures and results, and submits them to engineer for final interpretation and evaluation.

Two years of post-high school training in the following subjects is usually required for this job: Algebra, trigonometry, vector analysis; physics including mechanics, heat, electricity and magnetism; electric wiring; A-C and D-C circuits; electrical measurements; electrical design; and strength of materials. One year of on-the-job training is usually sufficient for graduates of schools offering technical institute type training in electrical technology.

ELECTRICAL EXPERIMENTAL TECHNICIAN (AIRCRAFT)

Assembles, installs, and tests electrically controlled mechanisms, wiring, and other electrical equipment on experimental airplanes. Tests generators, lighting and ignition systems, switches, and other electrical controls after they are assembled and installed to be sure that they are functioning efficiently. Diagnoses and corrects malfunctioning of electrical equipment or systems by adjusting, reworking, or replacing faulty equipment. Recommends engineering changes or modifications to electric system on experimental airplanes to improve performance or reduce manufacturing cost. May service and trouble shoot electrical equipment at control tower.

Job requires knowledge of the scientific principles and mechanical laws that apply to electrical work, including the principles of construction, installation, and maintenance of electrical equipment; proficiency in the use of electrical controls and measuring instruments; and ability to modify or redesign faulty equipment or circuitry. Two years of training beyond high school with courses in algebra, trigonometry, geometry, vector analysis, electrical theory, and analysis of electrical circuits plus one year's practical experience in the aircraft industry will prepare a worker to perform the job duties.

SOLENOID TECHNICIAN

Makes electrical tests on solenoids and recommends design changes required to meet prescribed performance characteristics. Reviews and analyzes engineering and customer specifications to determine kinds of tests required to test performance characteristics of existing and proposed solenoids. Selects and connects testing equipment, meters, and other instruments in required circuits and applies specified amount of current and voltage to make electrical tests to determine such characteristics as resistance, insulation breakdown, and duty cycle. Sets up, adjusts, and regulates equipment to test magnetic force of coil when current is applied. Performs experimental tests to develop new solenoids which will possess specific performance characteristics. Recommends changes in design and construction of prototypes as a result of tests. Interprets test data and prepares characteristics curves, using mathematics including algebra, geometry and trigonometry to make calculations. Submits reports of tests to engineers in charge of project.

Two years of training in electrical technology are required for this job, which should include algebra, trigonometry, vector analysis, mechanics, electric wiring, electrical measurement, electrical and machine design, drafting, heat and strength of materials. Graduates of such a course can usually be trained on the job in 3 to 6 months to interpret test data to prepare characteristics curves needed in recognizing limitations of existing electromagnetic devices and in suggesting modifications for improving their performance.

TEST TECHNICIAN (Electric Motors)

Tests experimental and production A-C and D-C electric motors to assure conformity to engineering specifications and customer requirements. Conducts tests specified by engineering department and modifies them, if necessary, to determine durability of product under simulated customer usage. Prepares test data reports and submits them to engineering department with recommendations for improving the product. Visually examines engineering drawings and specifications and compares dimensions and tolerances of parts and assemblies with those of the drawings to determine conformity with engineering specifications. Maintains engineering prints by checking incoming prints of newly designed motors for accuracy. Suggests necessary modifications required to correct errors in computing and recommends design changes which will facilitate production. May draft design of parts and complete assemblies for fractional and low horsepower motors.

Job requires knowledge of mathematics, including algebra, trigonometry, analytical geometry, and vector analysis, which is needed in the solution of electrical problems; ability to apply principles of electricity, mechanics, and design in checking drawings; ability to set up equipment for experimental purposes; proficiency in the use of controls and electrical measuring instruments; and skill in making technical drawings and writing reports that enable the worker to communicate his ideas effectively to others. Usually two years of technical training, including the study of electrical theory and laboratory analysis of circuits, plus one year of practical experience in industry will prepare a worker to perform the duties of this job.

ELECTRONIC LAYOUT TECHNICIAN

Lays out printed or wired circuits and prepares diagrams to illustrate circuitry for electronic systems such as aircraft and missile guidance, fire control, radio, television and radar communication, and electronic computers. Discusses function and purpose of proposed system with project engineers and prepares schematic diagram of proposed circuitry to meet engineering specifications. Indicates standard and special components and subcircuits, showing their relationship to each other and to the complete system, taking into consideration such factors as the position and location of servocontrol circuits, heat dissipation of vacuum tubes, amount of current to determine wire sizes, and the possibility of interacting signal pickup between circuits. Assembles or supervises others in the breadboarding and testing of circuits and components. Analyzes recorded data to determine need for modifications and makes circuitry layout changes to effect desired functioning and to optimize circuit performance. Makes full- or half-scale drawings of approved wiring diagrams for engineering reference handbooks, and revises standardized wiring diagrams to incorporate engineering changes. May design printed layouts to be maintained within prescribed size limitations (packaging) for use in guided missiles or laboratory test equipment. May test or direct the testing and recording of test results of the completed printed circuit board's performance. Interprets recordings of test equipment (oscilloscopes, voltmeters, ammeters, and brush recorders) and records results of calculations on appropriate forms for consideration by engineers.

Workers on this job must know how electronic circuits function, how and to what extent the packaging of circuits into limited space will affect the effectiveness of components, how to correct malfunctioning, and how to interpret and calculate test results as recorded on electronic test equipment. Such educational background is usually acquired through two years of rigorous, post-high school training in electronic technology. For successful job performance, two to three years of experience in solving a variety of research problems in connection with industrial problems are usually required.

ELECTRONIC TECHNICIAN, MULTIPLEXING

Works directly under physicist assigned to special research problems concerned with simultaneous transmission or reception of two or more messages between monitoring station and missile or satellite, using common carrier wave (multiplex transmission). Conducts research and analyzes experimental work done by others in developing multiplexing equipment of usable size. Studies rough sketches of experimental circuit prepared by the scientist and consults with him to become thoroughly familiar with the objectives of the experiment. Lays out one or more experimental circuits to test the scientist's theories, using knowledge of transistors and other semiconductor devices and following rough sketches as guide lines. Performs tests to evaluate functional operation and feasibility of experimental circuits, using pulse and sweep generators, vacuum tube voltmeters, oscilloscopes, frequency meters, and similar electrical and electronic test equipment to measure both electrical and nonelectrical quantities. Modifies circuitry to correct any malfunctions or to improve its operational characteristics; informs scientist of progress made; and obtains approval for futher modifications, if necessary. Prepares plans to be used by metal, glass, or chassis shops for assembling working models designed to incorporate best features of experimental circuits, using knowledge of the fundamentals of engineering drawing and experience with the layout of circuit diagrams. Prepares drawings of special component parts to be fabricated, using knowledge of shop techniques to overcome production problems which may be encountered. Performs tests to evaluate performance of working models. Prepares test data and charts indicating operating characteristics under each of the test conditions to which models were subjected. Directs attention of scientist to any peculiarities in circuit design and function, suggesting possible changes in future working models.

Most employers prefer graduates of technical institutes who have completed curriculum in electronic technology for this work. Besides other courses covered in such curriculums, algebra, vector analysis, electron physics, and an introduction to calculus are desirable. Workers meeting the educational requirements usually start to produce immediately on this job. The scientist and technician usually work together as a team and one learns from the other. In some projects neither the scientist nor the technician are familiar with the untried principles involved. In such cases they do research to learn what others have done in the field and to familiarize themselves with the subject.

ELECTRONIC TECHNICIAN, PRINTED CIRCUITS

Develops and lays out diagrams to provide patterns for printed circuits used in miniaturized packaging of electronic units in guided missiles or in other electronic equipment. Lays out diagram of printed circuit on graph or drawing paper to show position and location of individual circuits and components. Determines, through experience and by trial and error methods, the arrangement of components in layout, considering such factors as most effective use of space, effects of heat from other parts or units, voltage between parallel circuit lines, type of current, signal pickup or interference from generative units, and the effect of vibration. Inks in final circuit on Bristol board for photographing to produce a negative to be used as a pattern in etching circuits electrolytically on copper-sheeted dielectric board. Assembles or supervises assembly of final unit by soldering or otherwise fastening such components as tubes, resistors, coils, potentiometers, and rectifiers to prescribed positions on printed circuit board. Tests completed unit, using voltmeters, ammeters, and oscilloscopes to measure output and other performance characteristics. Interprets and records test readings and submits data to engineer. Suggests changes or new designs to engineer in order to improve performance of unit. May fabricate jigs, spacers, holders, and clips.

For this job, two years of training beyond high school are usually required. Curriculum should include electronic theory, circuitry, drafting, and shop mathematics, as well as familiarity with machine shop tools and equipment and familiarity with etching techniques.

ELECTRONIC TECHNICIAN, TELEMETERING

Develops, sets up, and evaluates experimental instrumentation systems used in connection with telemetering research and development. Makes plans to test proposed and commercial telemetering instrumentation systems to determine best modulation scheme for transmitting radar pulses from a missile in flight or from a distant test station and for receiving them at the ground test station or laboratory via a radio link. Sketches instrumentation setup including circuitry and standard or special test instruments required to determine best methods for detecting, amplifying, and transmitting the data in the form of radar impulses. Selects and assembles electrical and electronic test instruments and accessories such as radio frequency and video transmitters, radio receivers, spectrum analyzers, audio oscillators, wave form generators, tape recorders, oscillographs, and photographic equipment. Breadboards various possible solutions to the problems, using available equipment such as transformers, manometers, transistors, vacuum tubes, coils, pressure gages, and transducers and bolting, soldering, or riveting components to form a telemetering system. Evaluates experimental telemetering systems by sampling several types of test data relayed between missile and laboratory, setting up various known values of modulation. Makes comparisons of experimental systems and commercially available telemetering systems to determine which modulation setup produced desired data. Prepares reports to be used by engineers in further experimental work.

Education and training required for this job are usually acquired by two years of post-secondary school training specializing in electronic technology. Job requires a thorough understanding of the accuracies, capabilities, limitations, and operation of a wide variety of electronic test instruments; the ability to calibrate, and repair such instruments and to lay out circuitry for, and to construct, special electronic test equipment not commercially available. Workers must have ability to use small hand tools for very fine work approaching that of a watch repairman, in remodeling, repairing, and constructing electronic test instruments and assembling these and other components and parts into telemetering systems. A worker with suitable educational background in electronics usually requires one to two years of experience in research and development work and several months of on-the-job training in connection with telemetering problems for military aircraft, missiles, and rockets.

INSTRUMENTATION TECHNICIAN, ELECTRONIC

Plans setups and determines instrumentation required for measuring the effectiveness of aircraft and missile circuitry and servomechanisms, rocket ignition timing, electronic telemetering and guidance systems, and for a variety of electronic components and systems used in connection with such devices as automated office and production equipment. Obtains information from sponsoring engineer concerning equipment to be tested, purpose of the tests, and accuracies required. Visits test site to evaluate existing test stands, and clamping and supporting devices for securing recording instruments and units to be tested, activating equipment (motors, pulleys, electric power supply, etc.), and instruments, such as theromocouple probes, inductance and capacitance bridges, oscillators, power amplifers, oscilloscopes, filters, voltmeters, tachometers, and, if necessary, photographic equipment and optical instruments needed to record readings at some distance from hazardous testing areas. Redesigns or modifies test equipment or instrumentation to assure accuracy of test results if available equipment fails to meet required standards. Calibrates instruments to be used in tests and directs setting up of test equipment. Checks test setup by connecting it to activator and observing action of instruments and recording devices. Participates in instrumentation research in designing and developing circuitry for test recording instruments not commercially available and to improve existing instrumentation methods. May set up instrumentation and conduct complex tests, and may write operating and maintenance manuals for newly developed instrumentation.

Workers on this job must know how to apply electronic theory in redesigning circuitry and in laying out electronic circuits. Job also requires application of electromagnetic and mechanical principles and theories of vibration, laws of friction, magnetism, and magnetic induction. Workers must have understanding of accuracies, capabilities, limitations, and operation of a variety of electronic test instruments. Also requires application of mathematics, including trigonometry to determine angle of phase lag and algebra to calculate inductance and capacitor reactance, and power consumed. Must be able to use small tools similar to those of a watch repairman in remodeling, calibrating, and repairing electric and electronic test instruments. Education for this job is usually acquired through two years of post-secondary school training in electronic technology. For successful job performance, two to three years of intensive on-the-job training and experience in a specialized field of instrumentation are required.

RESEARCH TECHNICIAN, ELECTRONIC SYSTEMS

Develops and designs electrical and electronic systems used in controlling or activating various mechanical systems such as analog and digital computers, servomechanisms, missile guidance systems, machine tools, and the like. Studies sketches, schematic diagrams, and engineering specifications to determine circuitry and components needed to meet engineering and customer requirements. Selects components from stock or from catalogs and issues requisitions for parts to be purchased. Designs special component parts which cannot be purchased, and fabricates or directs others in fabricating them, using simple hand tools and machines such as milling machines, drill presses, lathes, and grinding equipment. Assembles and wires purchased and fabricated parts onto breadboard, to experiment with and test arrangement of parts until maximum performance is achieved. Conducts performance and environmental tests, using such standard equipment as voltmeters, frequency analyzers, frequency oscillators, ammeters, and oscilloscopes. Analyzes test data and writes summaries of tests for engineering department. Employs drafting technique and equipment in making drawings of final circuit for engineer's approval. Adjusts, calibrates, and maintains testing equipment. May install prototypes in customer's plant or laboratory and may instruct personnel in operation and maintenance of unit.

Job usually requires two years of post-high school training in electronic technology, which should include mathematics through trigonometry, electronic theory, circuitry and measurements, drafting, and physics with emphasis on mechanics, hydraulics, and pneumatics. Usually two years of informal and individualized on-the-job experience are required before a technician attains sufficient ability for relatively independent research.

TEST TECHNICIAN, GUIDANCE SYSTEMS

Performs electrical, mechanical, and environmental tests of prototype sections or complete units of missile guidance systems to evaluate conformance with engineering specifications and to recommend design or construction changes to achieve optimum efficiency and performance. Determines number and types of tests required and special test equipment needed to meet test objective by examining schematic drawings, diagrams, and specifications of gyroscope and servomechanism prototypes to obtain clear understanding of their operation and functions and of the interrelationship of their component parts. Designs and prepares drawings and specifications of special test equipment to be used, submitting drawings, after approval by engineer, to fabrication unit for construction of the panels, chassis, and other metal parts. Lays out circuits, obtains electronic components, and sets up test equipment, using hand tools such as pliers, soldering iron, hand drill, cutters, and screw drivers. May use small lathe. Transmits signal with signal generating equipment, such as oscillators, to activate or energize mechanical components of prototype. Observes and records action resulting from injected signal, using oscilloscopes, 4-channel Sanborn recorder, and meters. Analyzes results of tests to determine location of components that require modification or replacement to achieve optimum performance of prototype. Makes changes where necessary in layout of circuitry and components to increase efficiency of prototype. Revises drawings and specifications to reflect those modifications for use on construction of next prototype. Prepares reports for use of engineers and prepares instructions and procedures describing techniques and special equipment developed for the tests for use in future tests.

Job requires a minimum of two years post-secondary school education in electronic technology, which should include general and advanced applied mathematics such as algebra, analytical geometry, trigonometry, use of slide rule, vector analysis, and use of mathematical tables; direct and alternating current (theory and applications); ultra-high frequency techniques; mechanics; heat, light, and sound; and technical writing and engineering drawing. For graduates of schools providing such courses, two to three years of experience in electronic testing are usually required.

TRANSDUCER DEVELOPMENT TECHNICIAN

Conducts experiments to develop, modify, and improve magneto and piezoelectric transducers used in the application of ultrasonic and underwater reflecting devices. Develops and constructs magnetoelectric and piezoelectric transducer models from rough sketches provided by engineer or scientist, using knowledge of electrical engineering principles and properties and characteristics of ceramics and magnetostrictive metals. Selects crystalline elements, such as quartz crystals, Rochelle salts, or barium titanate, to be used for changing electrical to mechanical energy; determines construction, shape, and dimensions of piezoelectric elements required to produce the frequency of resonance specified by engineer or scientist. Fabricates or works with shop mechanics in the frabrication of these elements, using diamond grinding wheels to produce desired shapes and drills to make required holes. Draws or has draftsman draw accurate dimensional drawings of jigs, fixtures, or molds needed by machine shop for constructing component parts and casings in which components will be housed in the transducer model, following rough sketches provided by engineer and scientist. Sets up and operates equipment to be used for acoustical, mechanical, and electrical testing of transducer prototypes. Uses various electrical and electronic testing devices to measure beam patterns, A-C or D-C resistance and similar tests. Measures electrical characteristics of component parts or of complete unit, using vacuum tube voltmeters, oscilloscopes, frequency counters, and impedance bridges. Varies power input by means of power amplifiers, preamplifiers, and similar equipment to check effect on width of beam or strength of signal. Records data gathered during test run to provide reliable information for evaluating performance of prototype and for comparison purposes. Prepares reports on results of project for engineer or scientist in charge so that final evaluation of prototype can be made. May suggest modifications which would increase over-all efficiency of transducer.

Most companies prefer two years of post-secondary training in electrical or electronic technology. The minimum education requirements found for these jobs are four years of technical high school training in electrical technology plus two years of intensive on-the-job training under an engineer or scientist, working with piezoelectric and magnetostrictive elements in environmental testing, underwater sound measurement, and electronic measuring devices.

SECTION IV

TRAINING REQUIREMENTS

If the purpose of a training program is to prepare workers for a single occupation, the content for such a program is derived from the analysis of that specific job. However, if the program is designed to prepare workers for a cluster of closely related jobs, the content emanates from analyses of all of the jobs in the cluster. In the latter case, it is necessary to assemble the occupational data; compare the elements or characteristics of the various jobs; determine the elements that are common to the several jobs; ascertain the skills and knowledges required for their performance; and develop a reasonably complete composite list of the skills and knowledges needed for all the jobs in the cluster. From this list, the specific courses of study which make up the curriculum are developed.

The job descriptions contained in Section III of this publication, augmented by the individual job analyses made by the State, will provide much of the data needed for this purpose. The first paragraph in each job description describes the work performed, i.e., what the worker does and why he does it. The last paragraph covers performance requirements and provides information about the skills, knowledges, and abilities required of the worker in performing the job duties.

Form "B" illustrates a method for recording the skills and knowledges for each of the jobs in the major grouping. The subheadings on the form--"Electrical Technology" and "Electronic Technology"--are the fields of work.

The first column lists the subject matter areas generally recognized as basic in a training program for occupations in each field of work. It is probable that other subject matter areas will be found which belong in this cluster of related jobs. It should be recognized that the determination of the subject matter required for successful performance on each of the occupations listed depends upon the adequacy of the source data obtained through job analysis, and the ability of the person preparing the form to interpret these data.

The job titles for which job descriptions have been included in Section III head up the other columns. If the job descriptions indicate that a knowledge or skill in a certain area is essential, the letter "E" should be entered. If it is not absolutely essential but advisable for a worker to receive instruction in a specific area, the letter "A" should be entered. The following example illustrates how the data in a job description can be used:

The work performed section of the job description for Test Technician (Electric Motors) indicates that the worker requires knowledge of A-C and D-C circuits, A-C and D-C machines and controls, and skill in the use of electrical measuring instruments in order to evaluate performance characteristics of electric motors; that he must have knowledge of mechanical and electrical drafting, and machine design in order to compare dimensions and tolerances of component parts with those of the engineering drawings to determine conformity with engineering specifications and to recommend design changes to improve product performance; and that he should be familiar with machine shop operations and practices in order to recommend design modifications which will facilitate production. From this information, the letter "E" is entered for A-C and D-C circuits; A-C and D-C machines and controls; electrical instruments and measurements; mechanical and electrical drafting; machine design; and machine shop operations. In most cases, it is assumed that he should be familiar with the National Electric Code so an "E" is also entered opposite this item.

The performance requirements section states specifically that instruction is required in algebra, trigonometry, analytical geometry, and vector analysis as needed in the solution of electrical problems. Based on this information, an "E" is entered opposite arithmetic, algebra through quadratic equations, trigonometry (right triangle), and analytical geometry. Also, it is clear that the ability to apply principles of electricity, mechanics, and design; proficiency in writing technical reports; and skill in the use of small hand tools are required for successful performance on this job. Therefore, an "E" is entered opposite mechanics and the applicable headings under mechanics, which, in this case would be statics, dynamics, kinematics, and kinetics; and "E" is also entered opposite physics and its subheadings, electricity and magnetism, and heat, light, and sound. Also, it seems advisable to enter an "E" opposite technical writing and use of small hand tools as they appear to be important parts of this job.

The nature of the work and the industry in which a job under study is found usually suggests to an experienced analyst other subjects which might be helpful to a worker on this job. In some cases, it may be found that industry supplies training in these areas, and in others, it may not be advisable for the school to set up special courses in these areas because of limited demand for such skills in the employment market or lack of facilities in the school. The completed charts (Form B - 1 and 2) serve the following purposes:

1. They indicate the knowledges and skills needed by workers to perform the duties of the occupations listed.

2. They identify the subject matter areas that are common to several jobs in the cluster, and the relative frequency of these items.

3. They provide, in convenient form, a composite list of the subject matter areas that should be considered when building the training curriculum and the specific courses of study.

FORM B. - TRAINING REQUIREMENTS ANALYSIS

SUBJECT MATTER AREAS REQUIRED (Instruction must be given in the application of science and mathematics) Symbols: A- Advisable E- Essential	1. Electrical Technology Electrical Test & Development Technician	Development Technician, X-ray Equipment	Design Draftsman, Electrical	Electrical Experimental Technician (Aircraft)	Solenoid Technician	Test Technician (Electric Motors)
ELECTRICITY						
A-C Circuits	E	E	E	E	E	E
D-C Circuits	E	E	E	E	E	E
A-C Machines & Controls	E	E	E	E	E	E
D-C Machines & Controls	E	E	E	E	E	E
Electrical Power Systems	E	E	E			
Electrical Equipment Maintenance	E	E		E		
Electrical Instruments & Measurements	E	E		E	E	E
Fundamentals of Electronic Circuitry	A	E	A	A		
MATHEMATICS						
Arithmetic	E	E	E	E	E	E
Algebra through Quadratic Equations	E	E	E	E	E	E
Trigonometry (right triangle)	E	E	E	E	E	E
Logarithms & Slide Rule Usage	E	E	E	E		E
Analytical Geometry	E		E	E	A	E
Descriptive Geometry	E		E			
Introduction to Calculus	E					
Cost Analysis and Estimating		A		A		
SCIENCE						
Physics:						
Electricity & Magnetism	E	E	E	E	E	E
Heat, Light and Sound	E	E		E	E	
Mechanics:						
Statics & Dynamics	E	E		E		E
Kinematics	E					E
Kinetics	E					
Mechanics of Materials	E	E	E	E	E	
ADDITIONAL KNOWLEDGES & SKILLS						
Mechanical Drafting		E	E		E	E
Electrical Drafting	E	E	E	A	E	E
Machine Design		A	E		E	E
Machine Shop Operations & Practices 1/		E	E		A	
National Electric Code	E		E		E	E
Strength of Materials	E	E	E	E	E	
Use of Hand Tools	E	E		E	E	E
Technical Report Writing	E	E				E

1/ This should not be construed to mean skill in the operation of machine tools. It means familiarity with machine shop operations and practices.

FORM B. - TRAINING REQUIREMENTS ANALYSIS

SUBJECT MATTER AREAS REQUIRED (Instruction must be given in the application of science and mathematics)

Symbols: A- Advisable
E- Essential

	2. Electronic Technology							
	Research Technician, Electronic Systems	Electronic Layout Technician	Electronic Technician, Multiplexing	Electronic Technician, Printed Circuits	Electronic Technician, Telemetering	Instrumentation Technician, Electronic	Test Technician, Guidance Systems	Transducer Development Technician
ELECTRICITY & ELECTRONICS								
A-C Circuits	E	E	E	E	E	E	E	E
D-C Circuits	E	E	E	E	E	E	E	E
Basic Electronics	E	E	E	E	E	E	E	E
Industrial Electronics	E	E	E	E	E	E	E	E
Electronic Circuit Tracing	E	E	E	E	E	E	E	E
Electronic Circuit Design & Analysis	E	E	E	E	E	E	E	E
Radio Frequency Circuits	E	E	E	E	E	E	E	E
Television Circuits	E	E	E	E	E	E	E	E
Electrical & Electronic Instruments	E	E	E	E	E	E	E	E
MATHEMATICS								
Arithmetic	E	E	E	E	E	E	E	E
Algebra through Quadratic Equations	E	E	E	A	E	E	E	E
Trigonometry (right triangle)	E	E	E	A	E	E	E	E
Logarithms & Slide Rule Usage	E	E	E	A	E	E	E	E
Analytical Geometry	E			A	E	E	A	A
Descriptive Geometry	E							
Introduction to Calculus		A	A		A		A	A
Cost Analysis & Estimating								
SCIENCE								
Physics:								
Electricity & Magnetism	E	E	E	E	E	E	E	E
Heat, Light and Sound	E	E	E	E	E	E	E	E
Electron Physics	E	A	E	A	E	A	A	E
Mechanics:								
Statics & Dynamics	E	E	E	A	E	E	E	
Kinematics	E	A	E			E	A	E
Kinetics	E	A	A			E	A	
Mechanics of Materials	E						E	E
ADDITIONAL KNOWLEDGES & SKILLS								
Mechanical Drafting	E		E			E	E	E
Electrical & Electronic Drafting	E	E	E	E	E	E	E	E
Etching Techniques				E				
Machine Shop Operations & Practices 1/	E		E	E		E	E	E
Use of Hand Tools	E		E	E	E	E	E	E
Technical Report Writing	E	A	A		E	E		E

1/ This should not be construed to mean skill in the operation of machine tools. It means familiarity with machine shop operations and practices.

SECTION V

DEVELOPING THE CURRICULUM

When the field of work for which training is to be provided has been clearly defined, the individual occupations in the cluster of jobs found in the field of work have been analyzed, and the training requirements have been identified, the curriculum and individual courses of study required to prepare students to perform the job duties may be prepared.

A curriculum may be defined as a systematic group of courses of study designed to prepare persons for a cluster of jobs or for a specific occupation in a given field of work. It is an organized body of content for the training program, including all the content which may be offered by the school in order to reach the desired educational goals.

Curriculums can be developed in several different ways. The simplest method is to take the curriculum used by another institution and use it without modification. The hazard of such an approach lies in the possibility that the curriculum may not have been a good one or, even though it was satisfactory for the original institution, that it may not fit into the conditions of the setting where it is to be used. A second method is to study a number of curriculums from other institutions and to develop from them a composite curriculum embodying the best points of all of them. The difficulty sometimes encountered with this method is that the resultant program is made up of a group of subjects which may not be a complete, integrated curriculum.

Probably the most effective method is to use the approach outlined in this pamphlet which depends upon up-to-date analyses of the occupations with which the program is concerned and the development of a curriculum based upon these analyses. It is usually helpful to study other curriculums for structure and content as a check against that which is developed through the job analysis technique.

In undertaking the construction of a curriculum based upon job analyses the first task is to prepare a composite list of all of the knowledges and skills needed for effective performance in the occupations making up the cluster. In Section IV of this pamphlet two such lists have been prepared (Form B-1 and 2). The job descriptions in Section III represent typical occupations found in these two fields of work and are not meant to be all-inclusive. Therefore, it would be well to explore the fields further to ascertain if other payroll jobs should be included in the clusters. These jobs should then be analyzed and the findings checked against the present lists to determine whether additional subject matter areas are necessary. Thus, a reasonably complete list of items for the proposed curriculum would be assured.

A curriculum does not usually include all of the items which appear on the list. Students may be expected to have attained certain of the knowledges and skills previously. If the curriculum is on the post-high school level, the admission requirements may specify high school graduation; completion of certain subjects while the student was in high school; or the attainment of satisfactory scores on achievement or aptitude tests. In some cases, the list may include certain items which may be learned after the student is employed. Thus, the item list from which the curriculum is actually constructed should contain only those items which are appropriate for the proposed curriculum.

In theory, one might take the content revealed by the occupational analyses, organize the content into courses, select the methods to be used for instruction, list the equipment needed, plan the space required, set up standards for student admission and for the instructional staff, and arrive at the length of the program without regard to details of the setting in which the program is to operate. But, it doesn't work out that way in practice. There are many factors which must be taken into account. For example, the program may be one of several given by a large institution which has established admission standards, a predetermined length of school year and day, available space which may or may not lend itself well to the proposed program, a limited budget, and many other conditions which affect the curriculum planning. Therefore, the curriculum builder often has to compromise in order to adapt the desired elements of the curriculum to what is available.

After the subject matter areas have been selected for inclusion in the curriculum, they are divided into groups which become courses. Next, the courses are arranged in a pattern which recognizes time allocation, sequence and relative importance of each course. Modifications are then made to adust all of these considerations so that the final curriculum is a well balanced and integrated program.

It is not the purpose of this publication to describe in detail all of the steps which must be followed in developing a good curriculum, nor to discuss the many things which the curriculum builder must keep in mind. However, this section is designed to review these things rather briefly on the assumption that the reader is familiar with pedagogical practice and with curriculum building in other areas of education, and to point out some of the broad aspects of curriculum development as it relates to technician training.

In technician training of the level required for the fields of work described in this publication, the curriculum content should meet the following conditions:

1. The range of course content for preparation for the jobs in the cluster should be reasonable in view of the total time allotted to the training program.

2. The technical content should lend itself to organized instruction.

3. A substantial part of the total curriculum should be such that it can be mastered by a reasonably high proportion of students having the necessary educational backgrounds to benefit from the technical training provided.

4. The psychological order of learning should be followed to provide spiral teaching of the subject matter.

5. The curriculum content should include technology of the occupational field, applied science and applied mathematics (applied to the field of work for which the training is provided), and other applied content such as technical report writing, machine design, or other areas which are essential to satisfactory job performance.

6. The various areas of mathematics or science should be integrated so that the application of mathematical or scientific principles may be presented without regard to discrete subjects.

The subject matter areas in the lists of electrical and electronic occupations are not arranged as they will appear in a curriculum, but they indicate the areas of knowledge which should be covered. Analysis of these items is an important step in developing a course of study. From this list the curriculum builder should select, by careful analysis, those subjects which are considered essential to the cluster of occupations and practicable to include.

A second step is to group the selected items to provide an orderly, logical arrangement of the subjects, and then to determine if all of the items can be covered adequately within the time limits specified for the training program.

The completed lists developed by the processes described above provide an outline of the skills, knowledges, and understandings the student should have when he completes the curriculum. The over-all content in a curriculum for training technicians usually includes appropriate basic and applied science and mathematics and sometimes includes pertinent content of nontechnical character. For example, the basic principles of mathematics need to be understood in order to make application of mathematics in the particular technology. The specific types of mathematical applications need to be identified, and the training program needs to be arranged to provide the basic understandings of these principles in appropriate amounts, levels, and sequences.

For pedagogical purposes it may be necessary to include subject matter in addition to that indicated by the job analyses in order to make the learning of some of the previously selected content more effective. For example, it may be desirable to include an introduction to calculus through which certain aspects of physics might be taught more effectively, even though the job analyses do not show the need for calculus as such.

Another step in curriculum construction is to develop instructional units which will convey the necessary instruction and provide the trainee with the desired learnings. The instructional unit may take the form of a typical task to be performed, a laboratory experiment to be carried out, a problem to be solved, an assignment to be read and studied, a case to be discussed, a drawing to be made, or a malfunction to be analyzed. The type of instructional unit depends upon the kinds of educational objectives, the school facilities, and many of the other factors discussed heretofore.

In a good course of study, the instructional units may be arranged in psychological, rather than logical, sequence in order to provide spiral teaching of the subject matter. This enables the trainee to progress easily and naturally from one unit to the next. The easier units come first. As the student proceeds in the course, he is taught new and more difficult applications of the subject matter until he is finally able to handle more and more difficult assignments.

The techniques described in this publication, together with the charts, provide basic information needed to start organizing curriculums which will meet specific technician training needs in the fields of electricity and electronics.

ADDENDA

The job descriptions in Section III were developed from occupational analysis studies made by the author and others while he was associated with the Occupational Analysis Branch of the Bureau of Employment Security, U. S. Department of Labor, and from source data in the Dictionary of Occupational Titles, Vocational-Technical Training for Industrial Occupations, Bulletin No. 228, and similar publications.

The job relationship techniques described in Section II were adapted from Section VI of the Reference Manual for In-Plant Manpower Planning, which was prepared under the direction of the author. A more detailed description of these materials and their sources are given below:

Dictionary of Occupational Titles, Volume I, Definitions of Titles. Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Government Printing Office, March 1949, 1518 pp. (For sale by the Superintendent of Documents, Washington 25. $3.50.)

> Contains definitions of the various jobs found in the American economy arranged alphabetically according to job titles. There are 22,028 definitions which are known by 40,023 titles.

Dictionary of Occupational Titles, Volume II, Occupational Classification and Industry Index. Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Government Printing Office, March 1949, 743 pp. (For sale by the Superintendent of Documents, Washington 25. $2.00.)

> This volume consists of five (5) sections: (1) The occupational classification section wherein the individual jobs are arranged according to their code numbers; (2) an index of the common commodities sold in retail and wholesale trade for classifying persons engaged in sales work; (3) a glossary which clarifies the various terms used in the job definitions; (4) definitions of industrial designations to show the industry in which jobs defined in volume I are usually found; and (5) an alphabetical index of these industrial designations.

<u>Vocational-Technical Training for Industrial Occupations</u>. Division of Vocational Education, U. S. Office of Education, Federal Security Agency. (Vocational Education Bulletin No. 228.) Washington: U. S. Government Printing Office, 1944, 307 pp. (Out of print)

This is a report of a consulting committee appointed by the U. S. Commissioner of Education, setting forth findings concerning the need for vocational-technical training, typical jobs for which such training is essential, job descriptions exemplifying various occupational fields, and other information pertaining to the nature of the need for vocational-technical training, including subject-matter requirements.

<u>Employment Outlook for Technicians</u>. Bureau of Labor Statistics, U. S. Department of Labor, Washington: U. S. Government Printing Office, March 1958, 30 pp. (For sale by the Superintendent of Documents, Washington 25. 25 cents.)

This report describes the nature of work performed by technicians and the fields in which they are employed. It also explains how a person becomes a technician, and gives employment prospects. The report is limited to those technicians who work with physical scientists and engineers.

<u>Reference Manual for In-Plant Manpower Planning</u>. Bureau of Employment Security, U. S. Department of Labor. Washington: U. S. Goverment Printing Office, April 1951, 53 pp. (For sale by the Superintendent of Documents, Washington 25. 45 cents.)

The purpose of this manual is to provide employers with practical methods for use in manpower planning. It includes instructions and suggestions for: (1) Preparing a job inventory, (2) converting plant job titles to a standard classification system, (3) a method for inventorying work-force skills, (4) a method for filling vacancies by in-plant transfer of workers; and (5) a method for determining the relationship between jobs.

Training and Reference Manual for Job Analysis. United States Employment Service, U. S. Department of Labor. Washington: U. S. Government Printing Office, June 1944, 103 pp. (For sale by the Superintendent of Documents, Washington 25. 35 cents.)

This is a training and reference manual on job analysis which attempts to describe the best methods for obtaining accurate and discriminating information about jobs.

How to Prepare Training Materials. Lynn A. Emerson. New York State School of Industrial and Labor Relations, Cornell University. February, 1952. 356 pp. (Out of print.)

This book was designed as reference material and as a guide to help industry, the Armed Forces, and educators prepare instructional materials. It provides many ideas and suggestions for experienced people concerned with training and workable procedures for those less experienced.

GPO 886419