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INSTRUMENTATION AND AUTOMATIC CONTROL, SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL AND TECHNICAL EDUCATION PROGRAMS.

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THE PURPOSE OF THIS GUIDE IS TO HELP THE STATES ORGANIZE AND OPERATE EDUCATIONAL PROGRAMS FOR OCCUPATIONS IN THE FIELD OF INSTRUMENTATION. CHAPTER TITLES ARE--(1) INSTRUMENTATIONS--PAST, PRESENT, AND FUTURE, (2) THE OCCUPATIONAL FIELD, (3) WORK ACTIVITIES (DESIGN, FABRICATION, MAINTENANCE, REPAIR, AND SERVICE), (4) TRAINING REQUIREMENTS, AND (5) DEVELOPING THE CURRICULUM (JOB ANALYSIS). AN ANNOTATED BIBLIOGRAPHY LISTS 30 TITLES DEALING WITH RELATED TOPICS SUCH AS AUTOMATION, MANPOWER, OCCUPATIONS, AND TRAINING. THE APPENDIX CONTAINS (1) A LIST OF MATHEMATICS, INSTRUMENTATION TECHNOLOGY, AND SUPPLEMENTARY COURSE DESCRIPTIONS, (2) A SAMPLE CURRICULUM OUTLINE, AND (3) A SELECTED BIBLIOGRAPHY OF U.S. OFFICE OF EDUCATION PUBLICATIONS. THIS DOCUMENT IS ALSO AVAILABLE AS FS 5.280--80043 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, FOR $0.25. (EM)

SUGGESTED TECHNIQUES FOR DETERMINING
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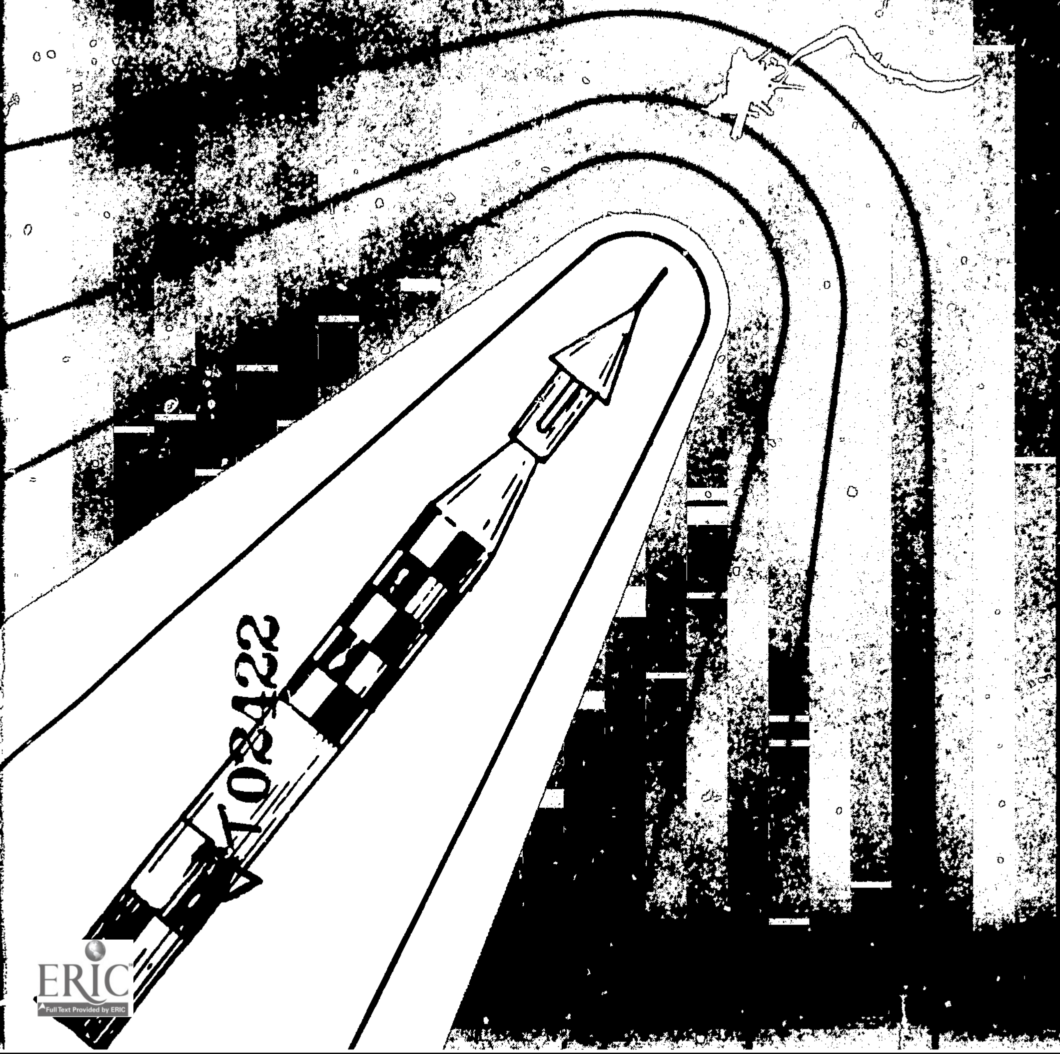

OE-80043

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

INSTRUMENTATION AND AUTOMATIC CONTROL

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
John W. Gardner, Secretary
OFFICE OF EDUCATION
Harold Howe II, Commissioner

FOREWORD

The purpose of this publication, which is one of a series, is to help the States organize and operate vocational and technical education programs for occupations in the field of instrumentation. It also should be useful to industry (management and labor); public employment services; and others concerned with the placement, training, and utilization of manpower. Other publications in this series are *Mechanical Drafting and Design Technology* (OE–80000), *Electrical and Electronic Technologies* (OE–80004), *Mechanical Technology Design and Production* (OE–80014), *Chemical and Metallurgical Technologies* (OE–80016), *Civil and Highway Technology* (OE–80018), and *Electronic Data Processing in Engineering, Science, and Business* (OE–80030).

The publications in this series indicate how job analysis and job relationship techniques can be used to facilitate the planning of training programs. Each publication contains the following information and suggestions:

1. General information about a technology or broad field of work.
2. A procedure for determining the relationship among jobs in order to develop homogeneous groups or clusters of occupations for which training may be given.
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 reader's attention is also called to two related publications—*Course in Instrument Maintenance: A Suggested 1-Year Training Program* (OE–86009) and *Instrumentation Technology: A Suggested 2-Year Post High School Curriculum* (OE–80033).

The occupations discussed in the present publication are typical of those found in the field of instrumentation and are by no means limited to entry jobs. Students who receive instruction in an organized training program for a cluster of occupations or for a specific occupation are provided with the knowledge and skills required in the field as a whole; but they usually require experience on the job in order to learn how to apply their knowledge to the problems that are likely to be encountered in the specific job to which they are assigned. The terms "technician" and "technical worker" refer to scope of training and to work capabilities rather than to employment classification.

Vocational and technical education programs conducted under State plans prepared by the State boards for vocational education and approved by the U.S. Office of Education are open to persons of any age, in any community of any State, who are qualified to benefit from the training offered.

The content of this publication has been subjected to review and comment by consultants and staff members of the U.S. Office of Education. The contents have been modified to take into account as many ideas, suggestions, and approaches as possible in keeping with the main purposes of the publication.

Much of the research for and preparation of this publication was carried out by Clarence E. Peterson, formerly Manpower Development Specialist of the Division of Vocational and Technical Education. Following Mr. Peterson's retirement, the manuscript was brought to completion by his successor, Emanuel Weinstein.

WALTER M. ARNOLD,
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CONTENTS

INTRODUCTION

This publication explains how basic occupational information resulting from job analysis can be employed to determine the relationships among jobs in the field of instrumentation and the knowledges and skills required for successful job performance; and how such information can then be used to establish the course of study required to prepare students for a cluster of closely related jobs or for a specific job within a cluster.

The nature of the job information required varies according to the program contemplated. But whatever the program, the information must be up to date, accurate, and presented in usable form.

Basically there are three parts to the analysis of any job: (1) The job must be completely and accurately identified; (2) the description of the duties and actions required to perform the job must be complete and accurate; and (3) the knowledges and skills required to perform each job element or task within a job must be specified.

After the need for occupational training has been determined, it will be necessary, in most cases, to analyze the various jobs for which training is contemplated. There are several methods of making a job analysis. Some widely used methods are described in the *Training and Reference Manual for Job Analysis* prepared by the U.S. Department of Labor, in the *Handbook for Naval Occupational Analysis* issued by the Department of the Navy, and in *Trade Analysis and Course Organization* by Bollinger and Weaver, used by many vocational educators for job analysis purposes. (See Selected Bibliography.)

The present publication does not describe the various methods and techniques of job analysis since it is assumed that this analysis will be performed by personnel experienced in this function. If a State lacks experienced personnel with sufficient time to make the necessary job analyses, it may obtain the information from other sources. In some cases, industry or labor has job analysts who can provide detailed information about the significant factors of each job or make the necessary analyses. Or, the State employment security agency may have the needed information in its files or may assign an occupational analyst to work with educators in gathering it.

Because of the specialized nature of highly skilled and technical jobs, it is essential that data regarding educational and training requirements be as complete as possible. For example, "basic knowledge of hydraulics and pneumatics as applied to fluid power transmission" is more specific and meaningful than "knowledge of hydraulics and pneumatics"; and "must have a working knowledge of algebra, trigonometry, analytical geometry and vector analysis to solve such problems as the determination of specifications, dimensions of irregular contours, and value characteristics of circuits, and to interpret, graph, and report test results" is more definitive than "uses mathematics to solve problems."

Successful training programs depend largely upon detailed information about the jobs for which training is to be given; this is especially true with regard to jobs requiring highly skilled and technical workers. Workers cannot be properly trained unless the nature, duties, responsibilities, and other pertinent job factors are known. The content of the training curriculum, the time required for training, and the selection of the trainees are dependent upon a thorough analysis of the job concerned.

Chapter I

INSTRUMENTATION—PAST, PRESENT, AND FUTURE

HISTORY OF INSTRUMENTATION

During the present century, this country has pioneered in three major industrial cycles. The first, which began early in the century, was *mass production*. Probably the most important factor in mass production was the interchangeability of parts which simplified assembly operations and was responsible for the rapid growth of many industries. The second was *mechanization*, which again increased productivity and made the work of production workers easier. A good example is the mechanization of mines whereby the pick-and-shovel work of the miners was replaced by machinery. The third cycle—the cycle in which we are now involved—is automation.

The term "automation," as defined by Webster, means the technique of making a process or system automatic. John Diebold, who is said to have coined the word, defines it as meaning the application to machines and processes of the principles of feedback and self-correction. Roger Bolz, editor of *Automation*, defines it as follows: "Automation is a philosophy of manufacturing. It is the final progression from hand methods to automatic production. In a popular vein, it is looked on as the description of what industry has been working toward for years in attempting to serve the needs of the people adequately—improved methods of producing more goods at acceptable costs." Milton Aronson, editor of *Instruments and Control Systems*, defines it as the "use of hydraulic, pneumatic, electronic, electrical, and mechanical devices to perform decision and control functions."

Instrumentation and automatic control, if not synonymous with automation, are usually recognized as the basic tools of automation. In this publication, the broad term "instrumentation" is used to include measurement and automatic control, and data storage and retrieval.

Although some of the principles of instrumentation have been known for many years, it is only within the last three decades or so that a concerted effort has been made to apply them. Prior to World War II, the emphasis was on measurement. Instruments used by skilled workers to make accurate measurements to meet specific tolerances were developed into systems of automatic measurement. The next step in the evolution of instrumentation was automatic control of a process or operation. At the outset, such systems were developed primarily for use in continuous-flow chemical plants and in oil refineries. Prior to 1920, automatic controls were developed slowly. Thermostats were used as controls in heating and air-conditioning units; automatic combustion and other controls were used in large electric generating stations.

World War II provided the necessary stimulus to establish instrumentation as a clearly defined field of engineering. Engineers, physicists, and mathematicians utilizing the knowledge and experience relating to existing industrial control equipment, by their concerted efforts, were able to develop the precision servomechanisms and digital computers which became a part of the automatic systems needed to control the weapons of war.

By 1950, industry, which had specialized in the development and manufacture of military control systems, was beginning to adapt these products and techniques to the production of peace-time products. Many new companies were organized and old ones expanded to develop and manufacture the systems needed to automate the production facilities of the Nation.

The use of instruments of increasing complexity for measurement and control is growing rapidly. Systems of indicating, recording, and control instruments have become a basic part of the design of plants where gases, fluids, and other chemicals are processed. Instruments not only measure and record such system or process variables as pressure, temperature, humidity, and flow but also activate controllers which open and close valves and operate pumps and other devices under rigidly controlled conditions. In recent years there has been a marked impetus in the use of instrumentation in processing plants for the remote or centralized control of operations through centralization of instrument readings and automatic controls.

Computers are being applied to process control so that complex computations based on the vast quantities of data supplied by the instruments can be made rapidly and accurately, and the results fed back to guide and control instruments.

Capital expenditures by manufacturing industries and public utilities in 1966 are expected to be 8 percent above that in 1965. Indications are that the major portion of the 1966 expenditures will be for improvement of existing facilities rather than for expansion. This will raise the ratio of instrument sales to total capital expenditures, and consequently, the sales of scientific, industrial and related instruments are expected to exceed those in 1965. The new value for instrument sales is put at $3.7 billion or 10 percent above the 1965 value. In 1965, sales increased by 9 percent to $3.4 billion. Other factors contributing to the increased 1966 value include expected increases in research and development facilities and outlays for airborne and ground-based navigation and monitoring systems.

Fluid Power Control

While electricity and electronics play a vital role in instrumentation systems, hydraulics and pneumatics are equally important. Fluid power, which embodies the principles of both hydraulics and pneumatics, is widely used in automatic control systems. Fluid power was used long before electrical energy was developed. In 1650, Pascal discovered that pressure in a fluid at rest is transmitted equally in all directions. Bernouli advanced this concept a hundred years later when he developed his law concerning the conservation of energy in a flowing fluid. The concept was not, however, applied to industry until 1850, when fluid power was used to power presses, cranes, winches, and other equipment and machines.

Toward the end of the 19th century fluid power was temporarily replaced by electricity; but in 1906 it was revitalized when a hydraulic system using oil was developed for elevating and controlling guns on battleships. Today, the applications of fluid power include controls in process industries and in systems on machine tools, automobiles, airplanes, and even space vehicles. Scientists have recently developed the so-called pure fluid amplifier which functions in a manner similar to that of an electron tube but on gas or liquid instead of electricity. This amplifier will be used in a pneumatic computer in the future. In 1945, the fluid power industry produced about one-third of a billion dollars worth of equipment. By 1970, it is estimated the volume will be worth at least $2 billion annually. This represents a growth of 600 percent in 25 years.

Approximately 60 percent of all manufactur plants in the United States use fluid power systems as part of the equipment employed to manufacture their products, and 53 percent of all industrial products produced in the country have a fluid power system or component built into them.

Numerical Control

In the metalworking industries, more automatic production is being achieved through numerical control—a technique used to operate machine tools and certain other types of equipment by means of numerically coded information recorded in advance on punched cards, magnetic tape, or punched paper tape.

First used in factories in 1957, numerical control is still in an early stage of development and use. About 4,000 numerically controlled machine tools were estimated to have been installed by the end of 1963, but these represented only a small proportion of the total of about 2 million machine tools in use in this country. It is anticipated that there will be 12,000 installations by 1967. Some industry experts expect numerically controlled machine tools to increase rapidly in the next few years to the extent of representing 30 to 50 percent of all such tools sold. In the aircraft industry, which had 629 numerically controlled machine tools at the end of 1963, a fourfold increase is expected by 1972.

EMPLOYMENT OUTLOOK

More than 75,000 instrument repairmen were employed in a variety of industries in early 1965. This number is expected to increase by a few thousand a year for the remainder of the 1960's. In addition to job openings resulting from the rapid growth of this technology, many job opportunities will arise from the need to replace experienced repairmen who transfer to other lines of work, retire, or die. Deaths and retirements alone will result in about a thousand job openings annually.

Technicians make up one of the fastest growing occupational groups in the United States. In recent years, the needs of the Nation's defense and space programs, as well as of the rapidly growing technologies such as instrumentation, have greatly intensified the demand not only for scientists and engineers but also for the technical workers who assist them. According to a recent study by the Engineering Manpower Commission of all industrial sectors, the instrument manufacturing industry indicated some of the biggest growth rates for engineers, scientists, and technicians. It is anticipated that over the 10-year period ending in 1973, the number of engineers, scientists, and technicians in this industry will have increased by 61 percent, 177 percent, and 68 percent respectively.[1]

The progress of instrumentation and automatic control affects in several ways the numbers and types of workers employed in industry. The design and the construction of complex instruments and related apparatus require thousands of scientists, technicians, and production workers. Employment in the manufacture of instruments and related products totaled 369,000 in 1964, slightly over 2 percent of the total for manufacturing employment, but about 48 percent more than in 1950. In manufacturing as a whole, employment increased by only about 14 percent over this same period.

Automated plants must keep this costly equipment operating as continuously as possible. Downtime is very expensive. Therefore, many employees in plants with advanced instrumentation systems are engaged in the maintenance and repair of equipment or in technical or other nonproduction jobs. In the petroleum refining industry, for example, which was a pioneer in the introduction of control instrumentation, the proportion of workers in nonproduction jobs has risen rapidly—from 23 to 38 percent between 1947 and 1964.

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[1] Engineering Manpower Commission of Engineers Joint Council, *Demand for Engineers, Physical Scientists, and Technicians—1964.* New York: The Commission, July 1964. pp. 29, 41, 53.

Chapter II

THE OCCUPATIONAL FIELD

Instruments and control devices play a vital role in the operation of all important scientific and industrial fields. Some of these fields are: Aeronautics; electronics; nucleonics; public utilities; medicine and health; missiles and space; chemicals; petroleum; glass and ceramics; pulp and paper; rubber; plastics; and electrical manufacturing.

The devices designated as intruments and controls are used to measure, indicate, record, and control almost any type of variable encountered in this wide variety of industries. Such variables as temperature, pressure, flow, velocity, level of material, position, density, and chemical composition are measured and controlled in order to manufacture the articles more efficiently, maintain uniform quality, and exercise control over the safety of operations.

Instruments and control devices are based on many engineering principles. They involve the knowledge and use of mechanics, optics, strength of materials, electricity, electronics, hydraulics, pneumatics, and mathematics, to name a few.

It is not essential that each instrument engineer, technician, or mechanic be an expert in all these fields, although most of the basic physical and chemical principles are involved in the design, operation, and application of instruments and control devices. A general understanding of the basic principles of optics, mechanics, electricity, and electronics is certainly of great value. But the field of instrumentation and control is so large and is expanding so rapidly that specialists are required in each specific area.

A review of occupations in the field of instrumentation and control revealed that instrumentation specialists (engineers and technicians) are employed in five broad categories:

1. In research and developmental laboratories, where they design, modify, and set up instrumentation to test and evaluate new concepts, products, and prototypes.
2. In the operation of complex test facilities, such as those used to evaluate the performance of missiles and propulsion devices, where they select and set up the instrumentation needed, conduct the tests, and interpret the results.
3. In instrument manufacturing establishments, where they design new instruments or control devices and modify existing ones.
4. In the continuous-flow processing industries (chemicals, food, paper, petroleum, and primary metals), where they engineer the instrumentation needed for industrial processing operations and install, maintain, service, and troubleshoot the devices.
5. In the numerical control of machining or other processing steps, inspection, and in automatic assembly where they specify and program the controlling devices and maintain and service them.

Discussion of instrumentation occupations with engineers, educational directors, and others concerned with the employment, training, and utilization of instrumentation technicians brought out the following facts:

1. Graduate engineers (chemical, electrical, and mechanical) most often are used to plan the instrumentation needed for industrial processing operations. These engineers and others in this field believe that the day will soon come when technically trained workers will assist in this work, but this is not the case in most establishments today.
2. Technicians are used to assist engineers in designing new instruments and in modifying existing ones. They may be involved in research and development. This may include the development and establishment of testing methods and procedures, and the planning, setting up, and conducting of laboratory performance and evaluation tests of prototypes of instruments.
3. Instrument makers and repairmen work on individual instruments on the bench. Such workers are classified as skilled craftsmen and not as technicians. They work from drawings, blueprints, and rough sketches; operate machine tools

to make replacement parts;[2] and use handtools common to the jewelers' and watchmakers' trades. Although they may work with a variety of metals, plastics, glass, and other materials, they require little, if any, knowledge of scientific principles or theory.

4. Field service engineers (technicians or engineers) who work for the instrument manufacturers are responsible for proving the worth of the products sold by the sales engineers. They must be familiar with the various processes involved and be able to demonstrate how the proposed instruments and controls will increase operating efficiency and help the customer make more and better products at less cost. They supervise the installation of the equipment and must be able to assist the customer in any difficulties involved in the operation of the equipment. They troubleshoot and maintain the instruments and devices sold by the company and perform preventive maintenance under agreements made between the instrument manufacturer and the customer. They train plant personnel in factory-approved operation and maintenance techniques.
5. Instrument technicians, who work in the industries where instruments and control devices are used, troubleshoot the instrumentation system, adjust controls to meet various processing conditions, calibrate the equipment, test out new equipment prior to operation, rectify faulty equipment, and suggest any modifications needed to improve their operating characteristics, using their knowledge of physics, electricity, and electronics, and their familiarity with the processes involved.

Brief descriptions of selected occupations illustrative of those in the above categories are given in Appendix A. These descriptions are based on definitions that appear in the third edition of the *Dictionary of Occupational Titles.*

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[2] The current trend is to replace parts with plug-in components. Defective parts are discarded or returned to the manufacturer for replacement at a fixed cost.

Chapter III

WORK ACTIVITIES

Before vocational-technical curriculums can be established, the functions involved in the field of work for which training is contemplated must be identified and categorized. This is accomplished by analyzing each of the jobs in the field of work and arranging them in homogeneous groups or clusters. Training curriculums which grow out of such analyses are commonly called cluster-based curriculums.

The procedure used for establishing homogeneous groups or clusters of occupations is called the job relationship technique. Descriptions of job relationship techniques were included in each of the earlier publications in this series and, therefore, are not repeated in the present publication. These techniques were used in establishing the three general categories of work activities dealt with in the following pages.

This chapter describes the work activities normally performed by workers in the field of instrumentation. These work activities make up the three general categories for which vocational and technical education may be provided. They are more general in nature than job descriptions, but it was felt that they would better serve to identify the broad fields of work for which training is required. There are three reasons for using work activities instead of job descriptions here: (a) Many of the jobs in instrumentation are comparatively new and are changing rapidly as technological advances are made; (b) job descriptions are not available for all of these jobs; and (c) the work activities cover a relatively broad field of work rather than specific occupations and are not as susceptible to change as are the functions and duties of individual jobs.

Each work activity description identifies and describes the significant characteristics of a field of work. The job duties and performance requirements may vary from plant to plant and from one industry to another. However, the descriptions can be used for comparison purposes, which may eliminate the need for time-consuming job analyses of certain occupations. In many cases, the nature of the work in local establishments may be similar to that described in the work activities presented in this chapter. In this event, only major differences in job content need be considered. Even in the case of major differences, many of the technical jobs for which training is required will undoubtedly fit into the general framework of the work activity descriptions. The following examples are typical of the work activities in the three general areas for which vocational and technical education courses may be given.

INSTRUMENTATION DESIGN

Produces design layouts of complicated mechanisms, servomechanisms, instruments and instrumentation systems from data received from engineers or other sources. Analyzes servomechanisms, assemblies, circuitry and component and system responses to visualize the end result in regard to function, cost, and manufacturing problems. Works with a variety of instruments and controls associated with a wide range of products. Performs engineering calculations of springs, gear and linkage mechanisms, static stresses, strength of materials, system and component time responses, and characteristics of electrical and electronic circuits and components.

Interprets specifications to acquire a functional understanding of the design. Constructs layouts and determines accuracy of the design by comparing relationships of the various parts and assemblies. Makes alterations and modifications to conform to design standards and to satisfy engineering and manufacturing requirements. Employs knowledge of applicable engineering theory and practices to work out new design details of complicated metal stampings and castings, die castings, plastic moldings, and forgings, and to recommend design changes which would improve operating efficiency of the manufacturing process. Prepares or reviews drawings prepared by others for conformance with assigned objectives, company standards and practices; and performs final design check on finished design drawings for accuracy, determination of tolerances, clearances, interferences, interchangeability, and feasibility of manufacture.

INSTRUMENT MAKING, MAINTENANCE, AND REPAIR

Assembles, installs, repairs, maintains, and adjusts indicating, recording, and controlling instruments used to measure and control such variables as pressure, flow, temperature, motion, force, and chemical composition, using handtools and precision instruments. Disassembles malfunctioning instruments and examines and tests mechanism and circuitry for defects. Reassembles instruments and tests assembly for conformance with specifications, using such checking instruments as potentiometer, resistance bridge, manometer, oscilloscope, and pressure gage. Inspects instruments periodically and makes minor calibration adjustments to insure functioning within specified standards. May adjust and repair final control mechanisms such as automatically controlled valves or positioners.

INSTRUMENTATION SERVICING

Field Service

Is responsible for proving the effectiveness of the product sold by the instrument manufacturer, for demonstrating its use, and for assisting the customer in solving technical problems involved in its operation. Inspects, troubleshoots, adjusts, and modifies instruments in the system in order to obtain optimum results from each of the devices. Inspects and services instruments in accordance with maintenance agreement and instructs customer personnel in operation, installation, and preventive maintenance procedures and practices. Assists customer in solving technical problems involved in the operation of the equipment. Uses knowledge of hydraulics in the solution of flow measurement and control problems. Uses knowledge of chemistry in the application of instruments in the process industries; knowledge of metallurgy where high temperatures are required; and knowledge of electricity in pyrometry, telemetry, and application of instruments to electrical measurement and control. Must understand the processes involved in the particular industry to which he is assigned. May demonstrate how the proposed use of instruments and controls will increase operating efficiency, improve the customer's product, and reduce manufacturing costs.

Systems Analysis and Checking for Process Control

Repairs instrumentation and control systems, adjusts controllers to the process, and performs other similar functions. Tests and checks out instrumentation equipment prior to or during operation. Calibrates equipment on the line. Analyzes malfunctions of equipment, following diagrams or blueprints. Adjusts or modifies instruments or controls to regulate the process, calculating the changes to be made in composition to meet quality control and safety standards as well as customer specifications. Consults with instrument engineer to acquire basic understanding of the particular specifications and the required physical and functional characteristics of items incorporated into the system. Participates in investigations concerned with processing, computing, and plotting mathematical values from given data and formulas and with resolving manufacturing deviations and design modifications. May analyze malfunction of newly designed equipment or prototypes and suggest modifications to improve operating efficiency.

Chapter IV

TRAINING REQUIREMENTS

If the purpose of a training program is to prepare workers for a single occupation, the content for such a program may be derived from an analysis of that specific job. But, if the program is designed to train workers for a cluster of occupations, the content should be derived from analyses of all jobs in the cluster. In either case, it is necessary to determine the significant elements or characteristics of all of the jobs found in the field of work, to ascertain the skills and knowledges required for their performance, and to develop a reasonably complete list of the subject-matter areas required to train workers in these occupations. From this list, the specific courses of study which make up the curriculum are developed.

It should be recognized that instruction for a specific job may require greater depth and emphasis on certain aspects of the training than would be required for a broad field of work. The highly specialized training required for a particular job may be given through extension courses after the individual has entered employment and has gained some experience and understanding of the field of work. Methods and procedures for determining requirements for extension training programs are described in *Determining Requirements for Development of Technical Abilities Through Extension Courses.* (See Selected Bibliography.)

In determining the training requirements for instrumentation workers, a study was made of the functions and duties of the various work activities previously described and of the courses used by selected educational institutions for training students in specific subjects, such as mathematics, science, and instrumentation. By this method, the subject-matter areas generally recognized as significant in preparing workers to perform satisfactorily in the several work activities were discovered.

The relationship of the subject-matter areas to the work activities are shown in the Training Requirements Analysis Form on pages 10–11. The main items in column (1) consist of the subject-matter areas which are considered basic in training for the work activities listed in columns (2), (3), and (4). Other subject-matter areas may have to be added as the requirements of these work activities vary from plant to plant, among industries, and in different parts of the country. The determination of the subject matter required to equip the student for successful performance in a particular job depends upon the adequacy of the source data obtained and the ability of the person preparing the form to interpret these data.

The subitems in column (1) show the courses in which the subject matter is taught. These courses (see Appendix B) are based on a study of a number of courses given in various schools throughout the country. They should be considered as composites and may not coincide exactly with courses offered in any given educational institution. Care should be exercised in using these courses; they should be adapted to fit the training situation as it exists locally. Once course organization and development are started, attention should be given to the selection of textbooks and reference books.

Columns (2), (3), and (4) show the three categories of work activities covered. Under each column, opposite the relevant course, appears one of the following three symbols: "E" signifying that the work activity description indicates that this particular knowledge or skill is essential; "A" that it is advisable, but not absolutely essential, that a worker should receive instruction in this particular area; and "D" that the knowledge or skill is required for instrumentation work in certain industries.

The nature of the work and the industry in which the jobs under study are found usually suggest to an experienced analyst other subjects which might be helpful to a worker in a particular field of work. In some cases, it may be found that industry supplies training in some of the areas; in other instances the limited demand for such skills in the labor market or a lack of facilities in the school make it inadvisable for the school to set up special courses.

The completed Training Requirements Analysis Form:

1. Indicates the technical knowledges and abilities needed by workers to perform the duties of

various occupations found in a given field of work.

2. Identifies the subject-matter areas that are common to the several work activities.
3. Provides, in convenient form, a list of the subject-matter areas and courses of study that should be considered when building the training curriculum.

TRAINING REQUIREMENTS ANALYSIS FORM

Subject matter areas and courses of study	Work activity*		
	Instrument making, maintenance, and repair	Instrumentation design	Instrumentation servicing
(1)	(2)	(3)	(4)
MATHEMATICS:			
Basic Mathematics I	E	E	E
Basic Mathematics II	E	E	E
Technical Mathematics I	A	E	E
Technical Mathematics II	A	E	E
Geometry I	—	E	—
Geometry II	—	E	—
Trigonometry & Graphic Analysis	A	E	A
SCIENCE:			
Basic Electricity I	E	E	E
Basic Electricity II	E	E	E
Basic Electronics	E	E	E
Industrial Electronics	A	E	E
Instrumentation Electronics	A	E	E
Chemistry I	D	D	D
Chemistry II	—	D	D
Physics I	E	E	E
Physics II	E	E	E
Fluid Mechanics I	E	E	E
Fluid Mechanics II	—	E	E

*Symbols: A—Advisable; E—Essential; D—Dependent on industry.

TRAINING REQUIREMENTS ANALYSIS FORM—Continued

Subject matter areas and courses of study (1)	Work activity*		
	Instrument making, maintenance, and repair (2)	Instrumentation design (3)	Instrumentation servicing (4)
INSTRUMENTATION TECHNOLOGY:			
Instrument Fundamentals I	E	E	E
Instrument Fundamentals II	E	E	E
Measurement Principles	E	E	E
Instrument Installation	E	E	E
Instrument Maintenance I	E	A	E
Instrument Maintenance II	E	A	E
Industrial Instrumentation Systems	E	E	E
Automatic Controls	E	E	E
Process Control—Pneumatic	—	E	E
Process Control—Electronic	—	E	E
Instrumentation System Design & Operation	A	E	E
SUPPLEMENTARY COURSES:			
Blueprint Reading	E	E	E
Technical Drawing	A	E	A
Mechanical Drafting	—	E	—
Machine Shop Operations	A	E	—
Basic Mechanisms	E	E	E
Strength of Materials	—	E	—
Design Project	—	E	—

*Symbols: A—Advisable; E—Essential; D—Dependent on industry.

Chapter V

DEVELOPING THE CURRICULUM

The general problem of curriculum design is treated briefly in this chapter. It is assumed that the reader is familiar with pedagogical practice and with curriculum building. A curriculum designed for a vocational and technical education program may be defined as a systematic group of courses of study designed to prepare students for a particular field of work or for a specific occupation. Such a curriculum should be clearly identified by its title, and its content should be so planned as to give the student mastery of the needed subject matter within a specified time. A substantial portion of the content should consist of courses designed to equip the learner with the knowledge, skills, and abilities peculiar to the field of work for which the training is given. The curriculum as a whole should prepare him for the following:

1. To become employable and productive in one of several entry jobs in an occupational field;
2. To be able to progress to positions of increasing responsibility;
3. To be able to increase his skills by means of advanced study.

Curriculums can be prepared in several ways. The simpliest procedure is to use the curriculum of another institution without modification. The hazard of such an approach lies in the possibility that the curriculum may not be a good one or, even though it may be satisfactory for the institution where it originated, it may not fit into the conditions of the new setting where it is intended for use. For example, entrance requirements of institutions vary from State to State and from one institution to another.

A second method of curriculum preparation is to study a number of curriculums from other institutions and to develop from them a composite embodying the best features of all. A difficulty sometimes encountered with this method is that the resultant program may be made up of a group of subjects which may not constitute a completely integrated curriculum.

Probably the most effective method is to use the approach advocated in this publication, that is, to develop a curriculum based on up-to-date information about the work activities concerned. As a check, it is usually helpful to study the structure and content of other curriculums. The construction of a curriculum should include the activities indicated below, although not necessarily in the order shown:

1. *Determine the Needs*—On the basis of occupational surveys, establish the local and national needs for specific kinds of workers and training programs in various fields of work.
2. *Determine the Objective*—This will involve, among other things, determining the level of training to be given and the trainee's entrance requirements.
3. *Determine the Subject Matter*—Analysis of the jobs or work activities should include the competencies required and should be stated in sufficient detail to provide a meaningful basis for a curriculum.
4. *Resolve Material Into Subjects*—This step, which overlaps with, and depends upon, the preceding one, is the key to good curriculum construction. The purpose is to resolve the different learnings into discrete subjects without any prejudgment as to what such a subject should include or how much time should be devoted to it. The resolution of subject matter into subject titles will include the indication of necessary and desirable learnings; the relationships between subjects; the level of the subject matter; the method of instruction (whether recitation, demonstration, laboratory, or shop); and finally, the time allotment.
5. *Blocking*—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 psychological sequence, time allocation, and the relative importance of each course. All of these factors then are taken under consideration and adjustments made so that the final curriculum is well-balanced and integrated. This is one of the most difficult steps in curriculum planning and one which, requires careful analysis

and, in many cases, contains compromises. Each school has rules regarding the number of hours assigned to classroom, shop, and laboratory instruction. Also, a definite number of hours must be allotted to general education and homework. It is necessary to know the time to be devoted to the entire curriculum and how this time is divided into quarters or semesters. When the hours are totaled for each semester or quarter, it may be found that some changes must be made to keep within the prescribed schedule.

An important aspect of the structuring of courses is the development of units which convey the necessary instruction and provide the trainee with the subject matter and learning experiences. A unit may take the form of a typical task to be performed, instruction in the principles to be mastered, a shop or laboratory experiment to be carried out, a problem to be solved, a case to be discussed, or a malfunction to be analyzed. The type of unit depends upon the educational objectives, the school facilities, and many of the factors discussed earlier.

In the ideal curriculum, everything would be presented to the student as he needs it, and many avenues of knowledge should open up before him at the proper psychological moment. But the actual curriculum is usually a compromise which strives to achieve these objectives. The decisions made in constructing a curriculum are important because any compromise with the ideal curriculum lessens its effectiveness.

Curriculum construction calls for experience, understanding, and vision. Some considerations to be borne in mind are:

a. Realization of the abilities of beginning students;
b. Recognition of the psychological as contrasted with the logical procedure in learning;
c. Provision for proceeding from the easy to the more difficult;
d. A reasonable ratio of recitation time to laboratory time and to study time;
e. An early introduction of the technology or field of work, in order to motivate the student;
f. An integration or relationship of subjects so that "tool subjects" such as mathematics will be covered at the proper time;
g. A frontal approach which will make possible spiral teaching without exact repetition;
h. A reasonable schedule that will fit the school's program of time, teachers, and facilities.

Finally, it must be recognized that no curriculum is ever finished. This is particularly true today when technological advances sometimes make the material obsolete even while it is being prepared.

The entire faculty should be organized to take part in the planning or revision of the curriculum. This may involve rescheduling and, in some cases, the rewriting of courses of study to make the material taught in each mutually supporting. A schedule should be established for the periodic review and revision of the curriculum, and the revised curriculum should be reproduced and issued to each faculty member to keep him advised of changes. To the greatest degree practicable, all teachers should be cognizant of the material offered in other courses, and should draw on it to illustrate and support their own programs.

Such procedures will produce a curriculum which (1) is up-to-date, (2) represents a reasonable workload for the students and faculty, (3) capitalizes at each step on previous learning, (4) satisfies the needs of the labor market, and (5) achieves the desired outcome in the most efficient manner.

In chapters III and IV, certain techniques have been suggested and described which can be used to provide the basic information for organizing curriculums to meet the specific training needs in the fields of work with which this document is concerned.

The work activity descriptions in chapter III contain occupational data which are typical of those found in three fields of work. They are not meant to be all inclusive, nor will they remain indefinitely up-to-date. Therefore, the fields should be explored further to ascertain what other job information may be obtained relating to instrumentation and automatic control. New or modified occupations should be analyzed and the findings checked against the basic occupational data contained in the work activity descriptions in chapter III, to determine whether revised or additional subject-matter areas are necessary. In this way, a reasonably complete list of items which are basic for the proposed curriculum will be assured.

A composite list should be prepared of all the knowledges and skills required for effective performance in all occupations in the particular field of work. On the basis of this list, the content of the curriculum can be determined and evaluated. In chapter IV, the techniques for developing a list of subject-matter areas have been described. The subject-matter areas and the courses of study listed on the Training Requirements Analysis Form are not arranged as they will appear in the curriculum, but they indicate the areas of knowledge which should be covered. Analysis of these items is an important step in developing the curriculum, since from these lists, the curriculum builder selects those subjects essential to the field of work with which he is concerned.

Generally speaking, a curriculum will not include all the items which appear on a Training Requirements Analysis Form. Students may be expected to have attained certain knowledges and skills previously. For example, if the curriculum is on the post-high-school level, administration requirements may specify high school graduation or completion of certain subjects undertaken while the student was in high school, or attainment of satisfactory scores on achievement or aptitude tests. It is also conceivable that the composite list of knowledges and skills may include some which could be learned after the student is employed.

On the other hand, the curriculum designer may find it necessary to include some items which do not appear on a Training Requirements Analysis Form. For example, analysis of a job might have led to the conclusion that proficiency in mathematics was not required in the training program because the duties of the job did not include mathematical calculations. Such a conclusion would have overlooked the need for mathematics as a learning and communications tool, and so would adversely influence curriculum and course design.

In theory, one might take the courses shown on a Training Requirements Analysis Form, select the methods to be used for instruction, list the equipment needed, plan the space required, set up standards for student admission and for instructional staff, and determine the length of the program, without regard to details of the setting in which the program is to operate. In practice, however, it is not feasible to do this. There are many other factors to be taken into account. For example, the program may be one of several given by a large institution which imposes conditions on admissions, the length of the school year and school day, the budget, and space, all of which would affect curriculum planning.

BIBLIOGRAPHY

American Federation of Labor and Congress of Industrial Organizations, Department of Research. *Labor Looks at Automation.* AFL–CIO Publication No. 21. Washington: The Federation and Organization, 1959. 28 p. Single copies free.

Examines and traces the progress of technological changes in factories and offices. Cites examples of the effects of automation and discusses implications for the national economy. Discusses need for consultation and planning between labor and management on the introduction of automated equipment and related problems such as labor's share in using productivity, employee dislocations, and procedures governing layoffs, rehiring, transfers, job classification, pension plans, and retraining. Concludes that economic growth should be encouraged and that disruptions caused by rapid technological change should be cushioned by government and private groups.

———, Industrial Union Department, Research Section. *Automation's Unkept Promise.* Washington: The Federation and Organization, 1962. 28 p. Single copies free.

Discusses automation's impact on overall employment and production; the shift to white collar workers; automation and general skill requirements; economic growth and full employment; the human problem; the Armour Union benefits program; some suggested specific collective bargaining measures; the role of government; the need for a permanent commission on technological change; some basic changes needed in human thinking; the inadequacy of long-run adjustments; and the so far unrealized promise of automation.

Bollinger, Elroy William, and Weaver, Gilbert G. *Trade Analysis and Organization for Shop Teachers.* New York: Pitman Publishing Co., 1955. 136 p. $4.

Designed to assist prospective teachers of occupational subjects to discover the teachable content of their specialized vocational knowledge and skills. The procedure advocated will produce an almost exhaustive analysis of everything to be taught within the scope of the vocational activity under consideration. The ultimate objective is the formulation of a master course of instruction based on well-known techniques utilized in building courses of study, which should satisfy the initial and the continuing needs of the teacher.

Buckingham, Walter S. *Automation: Its Impact on Business and People.* New York: Harper and Brothers, 1961. 196 p. $4.50.

Discusses such topics as: What is automation? What happens when automation takes over whole industries, as it is now beginning to do? What happens when it comes to a plant? An office? The coming victory over "paper" work. The new role of the businessman, freed by machines from minor decisionmaking. The rising "elite" of automation-minded managerial men.

DeGroat, George H. *Metalworking Automation.* New York: McGraw-Hill Book Co., 1962. 332 p. $11.50.

Discusses the latest advances in the automation of the metalworking industry, particularly in small plants where automation is used for mass production. A useful technical reference book that provides guidance for planning for automation, designing parts and products for easier production, automated techniques including numerical control systems of machine tools, and applications to various metalworking operations.

Diebold, John. *Automation: The Advent of the Automotive Factory* Princeton: D. Van Nostrand Co., 1952. 181 p. $3.50.

A clearly written, informative, well-balanced and provocative study of the possibilities, limitations, social and economic consequences of the revolutionary new machines of the electronic age, in terms of jobs, costs of goods and services, standards of living, increased leisure time, and education and training. A popular approach that can be easily understood by the mature student and the lay reader. Though published in 1952, it is still frequently referred to. A basic publication for an understanding of automation and its impact.

Engineering Manpower Commission of Engineers Joint Council. *Demand for Engineers, Physical Scientists,*

and Technicians—1964. New York: the Commission, 1964. 80 p. $4.

ontains the results of a survey of current and future mployment of engineers, physical scientists, and technicians.

riedmann, Georges. *Industrial Society: The Emergence of the Human Problems of Automation.* Glencoe, Illinois: The Free Press. 1955. 436 p. $5.95; paperback, $2.45.

urveys the problems created by large-scale mechanized industry, the various ways in which industrial organizations have tried to deal with them, and the contributions of the social sciences to the life of the worker.

ugh-Jones, E. M., *editor. The Push-Button World: Automation Today.* Norman: University of Oklahoma Press, 1956. 158 p. $3.75.

utlines the social and economic implications of automation for society, labor, and employment. Includes redictions of the future course of automation. Contains much valuable background material with regard o today's manpower developments and training.

nstrument Society of America. *The Instrumentation Technician.* Final Report of the Instrument Society of America's Task Force on Instrumentation Technicians. Hollywood, Calif.: Grantham School of Electronics, 1961. 51 p. 35 cents.

ontains a set of definitions for instrumentation personnel known by such titles as "instrument mechanic" nd "instrumentation technician." Indicates the techniques and results of a national survey conducted durng 1959 and 1960 of the job functions of these workers.

acmillan, Robert H. *Automation: Friend or Foe.* New York: Cambridge University Press, 1956. 108 p. $1.95.

eals chiefly with the principles of automatic control with familiar examples) and the technical problems ccompanying automation. Also contains interesting omments on the social and economic aspects of automation and electric computers.

ational Association of Manufacturers. *Calling All Jobs: An Introduction to the Automatic Machine Age.* New York: the Association, 1954. 22 p. Free.

concise easy-to-read presentation of the historical ackground of the automatic machine age together ith some implications and applications.

Rogers, Jack. *Automation: Technology's New Face.* Berkeley: University of California, Institute of Industrial Relations, 1958. 94 p. 50 cents.

Informs the general reader on the present uses, the implications, and the future challenge of automation.

Rusinoff, S. E. *Automation in Practice.* Chicago: American Technical Society, 1957. 261 p. $4.50; Study Guide, $1.00.

Discusses in practical terms automation as applied to the many processes found in modern industry. Should be of vital interest to vocational schools training workers for skilled maintenance jobs and to individuals who are concerned with a breakdown of training aspects and functions. Is well illustrated and contains a wealth of professional know-how in the techniques of automated production.

Schmidt, Emerson P. *Automation and Unemployment.* Washington: Chamber of Commerce of the United States, 1961. 34 p. 50 cents.

A reprint of the author's testimony before the House Committee on Education and Labor, April 12, 1961. Discusses the types and causes of unemployment, the problems created, and suggestions for their alleviation or solution.

Schultz, George P., *and* Baldwin, George B. *Automation: A New Dimension to Old Problems.* Washington: Public Affairs Press, 1955. 20 p. $1.00.

Includes definitions of types of automation and discussion of some industrial relations problems, of the opportunities automation affords, and of the importance of providing retraining opportunities for displaced workers.

U.S. Department of Commerce, Business and Defense Services Administration. *U.S. Industrial Outlook 1966.* Washington: U.S. Government Printing Office, December 1965. 213 p. $1.00.

Presents accurate, up-to-date information on key U.S. industries. Analyzes trends, reports vital background information and statistics, gives detailed, industry-by-industry review, and outlines prospects for 1966. Provides the latest facts and figures on production, sales, shipments, employment, productivity, imports and exports, new products, and developments.

U.S. Department of Labor. *Manpower Report of the President and a Report on Manpower Requirements, Resources, Utilization, and Training.* Transmitted

to the Congress, March 1966. Washington: U.S. Government Printing Office, 1966. 229 p. $1.50.

The first section contains the text of President Johnson's report to the Congress, March 1966, in which he discusses the background for the Nation's manpower policy, the challenges to be met—unemployment; young workers; and changes in manpower sources and in requirements; and suggests actions which are necessary to meet our manpower needs. Following the President's report is the text of an extensive report by the U.S. Department of Labor on the manpower situation. A statistical appendix also is included.

U.S. Department of Labor, Bureau of Employment Security. *Dictionary of Occupational Titles.* Published in two volumes. Washington: U.S. Government Printing Office. (For detailed information on each volume, see below.)

Volume I. *Definitions of Titles.* Third Edition, 1965. 809 p. $5.00.

Defines occupations and supplies uniform names for basic occupations in agriculture, services, industry, professions, and crafts. Approximately 22,000 jobs with approximately 36,000 titles are identified by code numbers.

Volume II. *Occupational Classification and Index.* Third edition, 1965. 656 p. $4.25.

Presents the U.S. Employment Service occupational classification structure. Titles defined in volume I are listed here in numerical order according to assigned code numbers. They are arranged in defined major groups, divisions, and subdivisions which bring together jobs that demand similar skills, knowledges, and abilities.

———. *Guide for Analyzing Jobs.* Washington: U.S. Government Printing Office, 1944. 39 p. 25 cents

A pocket-size companion workbook to *Training and Reference Manual for Job Analysis* (see below). Contains basic principles of job analysis in outline form, with an explanation for each job analysis component. Helps the analyst determine what the worker does, why he does it, how he does it, and the skills involved.

———. *Technical Occupations in Research, Design, and Development Considered as Directly Supporting to Engineers and Physical Scientists.* Washington: U.S. Government Printing Office, 1961. 113 p. 50 cents

Includes composite descriptions of 29 technical occupations, including worker trait requirements.

———. *Training and Reference Manual for Job Analysis.* Washington: U.S. Government Printing Office, May 1965. 91 p. 60 cents.

Presents principles and practices for obtaining accurate information about jobs, including the uses of job analysis, job analysis methods, and suggestions for the study of job analysis. Designed as an operational and reference text for use in any program requiring the compilation of job information.

U.S. Department of Labor, Bureau of Labor Statistics. *Impact of Automation.* Bulletin No. 1287. Washington: U.S. Government Printing Office, 1960. 114 p. 60 cents.

A collection of 20 articles about technological change, reprinted from the *Monthly Labor Review.*

———. *Implications of Automation and Other Technological Developments: A Selected Annotated Bibliography.* Bulletin No. 1319. Washington: U.S. Government Printing Office, 1962. 136 p. 65 cents.

Contains more than 500 references to publications issued from 1956 to 1961.

———. *Implications of Automation and Other Technological Developments: A Selected Annotated Bibliography.* Bulletin No. 1319–1. Washington: U.S. Government Printing Office, 1963. 90 p. 50 cents.

Contains 307 supplementary references published between the latter part of 1961 and early 1963. Includes some earlier references not given in Bulletin 1319.

———. *Occupational Outlook Handbook.* 1966–67 edition, Bulletin No. 1450. Washington: U.S. Government Printing Office, 1965. 858 p. $5.00.

Explores employment trends and economic conditions likely during the next decade. Presents concise profiles of nearly 700 occupations and 30 major industries, and includes information on employment outlook, nature of work, earnings and working conditions, training and education, and prospects for promotion.

———. *Outlook for Numerical Control of Machine Tools.* Bulletin No. 1437. Washington: U.S. Government Printing Office, 1965. 63 p. 40 cents.

Numerical control represents the latest major development in making machining more automatic. Used primarily for automatically producing parts in small

quantities, this innovation draws on advances in electronics that have developed out of postwar research and development. The nature of this innovation, the extent of present and prospects for future usage, and some of its probable implications for productivity, occupations, training, employment, and industrial relations are covered in this study.

U.S. Department of Labor, Bureau of Labor Statistics. *Productivity: A Bibliography.* Bulletin No. 1226. Washington: U.S. Government Printing Office, 1957. 182 p. $1.00.

Contains nearly 900 references on productivity measurement, factors affecting productivity, and significance of productivity changes.

U.S. Department of the Navy, Bureau of Naval Personnel. *Handbook for Naval Occupational Analysis.* NAVPERS 15803–A. Washington: The Department, 1961.

A guide for making occupational analyses in naval installations but is readily adaptable to civilian occupations. Provides methods for planning a study, collecting information and preparing job descriptions. Includes a questionnaire form and a list of functional verbs for use in preparing occupational analysis schedules. A limited number of copies have been made available to the division, Program Services Branch, U.S. Office of Education, Washington, D.C., 20202.

U.S. 84th Congress, Second Session, Joint Economic Committee. *Instrumentation and Automation: Hearings Before the Subcommittee on Economic Stabilization.* U.S. Government Printing Office, 1957. 202 p. 75 cents.

Presents statements by representatives of industry, labor, and education on various topics such as the development of scientific, engineering, and technical skills; the effects of instrumentation and automation in the area of automatic processing and in nucleonics; the changes and problems in the field of education in connection with the introduction and expansion of automatic controls, and the need for trained scientists and research workers in the field of automation.

Appendix A

SELECTED OCCUPATIONS IN THE FIELD OF INSTRUMENTATION[3]

INSTRUMENTATION ENGINEER. A term applied to one who designs and supervises operation and maintenance of electrical, mechanical, and thermal instruments and control equipment necessary for safe and efficient operation of industrial plant. Studies plant layout and process requirements to determine type and number of items needed. Writes specifications for selection of stock or special instruments from suppliers. Directs installation, calibration, and testing of equipment. Supervises application, inspection, and maintenance of instruments in operation. Classifications are made according to field of engineering specialization.

INSTRUMENTATION TECHNICIAN 003.281. Devises, sets up, and operates electronic instrumentation and related electromechanical or electrohydraulic apparatus involved in operational and environmental testing of mechanical, structural, or electrical equipment, and translates test data for subsequent use by engineering personnel in making engineering design and evaluation decisions. Selects, installs, calibrates, and checks out sensing, telemetering, and recording instrumentation and circuitry, and develops specifications for nonstandard apparatus according to engineering data, characteristics of equipment under test, and capabilities of procurable test apparatus. Sketches and builds or modifies jigs, fixtures, instruments, and related apparatus, and varifies dimensional and functional acceptability of devices fabricated by craft or technical personnel. Performs preventative and corrective maintenance of test apparatus and peripheral equipment. Directs technical personnel in installation of object in test chamber or other test facility. Operates test apparatus during test cycle to produce, regulate, and record effects of actual or simulated conditions such as vibration, stress, temperature, humidity, pressure, altitude, and acceleration. Mathematically reduces test data to usable form, and prepares graphs and written reports to translate test results into meaningful terms such as speed-temperature-horsepower ratios. May plan complete test program. May be designated according to equipment tested as ROCKET-CONTROL TECHNICIAN or according to nature of test as ENVIRONMENTAL-RESEARCH-TEST TECHNICIAN.

INSTRUMENT MAKER II. 600.280 (mechanical technician; parts mechanic; precision-instrument and toolmaker; precision-mechanical-instrument maker). Fabricates, modifies, or repairs mechanical instruments, or mechanical assemblies of electrical or electronic instruments, such as chronometric timing devices, barographs, thermostats, seismographs, and servomechanisms, following blueprints and engineering sketches and using machine tools, welding and heat-treating equipment, precision measuring instruments, and handtools. Lays out cutting lines of structural parts, such as brackets, fittings, and housings on stock, such as silver, nickel, platinum, steel, ivory, and plastic, using square, rule, and scribe. Cuts and shapes parts, using machine tools, such as lathes, drill presses, punch presses, milling machines, grinders, brakes, and lapping and polishing machines. Anneals and tempers metal parts. Assembles parts in jig and brazes or welds them. Fits and installs precision components, such as timing devices, springs, balance mechanisms, and gear trains in housing, using jeweler's lathe, tweezers, loupe, and handtools. Verifies dimensions of parts and installation of components, using measuring instruments, such as micrometer, calipers, and electronic gauges. Coats assembled instrument with protective finish, such as lacquer or enamel, using spray gun. May set up and operate machines to fabricate dies for punch presses.

INSTRUMENT REPAIRMAN I. 710.281 (instrument-maintenance mechanic; instrument man; weights-and-measuring man). Installs, repairs, maintains, and adjusts indicating, recording, telemetering, and controlling instruments used to measure and control

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[3] Descriptions are based on definitions that appear in the *Dictionary of Occupational Titles*, Vol. I, 1965 edition, pp. 386–388, 638.

variables such as pressure, flow, temperature, motion, force, and chemical composition, using handtools, and precision instruments. Disassembles malfunctioning instruments, and examines and tests mechanism and circuitry for defects. Troubleshoots equipment in or out of control system and replaces or repairs defective parts. Reassembles instrument and tests assembly for conformance with specifications, using instruments such as potentiometer, resistance bridge, manometer, and pressure gauge. Inspects instruments periodically and makes minor calibration adjustments to insure functioning within specified standards. May adjust and repair final control mechanisms such as automatically controlled valves or positioners. May be designated according to type of instrument repaired as METER SERVICEMAN; PANEL-INSTRUMENT REPAIRMAN; and X-RAY CONTROL-EQUIPMENT REPAIRMAN.

SERVICE ENGINEER. A term used to designate an engineer who is retained by a manufacturing concern, such as firms engaged in manufacture of air-conditioning equipment, furnaces, sound equipment, or aircraft, to service and repair equipment or other products.

Appendix B

LIST OF COURSES

MATHEMATICS COURSES [4]

BASIC MATHEMATICS I. This is a course in practical arithmetic. Includes addition, subtraction, multiplication, and division of fractions; addition, subtraction, multiplication, and division of decimals; conversion of fractions to decimals; powers, square roots, and round off of numbers; significant figures, reciprocals, and averages. This course requires 64–80 hours.

BASIC MATHEMATICS II. This is a continuation of Basic Mathematics I and deals with logarithms; formula manipulation; use of slide rule; measurement of area and volume; measurement of weight, time, and temperature; conversion of units; solution of simple equations; calculations with denominate numbers; and practice problems encountered in instrument maintenance. This course requires 64–80 hours.

TECHNICAL MATHEMATICS I. This course is equivalent to the algebra usually taught at the high school level. It usually includes literal numbers; positive and negative numbers; addition, substraction, multiplication, and division of algebraic expressions; simple equations; and introduction to simultaneous linear and quadratic equations; the binomial theorem; and ratio, proportion, and variation. This course usually requires 3 class hours per week.

TECHNICAL MATHEMATICS II. The first part of this course is usually devoted to a review of arithmetic and high school algebra including factoring and clearing of fractions and decimals. Instruction is given in the use of the slide rule. The second and longer part of the course usually includes fundamental algebraic operations, equations, and formulas; introduction to analytic geometry and graphing; simultaneous equations; exponents, radicals, and complex numbers; quadratic equations in one unknown; ratio, proportion and variation; logarithms; and introduction to trigonometry. This course usually requires 5 class hours per week.

GEOMETRY I. This is a course in plane geometry and includes axioms and theory, the triangle, the circle, the properties of the circle, geometric problems of construction, and areas of plane geometric figures. This course usually requires 3 class hours per week.

GEOMETRY II. (Prerequisite—Geometry I.) This is a course in solid geometry and includes areas and volumes of solids, methods and short cuts in estimating weights, specific gravities of various materials, and geometric principles applied in the solution of shop problems. This course usually requires 3 class hours per week.

TRIGONOMETRY AND GRAPHIC ANALYSIS. (Prerequisite—Technical Mathematics I.) In this course trigonometry, analytic geometry, and algebra are continued and expanded to more advanced phases of mathematics as required in the field of work for which instruction is given. Calculus is incorporated in a manner emphasizing concept and principle rather than facility in its use. Included in the course are solution of right and oblique triangles, trigonometric functions for any angle, trigonometric identities and equations, trigonometric graphing, complex numbers and vectors, sequences and series, vector analysis, graphic analysis, and applied problems. This course usually requires 4 class hours per week.

SCIENCE COURSES

BASIC ELECTRICITY I. This course teaches the fundamentals of electricity and includes the electron theory; types of basic circuits; electrical symbols and sources of electricity; the relationship between voltage, current, and resistance in a circuit and the application of Ohm's law; magnetic principles and common applications of the electromagnet; theory and applications of the transformer; theory and

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[4] In certain situations, it may be desirable to consider the use of a mathematics course related to electronic data processing.

operation of induction coils; principles of induction motors; solenoids and relays; wire size and fuses; circuit drawing—use of symbols and types of circuits; basic wiring methods, code requirements, installation of outlets and switches; batteries, electrochemical action, and Kirchhoff's law. This course usually requires 3 class hours and 4 laboratory hours per week.

BASIC ELECTRICITY II. (Prerequisite—Basic Electricity I.) This is a continuation of Basic Electricity I and includes basic physics of the electron; electric units and Ohm's law; series circuits, parallel circuits, and combination circuits; circuit laws; electrochemical action; conductors and insulation; magnetism; electrocapacitance; electrical machines and motor testing. Much of the time in the laboratory is devoted to mathematical calculations, including the use of the slide rule. This course usually requires 3 class and 4 laboratory hours per week.

BASIC ELECTRONICS. This is a basic course to prepare trainees for servicing electronic equipment—radio, radar, television and digital computers. It usually includes diodes and triodes, circuit time constants, power supplies, electron tube characteristics, low frequency amplifiers, high frequency amplifiers, LC oscillators, RC oscillators, transistors, transistor circuits, amplitude modulation, amplitude modulators and demodulators, frequency modulation, and frequency modulators and demodulators. Courses in basic electricity such as Basic Electricity I and II are usually a prerequisite for this course. This course usually requires 3 class hours and 3 laboratory hours per week.

INDUSTRIAL ELECTRONICS. This course is designed to familiarize the student with industrial circuits and usually includes measuring systems, electronic components, reactance effects on AC power in reactive circuits, inductors and transformers, vacuum tubes, gaseous electron tubes, rectifier circuits, glow tubes and voltage regulators, regulated power supplies, basic amplifier circuits, electric motors, electronic timers, light and optics, photoelectric cells, magnetic amplifiers, and LC oscillators. The course in Basic Electronics is usually a prerequisite for this course. This course usually requires 3 class hours and 4 laboratory hours per week.

INSTRUMENTATION ELECTRONICS. This course is designed to familiarize the student with the electronic equipment and devices found in electronic instrumentation. It usually includes grid-controlled rectifiers, nuclear particles, radiation detectors, radiation detector characteristics, high voltage power supplies, commercial scalers, input and output transducers, recording devices, ultrasonics, mechanical linkages, synchros, positions detectors and controls, servomechanisms, temperature controls, flow and pressure controls, carrier current transmission, telemetering and remote control. The course in Basic Electronics is usually a prerequisite for this course. The course usually requires 5 class hours per week and 6 laboratory hours.

CHEMISTRY I. This is a course in general chemistry and includes an introduction to fundamental principles, atomic structure; periodic classification; formulas and chemical equations; oxygen and hydrogen; the gaseous state; valence and oxidation number; classification and nomenclature; weight and volume relations; water and liquid state; solutions and colloids. It usually requires 5 class hours per week and one period (2-3 hours) of laboratory work.

CHEMISTRY II. (Prerequisite—Chemistry I.) This is a more advanced course in chemistry and includes chemical equilibriums; ionization; oxidation and reduction; metals and metallurgy; representative metals; electrochemistry; corrosion; transition metals; and nuclear changes. Five hours per week of classroom work and 6 hours in the laboratory are usually required for this course.

PHYSICS I. This course is equivalent to the physics usually taught at the high school level. It usually includes mechanics; forces; motion; gravitation; work, energy and power; machinery, heat, sound, and light; electricity and magnetism. It usually requires 3 hours per week of class and one period (2–3 hours) of laboratory work.

PHYSICS II. (Prerequisite—Physics I.) This is a more advanced course in physics and includes basic measurement; properties of solids, liquids, and gases; statics; rectilinear motion and momentum; angular and simple harmonic motions; work, energy and power; heat and temperature; thermodynamics; hydraulics and pneumatics; and optics. This course usually requires 3 class hours and 4 laboratory hours per week.

FLUID MECHANICS I. This course acquaints the student with the physical properties of gases and liquids and their behavior under various conditions. It includes atmospheric pressure; intensity of pressure; energy of liquids; properties of gases and liquids; various laws and principles governing gases and liquids; and pneumatic and hydraulic machines and devices. This course usually requires 32–48 hours of class and 32–48 hours of laboratory work.

FLUID MECHANICS II. This is a continuation of Fluid Mechanics I and stresses the application of working formulas such as the Bernouli and momentum equations as they relate to the physical properties of gases and liquids; the flow of fluid in pipes; the measurement of fluid flow; the multiplication of fluid force; and the calculation of pipe sizes, pressures developed, and pump deliveries. This course usually requires 32–48 hours of class and **48** hours of laboratory work.

INSTRUMENTATION TECHNOLOGY

INSTRUMENT FUNDAMENTALS I. (Prerequisites—Basic Electricity I and Basic Mathematics I.) This course is designed to provide the student with a basic knowledge of instruments. It includes an introduction to the field of work; shop and industrial safety practices; instrument cleaning and lubricating; care and use of small hand and power tools; soldering techniques; instrument charts; and types of instruments used in industry. This course usually requires 32–48 hours of class and 64–80 hours of laboratory work.

INSTRUMENT FUNDAMENTALS II. This is a continuation of Instrument Fundamentals I. It includes reading and interpreting instrumentation drawings; fundamentals of measurement and control devices; final control elements; and an introduction to standards and calibration. This course usually requires 32–48 hours of class and 64–80 hours of laboratory work.

MEASUREMENT PRINCIPLES. This course introduces the student to industrial methods for measuring pressure and temperature with various types of gauges and other devices. It includes the basic theory of operation, construction, installation, normal care and handling, operational checks and calibration of gauges, manometers, and nonelectric thermometers. This course usually requires 48–64 hours of class and 96–112 hours of laboratory work.

INSTRUMENT INSTALLATION. (Prerequisites—Instrument Fundamentals I and II.) This course equips the student with knowledge and skills necessary to install and service sensing devices commonly found in industry. It includes basic theories of operation: Installation, care and maintenance of various types of sensing devices, such as glass thermometers, bimetallic elements, filled systems, thermocouples, optical and radiation pyrometers, flow orifices, variable area meters, Pitot tubes, flow receivers, level-displacement, and electric elements. This course usually requires 32–48 hours of class and 64 hours of laboratory work.

INSTRUMENT MAINTENANCE I. (Prerequisites—Instrument Fundamentals I and II, Measurement Principles, Instrument Installation.) This course gives the student practical experience in instrument maintenance. It includes tests and calibration; basic troubleshooting of instruments; installation of instruments and control elements; instrument mounting and panel installation; thermocouple installation; instrument shop operations; preventive maintenance; and an understanding of basic industrial instrumentation systems. This course usually requires 48–64 hours of class and 96 hours of laboratory work.

INSTRUMENT MAINTENANCE II. (Prerequisite—Instrument Maintenance I.) This course equips the student with an understanding of the fundamental purpose and operation of electrical indicators and recorders and sufficient knowledge and skill to enable him to carry out the routine calibration and maintenance functions. It includes theory, application, servicing, and simple operational checks of electrical indicators and recorders. This course usually requires 32–48 hours of class and 32 hours of laboratory work.

INDUSTRIAL INSTRUMENTATION SYSTEMS. This course consists of lectures by industry representatives, instructor-led discussions, and field trips to introduce trainees to the types of instruments and controls used in various kinds of industrial establishments. This course usually requires a minimum of 48 hours including approximately 16 hours of field visitations.

AUTOMATIC CONTROLS. This course is designed to give the student an understanding of automatic control principles. It usually includes open and closed loop control system fundamentals; feedback principles; control system stabilization; types of transducers and their applications; bridge circuits used in measurement and control; self-balancing potentiometer; and servomechanism principles. The course usually requires 2 class hours per week.

PROCESS CONTROL—PNEUMATIC. This is a study of process control using pneumatic principles. It includes on-off proportional, proportional plus reset and derivative actions. Also included are control auxiliaries, such as pneumatic set, rates control, cascade control, duplex controllers, and pneumatic integrating. Various makes and kinds of pneumatic relays are studied. Valves and pneumatic operators are also included. Laboratory work includes the alignment and setting up of various makes of pneumatic controllers. Adjustments for optimum control are studied and demonstrated, using small processes and analog computers. This application of controllers to various processes is covered from simple on-off to complete automation with emphasis on miniaturization, graphic panels, and central control. The course usually requires 5 class hours and 6–8 laboratory hours per week.

PROCESS CONTROL—ELECTRONIC (Prerequisite—Process Control, Pneumatic.) This course covers the theory and application of electrical and electronic instruments to process control. Electronic off-on control, proportional, proportional plus reset, and proportional plus reset and derivative actions are covered in theory and practice. Also included is the combining of electronic and pneumatic methods of control using the advantages of both. The course usually requires 3 class hours and 6 laboratory hours per week.

INSTRUMENTATION SYSTEM DESIGN & OPERATION (Prerequisites—Automatic Control; Process Control—Pneumatic; Process Control—Electronic.) This course is designed to give the student an understanding of instrumentation systems and their design and operation. It includes electronic and pneumatic transmission systems and mechanical pressure mechanisms; mechanical and resistance thermometers; pyrometry; EMF and resistance transducers; the dynamics of temperature measurement; mechanical and magnetic flow meters; flow, liquid level, and other measurements; analytical instruments; control valves—mechanisms and techniques; control dynamics; and instrumentation systems. In the laboratory the student gets practical experience in designing and troubleshooting instrumentation systems. This course usually requires 4 hours of class and 8 hours of laboratory per week.

SUPPLEMENTARY COURSES

BLUEPRINT READING. This course is designed to provide the student with fundamental knowledge of blueprints and engineering drawings and some skill in the reading and interpretation of drawings. It includes engineering drawings and blueprints; mechanical drawings; lines used on drawings; sectional views; common conventions; abbreviations and notations on drawings; scales; dimensions; fits and finish marks; surface roughness and lay; threads; rivets; tapers; and examples of blueprint reading. This course usually requires 2 hours of class work per week.

TECHNICAL DRAWING. This is an elementary course designed for students with limited drawing experience who plan to work in drafting and design work. It includes the fundamentals of drawing and drafting room procedures and practices; shape description; dimensioning drawings; threads and fasteners; pictorial drawings; working drawings; electrical circuit; electrical layouts and equipment. This course usually requires 48–64 hours of class and 96 hours of laboratory work.

MECHANICAL DRAFTING. This is usually a continuation of the course in Technical Drawing. It should provide additional understandings of drafting problems, and skills and techniques that are essential to the work of the mechanical draftsman. Emphasis is placed on interpretation of industrial prints, ability to use handbooks and other source materials, and the development of skill in sketching. Included in this course are intersections and developments; gears, cams, jigs and fixtures; welding drawings; perspective drawing and engineering drafting practices. This course usually requires 48–64 hours of class and 128 hours of laboratory work.

MACHINE SHOP OPERATIONS. This course is designed to give the student an understanding of machine shop operations and practices and some skill in the use of measuring instruments and in the operation of basic machines. It usually includes orientation in machine shop work; measuring tools—precision and semiprecision; bench tools including small power tools; drill press; engine lathe; shaper and planer; milling machines; steels and their alloys; heat treating—methods, equipment, and hardness testing; and machinability of metals. This course usually requires 80–96 hours of class and 128 hours of laboratory work.

BASIC MECHANISMS. This course deals with the analysis of motion characteristics of a mechanism of existing design and the application of this study in the design of a mechanism to provide desired motion characteristics. It includes definition of major terms; displacement, velocity and acceleration; instant centers; plane motion; slider-crank mechanisms; cam displacement diagrams; spur, helical, and bevel gears; gear trains; flexible conductors; and miscellaneous mechanisms. This course usually requires 32 class hours and 64 hours of laboratory work.

STRENGTH OF MATERIALS. This course covers the application of the principles of strength of materials which is considered fundamental in the design of structures and machines. Emphasis is given to the analysis of the simple and combined stresses and properties of materials to meet the functional requirements of the design. The course usually includes such units as stress and strain; riveted and welded joints; center of gravity and centroids; shear forces; bending moments and design of beams; torsions, shafts, shaft couplings and keys; combined stresses, columns, and intermediate beams. This course usually requires 64–80 hours of class and 96 hours of laboratory work.

DESIGN PROJECT. This course enables the student to work on the design and fabrication of an instrument, test fixture, or other suitable device. The student confers with the instructor about the project, but most of the time is spent in the laboratory in designing the device, in preparing drawings and prints, and in construction of the unit. The student tests and evaluates the finished product and prepares a test report. This course usually requires 80–96 hours in the laboratory.

Appendix C

SAMPLE CURRICULUM OUTLINE

To show how a curriculum can be developed from the techniques suggested in this publication. the work activity of instrument making, maintenance and repair was selected. The following steps were followed in developing the sample curriculum outline:

1. *Analyze the purpose and activities of instrument making, maintenance, and repair and the competencies required for it.* During the past few years, instrumentation has become a major technological field and the costly equipment involved must be kept operating as continuously and efficiently as possible. The installation, repair, adjustment, calibration, and general maintenance of the vast amount of "hardware" covered by this technology is of utmost importance. To carry out this work, the student in this field needs some mathematics and science, an understanding of instrument maintenance procedures, and skill in the use of small hand and power tools and in the application of measurement principles.
2. *List the essential subject-matter areas shown on the Training Requirements Analysis Form under this work activity.*

    MATHEMATICS
      Basic Mathematics I
      Basic Mathematics II
    SCIENCE
      Basic Electricity I
      Basic Electricity II
      Basic Electronics
      Physics I
      Physics II
      Fluid Mechanics I
    INSTRUMENTATION TECHNOLOGY
      Instrument Fundamentals I
      Instrument Fundamentals II
      Measurement Principles
      Instrument Installation
      Instrument Maintenance I
      Instrument Maintenance II
      Industrial Instrumentation Systems
      Automatic Controls
    SUPPLEMENTARY COURSES
      Blueprint Reading
      Basic Mechanisms

3. *List the subject matter areas shown on the Training Requirements Analysis Form under this work activity which are considered advisable but not essential.*

    Technical Mathematics I
    Technical Mathematics II
    Trigonometry & Graphic Analysis
    Industrial Electronics
    Instrumentation Electronics
    Instrumentation System Design and Operation
    Technical Drawing
    Machine Shop Operations

4. *List the general education subjects which are required by law in the State where the curriculum will be used or which help to broaden the student's education.*

    Communication Skills.
    Labor Relations

5. *Determine other courses which may be required as learning or communications tools.* (Bear in mind that the subject-matter areas in the Training Requirements Analysis Form represent only those subjects needed to perform the duties of the job.)

    None required

6. *Arrange the courses in a pattern which represents psychological sequence, time allocation, and the relative importance of each course.* It is important to set up one course which will motivate and maintain student interest right from the start. For example, a student enrolling for a curriculum in Instrument Making, Maintenance and Repair should start working immediately with instruments. This is his real interest. Hence, Instrument Maintenance I and Fluid Mechanics I are offered as courses in the first semester. He will soon discover that mathematics and other subjects which may have been distasteful to him are necessary if he wishes to make a career in instrumentation.

The list of courses and the sample curriculum outline on page 27 were developed in accordance with the steps outlined above. The list of courses was developed first and the curriculum outline was based on this. The hours for each course were taken from the courses of study in appendix B. The time schedule used is three 16-week instruction periods, 35 hours per week. Any remaining time may be allotted for directed study, remedial instruction, and testing. Two general education courses were added to round out the curriculum. General education courses may vary from State to State and/or to meet local situations.

It should be recognized that the hours shown for each course may vary, depending upon the ability of the students to profit from the instruction given. The hours shown are those normally required to train students who have completed high school and have had some algebra and science.

Further analysis of the Training Requirements Analysis Form reveals that training for the occupations involved in the category of instrument making, maintenance, and repair is not strictly technical in nature as it involves only an elementary knowledge of basic mathematics and the fundamentals of electricity and electronics. The sample curriculum outline shows that this training can be provided in three semesters of 16 weeks each. This means that such a training program can be set up under the provisions of the Manpower Development and Training Act.

Occupations in the remaining two categories of work activity appearing on pages 10–11, however, require a 2-year technical education program in which the students acquire knowledge of mathematical and engineering principles and the ability to apply these principles to instrumentation problems.

LIST OF SUGGESTED COURSES FOR A CURRICULUM IN INSTRUMENT MAKING, MAINTENANCE, AND REPAIR, BY STUDY UNITS AND HOURS

Course	Class hours [1]	Laboratory hours [1]	Total hours [1]
Basic Mathematics I	64	0	64
Basic Mathematics II	64	0	64
Basic Electricity I	48	64	112
Basic Electricity II	48	64	112
Basic Electronics	48	96	144
Basic Mechanisms	32	64	96
Physics I	48	32	80
Physics II	48	64	112
Fluid Mechanics I	32	32	64
Instrument Fundamentals I	32	64	96
Instrument Fundamentals II	32	64	96
Measurement Principles	48	96	144
Instrument Installation	32	64	96
Instrument Maintenance I	48	96	144
Instrument Maintenance II	32	32	64
Industrial Instrumentation Systems	48	0	48
Automatic Controls	32	0	32
Blueprint Reading	32	0	32
Communication Skills	48	0	48
Labor Relations	32	0	32
Total	848	832	1,680

[1] Minimum number of hours. This may have to be increased for slow learners or for students who have not graduated from high school.

SAMPLE CURRICULUM OUTLINE FOR A SUGGESTED COURSE IN INSTRUMENT MAKING, MAINTENANCE, AND REPAIR, BY SEMESTER

Course, by semester	Hours per week		
	Class	Laboratory	Total
First Semester (16 weeks):			
Basic Mathematics I	4	0	4
Physics I	3	2	5
Instrument Maintenance I	3	6	9
Measurement Principles	3	6	9
Fluid Mechanics I	2	2	4
Communication Skills	3	0	3
Total	18	16	34
Second Semester (16 weeks):			
Basic Mathematics II	4	0	4
Physics II	3	4	7
Basic Electricity I	3	4	7
Instrument Fundamentals I	2	4	6
Instrument Installation	2	4	6
Industrial Instrumentation Systems	3	0	3
Total	17	16	33
Third Semester (16 weeks):			
Basic Electronics	3	3	6
Basic Electricity II	3	4	7
Basic Mechanisms	2	4	6
Instrument Fundamentals II	2	4	6
Instrument Maintenance II	2	2	4
Automatic Controls	2	0	2
Blueprint Reading	2	0	2
Labor Relations	2	0	2
Total	18	17	35

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Determining Requirements for Development of Technical Abilities Through Extension Courses. OE–80010. 1961. 14 p. 15 cents

Suggests procedures for training skilled workers to meet scientific and technological changes in their occupations or to undertake new jobs.

Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs. OE–80015. 1962. 26 p. 15 cents

Provides educators and others with an understanding of the nature and scope of work activities performed by highly skilled technicians; the general abilities and personal characteristics of workers employed in technical occupations; and the depth, range, and balance of curriculum content needed to prepare such technicians. Should be of particular value to State and local administrators, teacher trainers, and supervisors and teachers of technical education programs in planning, developing, and evaluating such programs.

Progress in Title VIII Programs: National Defense Education Act of 1958: Fiscal Year 1963. July 1964. 7 p. Free.

The following six guides are designed to serve States in organizing and operating programs under Title VIII of the National Defense Education Act of 1958, and under Title III of the George-Barden Act (1946):

Chemical and Metallurgical Technologies: Suggested Techniques for Determining Courses of Study in Vocational Education Programs. OE–80016. 1962. 22 p. 25 cents.

Civil and Highway Technology: Suggested Techniques for Determining Courses of Study in Vocational-Technical Education Programs. OE–80018. 1964. 20 p. 25 cents.

Electrical and Electronic Technologies: Job Descriptions and Suggested Techniques for Determining Courses of Study in Vocational Education Programs. OE–80004. 1964. 34 p. 30 cents.

Electronic Data Processing in Engineering, Science, and Business: Suggested Techniques for Determining Courses of Study in Vocational and Technical Education Programs. OE–80030. 1964. 34 p. 30 cents.

Mechanical Drafting and Design Technology: Job Descriptions and Suggested Techniques for Determining Courses of Study in Vocational Education Programs. OE–80000. 1964. 26 p. 25 cents.

Mechanical Technology—Design and Production: Suggested Techniques for Determining Courses of Study in Vocational Education Programs. OE–80014. 1964 29 p. 25 cents.

The following curriculum guides are designed to aid school administrators, supervisors, and teachers in organizing or evaluating full-time study programs in certain fields of technology:

Chemical Technology: A Suggested 2-Year Post High School Curriculum. OE–80031. 1964. 119 p. 70 cents.

Electrical Technology: A Suggested 2-Year Post High School Curriculum. OE–80006. 1960. 118 p. 75 cents.

Electronic Data Processing—I: A Suggested 2-Year Post High School Curriculum for Computer Programers and Business Application Analysts.

OE–80024. 1963. 49 p. 40 cents.

Electronic Technology: A Suggested 2-Year Post High School Curriculum. OE–80009. 1960. 97 p. 70 cents.

Instrumentation Technology: A Suggested 2-Year Post High School Curriculum. OE–80033. 1964. 119 p. 75 cents.

Mechanical Technology—Design and Production: A Suggested 2-Year Post High School Curriculum. OE–80019. 1964. 103 p. 70 cents.

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