# R E P O R T   R E S U M E S

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MECHANICAL TECHNOLOGY, DESIGN AND PRODUCTION, SUGGESTED TECHNIQUES FOR DETERMINING COURSES OF STUDY IN VOCATIONAL EDUCATION PROGRAMS.

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DESCRIPTORS- *JOB ANALYSIS, *CURRICULUM DEVELOPMENT, TECHNICAL EDUCATION, TRADE AND INDUSTRIAL EDUCATION, OCCUPATIONAL CLUSTERS, CURRICULUM PLANNING, *OCCUPATIONAL INFORMATION, EDUCATIONAL NEEDS, *MECHANICAL DESIGN TECHNICIANS, *PRODUCTION TECHNICIANS, MECHANICAL DESIGN TECHNOLOGY, PRODUCTION TECHNOLOGY,

THIS PUBLICATION IS THE THIRD IN A SERIES DESIGNED TO PROVIDE INFORMATION TO HELP STATES ORGANIZE AND OPERATE PROGRAMS UNDER TITLE VIII OF THE NATIONAL DEFENSE EDUCATION ACT OF 1958. THE OTHER PUBLICATIONS ARE "MECHANICAL DRAFTING AND DESIGN TECHNOLOGY" (VT 001 823) AND "ELECTRICAL AND ELECTRONIC TECHNOLOGY" (VT 002 421). EACH PUBLICATION INDICATES HOW JOB ANALYSIS AND JOB RELATIONSHIP TECHNIQUES CAN BE USED TO FACILITATE THE PLANNING OF TRAINING PROGRAMS. MECHANICAL DESIGN TECHNOLOGY IS CONCERNED WITH THE DEVELOPMENT, TESTING, EVALUATION, AND DESIGN OF MACHINERY, EQUIPMENT, INSTRUMENTS, AND OTHER MECHANICAL SERVICES PRIOR TO PRODUCTION. PRODUCTION TECHNOLOGY IS CONCERNED WITH INDUSTRIAL ENGINEERING PROBLEMS INVOLVING THE EFFICIENT USE OF MANPOWER, MATERIALS, AND MACHINES IN MASS PRODUCTION PROCESSES. BEFORE TECHNICAL CURRICULUMS CAN BE ESTABLISHED, IT IS NECESSARY TO IDENTIFY THE SPECIFIC OCCUPATIONS FOR WHICH TRAINING IS NEEDED AND TO ANALYZE AND TO PREPARE BRIEF JOB DESCRIPTIONS OF EACH. THE 20 JOB DESCRIPTIONS INCLUDED IN THIS BOOKLET WERE TAKEN FROM VOLUME I OF THE "DICTIONARY OF OCCUPATIONAL TITLES." AFTER SUBJECT MATTER AREAS ARE IDENTIFIED THROUGH THE JOB ANALYSIS, THE SUBJECTS MUST BE ARRANGED IN A LOGICAL ORDER AND INSTRUCTIONAL UNITS MUST BE DEVELOPED TO PROVIDE THE DESIRED LEARNING. THE PURPOSE OF THE SUGGESTED TECHNICAL TRAINING PROGRAMS IS TO PREPARE WORKERS FOR SINGLE OCCUPATIONS WITH CONTENT DERIVED FROM THE ANALYSIS OF THE SPECIFIC JOBS. A TRAINING REQUIREMENTS ANALYSIS FORM AND AN ANNOTATED BIBLIOGRAPHY TO PROVIDE A SOURCE FOR MORE DETAILED INFORMATION ARE INCLUDED. THIS DOCUMENT IS AVAILABLE FOR 25 CENTS FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (HC)

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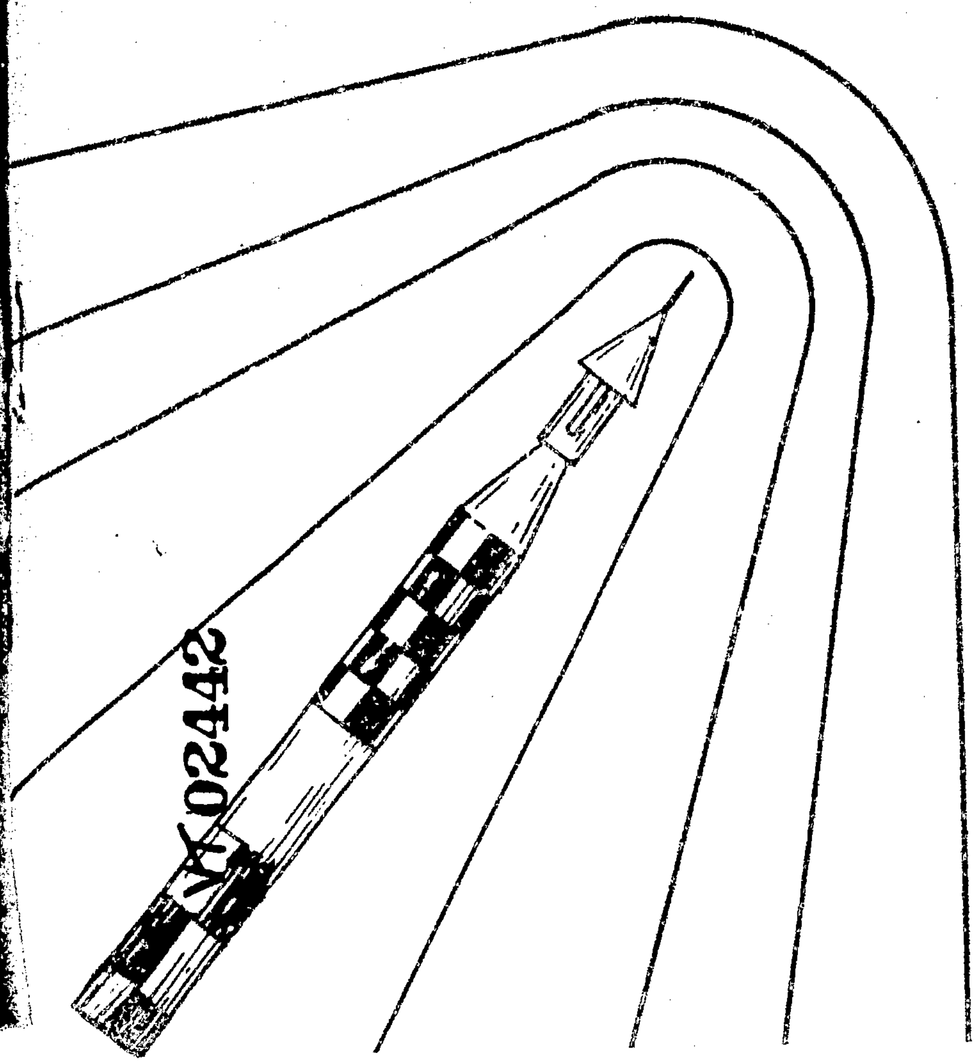
COURSES OF STUDY IN
VOCATIONAL EDUCATION PROGRAMS

# Mechanical Technology Design and Production





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VOCATIONAL EDUCATION PROGRAMS

# Mechanical Technology

## Design and Production

1966

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Abraham Ribicoff, Secretary
Office of Education, Sterling M. McMurrin, Commissioner
Division of Vocational Education, Area Vocational Education Branch

## FOREWORD

This publication, covering mechanical technology, is the third in a series designed to provide information to help the States organize and operate programs under title VIII of the National Defense Education Act of 1958, Public Law 85-864. The other publications are: Mechanical Drafting and Design Technology (OE-80000) and Electrical and Electronic Technologies (OE-80004).

The programs established under this title meet several provisions. Among these are requirements for scientific or technical knowledge, and training in occupational fields necessary for the national defense. Having met the requirements of the act, programs are not precluded because of the occupational titles or classifications under which persons may be employed or because of the segment of industry concerned. For purposes of this document, the terms, "technician" and "technical worker" refer to respective scopes of training and work capabilities rather than to employment classifications as such.

Each publication in this series indicates 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 occupations discussed in this document are typical of those found in two broad fields of work, but are not meant to be all-inclusive. They represent typical areas of activity in which technical workers are engaged and should not be considered in all cases as entry jobs. Students who have received instruction in an organized training program for a specific technology are provided with the technical knowledge and skills of this field of work, but they usually serve a period of internship in order to learn how to apply their knowledge to technical problems likely to be encountered in the specific job to which they are assigned.

This manuscript was prepared by Clarence E. Peterson, occupational analyst, Area Vocational Education Branch, Division of Vocational Education. He was assisted by other staff members of the Branch.

W. M. Arnold, Assistant Commissioner
for Vocational Education

## CONTENTS

## INTRODUCTION

Accurate information about jobs is fundamental to the planning of any occupational training program. The nature of the job information required varies according to the program contemplated. Regardless of its ultimate use however, the data must be up to date, accurate, and presented in usable form.

The process of obtaining and reporting pertinent information concerning the nature of a specific job is called "job analysis." This technique is used in determining the actions, skills, knowledge, abilities and responsibilities which are required of a worker for successful performance of his job and in identifying the tasks or elements which differentiate the job under study from all others.

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

"Job analysis," as used in this document, does not pretend to establish a means for determining absolute or relative wage rates, nor is it to be used as a means of establishing seniority groupings or units for purposes of collective bargaining.

After the needs for technical manpower have been determined, it will be necessary, in most cases, to analyze the various jobs for which training is contemplated. There are several methods for making a job analysis. Some methods that are widely used are those described in the Training and Reference Manual for Job Analysis, prepared by the U. S. Department of Labor.

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

Because of the specialized nature of technical jobs, it is essential that the data be as detailed and complete as possible. This is especially true of educational and training requirements where the technical knowledge and abilities required for employment in these occupations should be clearly defined. For example, (a) basic knowledge of physics with emphasis on mechanics, heat, sound, light, electricity, and magnetism is more specific and meaningful than basic knowledge of physics; and (b) must have a working knowledge of algebra, trigonometry, analytical geometry, and vector analysis is more definitive than uses mathematics in solving electrical problems.

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

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

# CHAPTER I

## THE FIELDS OF WORK

Workers trained in mechanical technology are employed in many industries necessary for the national defense. Most of them are found in metal-working plants, especially those using mass-production methods, and in the engineering organizations which service them. While accurate statistics are not available on the current or anticipated demand for technicians engaged in mechanical design or production activities, there are indications that the need is significant.

Mechanical design technology is concerned with the development, testing, evaluation, and design of machinery, equipment, instruments, and other mechanical devices prior to production and with the determination and design of the tooling required to manufacture a proposed product economically. Technicians in this field of work participate in determining the suitability of design, materials, tooling, and fabrication methods and suggest modifications in design, if necessary, to facilitate production and reduce manufacturing costs. They may conduct performance and endurance tests of mechanically and electrically-propelled devices, and determine weight, and stress and strain of components. These tests involve the selection, arrangement, connection, and calibration of test equipment and measuring instruments; the devising, conducting, and followup of test procedures; the recording of reactions; and the preparing of reports of the results of the tests.

Production technology is concerned with industrial engineering problems involving the efficient use of manpower, materials, and machines in mass production processes. Technicians in this field of work prepare layouts of machinery and equipment, plan the flow of work, investigate and analyze production costs to eliminate unnecessary expense, study different production methods in order to determine the most efficient way of manufacturing a particular item, and develop recommendations pertaining to time allocated for production operations.

Basically, the technicians engaged in mechanical design or production activities require similar educational backgrounds. In addition to general education subjects, both require an understanding of the operations, capacities, and limitations of machine tools and equipment, and training in such subjects as mathematics, drafting, and tool and machine design. The production technician also requires fundamental knowledge of industrial organization, statistical quality control, production methods, and plant layout; while the technician engaged in mechanical design requires knowledge of such subjects as mechanics, strength of materials, and metallurgy.

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

MECHANICAL DESIGN TECHNOLOGY

Engine Development Technician, Internal Combustion
Engineering Assistant, Mechanical Equipment
Engineering Designer, Aircraft Structures
Engineering Propulsion Development Technician, Rockets
Laboratory Technician and Tester, Flowmeters
Mechanical Engineering Technician, Steam Turbine
Milling Machine Design
Tool Designer

PRODUCTION TECHNOLOGY

Cost Analysis Engineer
Machine-Load-Control Planner
Process Description Writer
Production Estimator
Production Planner
Specifications Writer, Airplanes
Standard-Practice Man
Tool Planner
Tool-Project Man

## CHAPTER II

## JOB RELATIONSHIPS

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

The occupations should then be arranged in homogeneous groups or clusters, and the kind and amount of basic and applied science, mathematics, and technical "know-how" required to prepare workers to perform the duties of each job should be specified. Training curriculums which grow out of such analyses and groupings are commonly known as "cluster-based" curriculums.

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

1. Similarity of work performed.

2. Abilities and knowledge required of the worker for successful job performance.

3. Pattern of worker characteristics required by the job, such as high degree of accuracy, above-average mental application, creativity, and use of independent judgment.

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

5. Basic material worked on or with. Occupations may involve working with more than one material or working with the same material in different forms.

In a cluster of related jobs, most of these factors should be present and, though not exactly matched, should be analogous. For example, in developing the relationships of jobs found in the broad field of drafting and design, it is readily apparent, when using the criteria shown above, that the electrical draftsman and the mechanical draftsman have one factor in common--that of drawing. The abilities and knowledge required for successful job performance and the basic materials worked upon or with are totally dissimilar. The mechanical draftsman prepares drawings for mechanical devices. He must know how to calculate such engineering details as strength-weight ratios, tolerances, and elements of practical machine design. He must be familiar with the working properties of metals, metal alloys, and other materials, as well as with machine shop operations and practices. On the other hand, the electrical draftsman prepares plans and wiring diagrams. His knowledge must encompass electricity and magnetism, circuitry, and other factors related to electrical engineering. Therefore, it is evident that these two jobs are not closely related and do not belong in the same cluster or major grouping. The same conclusions might be drawn regarding construction or architectural drafting.

Before a detailed analysis of job characteristics is made, it might seem that the functions of technicians engaged in mechanical design and production activities are closely related. Such worker characteristics as high degree of accuracy, above-average mental application, creative ability, and use of independent judgment are common to both fields of work, but they also apply to most technician jobs. It is true that both require the ability to understand and interpret engineering drawings and that they both possess knowledge of machine shop operations and practices. Yet, a careful analysis of the two occupational categories indicates that some of the factors are not analogous and that there are two distinct fields of work.

The Job Factor Comparison Chart on page 18 is a suggested procedure for establishing clusters of related jobs by comparing the characteristics or factors of a number of occupations. It should be clearly understood that no attempt is made herein to place a relative value upon any of the factors. The mere quantity of factors associated with each job is not, of necessity, reflective of the skill level required.

A preliminary analysis was made of a number of jobs which seemed to belong in the two fields of work under study. The characteristics or significant factors of these jobs were identified, and only those jobs having similar characteristics were used. Of these, 20 jobs were selected for comparison purposes in order to determine their interrelationships. It is recognized that many other jobs might have been included in this list. Those selected merely illustrate how the technique may be used.

The Job Factor Comparison Chart provides a graphic illustration of the relationship among these various jobs. It discloses that at least 50 percent of the factors are present in 17 of the jobs. Less than half of the factors are present in job A (Design Checker), in job J (Tool Drawing

Checker) and in job L (Engineering Scheduler). Usually, if fewer than half of the elements are present in a particular job the relationship would not be close enough to warrant its inclusion in the cluster or major grouping.

It is interesting to note that job A (Design Checker) and the Engineering Drawings Checker, which is not on the chart but is similar to job J (Tool Drawing Checker) are included in Mechanical Drafting and Design Technology (OE-80000) where they properly belong.

Job factors 1 through 8 are generally considered worker characteristics of technical occupations in mechanical design technology while factors 9 through 14 are characteristics of production technology workers.

The chart clearly shows that some of the factors are common to all of the jobs under consideration and that factors 1 through 8 are found in most of the jobs in mechanical design technology while factors 9 through 14 predominate in the occupations in production technology. For example, factors 1, 2 and 3 are common to all of the jobs except A and I where number 3 is lacking. Job factors 1 through 6 predominate in jobs B,C,D, E,H, and I while more than 50 percent of job factors 9 through 14 prevail in jobs K,M,N,O,P,Q,R,S, and T. This indicates that 8 of the first 10 jobs are in mechanical design technology and 9 of the last 10 jobs belong in production technology. As stated previously jobs A, J, and L do not belong in either field of work.

## CHAPTER III

## JOB DESCRIPTIONS

The job descriptions included in this chapter are examples of the kinds of occupations found in mechanical design technology and in production technology. These definitions were taken from volume I of the Dictionary of Occupational Titles, supplement I of the Dictionary of Occupational Titles, (March 1955), and Technical Occupations in Research Design and Development Considered as Supporting to Engineers and Physical Scientists, BES No. E-194, February 1961. Since they are based on data assembled from studies made in many plants in various parts of the country, they must be considered as composites and may not coincide exactly with any single position in a specific employing establishment.

It should be clearly understood that these job descriptions are given as examples of closely related jobs for which vocational training can be provided and cannot be considered as standards for the determination of hours, wages, jurisdictional matters, or appropriate bargaining units; or for use in formal job evaluation systems.

The following job descriptions identify and describe the principal duties of each job, and they should be useful in identifying technical jobs in the mechanical and production technologies. Also, they may be used for comparison purposes when making analyses of related jobs. In many cases, the plant jobs studied may reveal only minor differences from those shown in one of these job descriptions. In such an event, only the differences in job content and the performance requirements need be considered. Care should be exercised so that courses of study will not be limited by local conditions. Actually, instruction for a technology should be broad enough to fit the training needs of industry nationally as well as locally.

### COST-ANALYSIS ENGINEER--0-68.543

Recommends changes in aircraft design to effect greatest economy in production methods and material costs. Suggests policies regarding use of forgings, castings, spot welding, and die-formed parts. Coordinates over-all design with tooling and production departments.

## DESIGN CHECKER--0-48.38

Examines revised production drawings of tools, dies, jigs, fixtures, and gages to determine accuracy of changes. Computes dimensions of drawings, to check accuracy of figures and proper placement of lay-out. Ascertains that parts can be fabricated on machines indicated on revised drawings by checking machine blueprints or through a knowledge of machine capacities. Returns erroneous drawings to original designer for correction, indicating orally or in writing changes to be made.

## ENGINE DEVELOPMENT TECHNICIAN, INTERNAL COMBUSTION--0-67.42

Tests experimental prototype internal combustion engines, evaluates test results, and prepares reports for engineer, making suggestions for developing new models, improving performance of standard models, and eliminating production problems.

Selects and modifies drawings of standard engines, subassemblies, and parts having design characteristics related to proposed engines. Corrects standard size and tolerance dimensions to meet new objectives, developing dimensions and tolerances for fixed and moving parts and subassemblies to conform to overall specifications established by engineer. Prepares outlines of test plans and draws layout sketches of complete engine prototypes, including subassemblies and test stand equipment. Directs assembly of experimental engine for testing.

Conducts performance and wear tests on various types of new design or modified engines by attaching test equipment to prototype engines, to obtain data such as temperatures, pressures, compressions, vibrations, and fuel consumption. Operates engines until all conditions of temperature and pressure, as measured by gages, become constant. Adjusts valves, parts, fuel nozzles, fuel injection pumps, air blowers, and timing mechanisms to normalize engine performance. Operates engines continuously at predetermined speeds and loads, checking normal operating pressures and temperatures of exhaust systems, engine fuel, lubricating oil, water, air, and turbines and compressors, until entire test range is covered.

Directs dismantling of prototype engines and inspection of all moving parts for wear and breakdown. Reduces all test data by calculations involving algebra and engineering formulas, and draws charts, graphs, and curves representing indicated and mean effective pressures, heat balance, fuel consumption, wear, and friction throughout entire range of tests to show indicated brake and friction horsepower. Determines mechanical efficiency of engines. Prepares curve charts of sound, vibration, and strain tests performed on engines for engineering analysis.

Analyzes indicated and calculated test results against design or rated specifications and objectives of tests. Suggests actions to correct performance discrepancies, noting parts and subassemblies that need redesign. Draws sketches of suggested improvements. Prepares reports of tests including objectives, procedures, findings, conclusions, and suggestions for improvements.

The duties described above are applicable to a variety of internal combustion engines such as small and large power and marine-diesel engines, semidiesel engines, and those used for outboard motors, power lawnmowers, motor scooters, motorcycles, and chain saws.

## ENGINEERING ASSISTANT, MECHANICAL EQUIPMENT--0-48.82

Plans, sketches, and makes drawings of parts and assemblies of mechanical equipment such as internal combustion engines, diesel engines, outboard motors, or machine components.

Studies engineering specifications, sketches, and related drawings of existing parts to determine such design factors as size, shape, and arrangement of parts. Makes preliminary freehand sketch and rough layouts, and notes items which require additional development of detail and computation such as angles, weights, holes, surface areas, curves, and dimensions. Evaluates developed ideas against accumulated engineering data and specifications to determine feasibility of design in terms of material strength, machining practicability, cost, heat-treating requirements, physical requirements, and surface finish.

Lays out and draws design in three or four views, using orthographic or isometric projection techniques showing linear as well as geometric dimensions, and drafting machine or standard drafting equipment.

Determines other design factors, such as clearances, tolerances, bearing loads, stresses, strains, speeds, gear ratios, electrical values, and leverages, using knowledge of algebra, geometry, and trigonometry and referring to engineers' and machinists' handbooks, and standard parts and materials handbook. Interprets details of material, size, shape, assembly, and operating specifications to model-maker.

## ENGINEERING DESIGNER, AIRCRAFT STRUCTURES--0-48.83

Designs or redesigns complex aircraft and missile structures, systems, and installations in accordance with fundamental design data and aeronautical engineering principles to assure maximum strength-weight and aerodynamic efficiency, coordination of all related functional parts, and conformity with requirements of company and customer.

Studies and analyzes completed or partially completed layouts, rough sketches, and notes on dimensional features provided by the engineer to evaluate manufacturing practicability, strength-weight efficiency, interchangeability of parts, and possible interference among components.

Prepares preliminary sketches and drawings incorporating features of new design, applying theorems, basic laws, and complex mathematical formulas so that new design will meet customer and company strength and load specifications and requirements. Designs machined parts and castings to meet stress and load specifications, using mathematics to determine such factors as thickness of housing walls, bearing loads, and size, weight, and strength of gears. Determines and selects from commercially available sources appropriate shapes and sizes of such components as electric motors, potentiometers, relays, and other equipment that will withstand service loads indicated in engineering specifications. Prepares design in layout form for use by others, indicating all pertinent fits or tolerances, dimensions, critical materials, and other information necessary to understand design.

Participates in setting up power-operated tests and in performing stress and strain tests of parts such as rib assemblies, struts, and landing gear, to reveal faults in design, material, or fabrication. Measures variations from normal with precision instruments such as micrometers and calipers, and records results on data forms.

Prepares general load analysis and detailed stress analysis reports on which final engineering decisions will depend. Collaborates with engineer in preparation of reports and graphs which describe and illustrate findings of design studies and interpretation of test data. Suggests design and material changes for items not in conformance with stress or load requirements.

## ENGINEERING PROPULSION DEVELOPMENT TECHNICIAN, ROCKETS--0-67.43

Plans methods for constructing and testing experimental rocket engines and related systems. Conducts experimental tests and makes

# JOB FACTOR COMPARISON CHART

| Significant characteristics in: | OCCUPATIONS IN MECHANICAL DESIGN TECHNOLOGY | | | | | |
|---|---|---|---|---|---|---|
| | Design checker<br>A | Engine development technician, internal combustion<br>B | Engineering assistant, mechanical equipment<br>C | Engineering designer, aircraft structures<br>D | Engineering propulsion development technician, rockets<br>E | Laboratory technician and tester, flowmeters<br>F |
| **MECHANICAL DESIGN ACTIVITIES** | | | | | | |
| 1. Understands and interprets engineering drawings and blueprints. | ■ | ■ | ■ | ■ | ■ | ■ |
| 2. Uses standard engineering and other handbooks efficiently. | ■ | ■ | ■ | ■ | ■ | ■ |
| 3. Has knowledge of working properties of metals and metal alloys. | | ■ | ■ | ■ | ■ | ■ |
| 4. Assists in designing mechanical devices, tools, dies, gages, jigs and fixtures. | | ■ | ■ | ■ | ■ | ■ |
| 5. Uses mathematical principles in computing such factors as weight, dimensions, tolerances, stresses and metal fatigue. | ■ | ■ | ■ | ■ | ■ | ■ |
| 6. Develops drawings for production or other purposes from rough sketches. | ■ | ■ | ■ | ■ | ■ | ■ |
| 7. Sets up and conducts physical tests of mechanical devices to discover faults of design or fabrication. | | ■ | | ■ | ■ | ■ |
| 8. Evaluates and prepares reports of results of tests for use by engineers. | | ■ | | ■ | ■ | ■ |
| **PRODUCTION ACTIVITIES** | | | | | | |
| 9. Solves assembly and fabrication problems by design modifications. | ■ | | ■ | | | |
| 10. Determines tools, fixtures, jigs, and equipment required to produce mechanical devices. | | | | | | |
| 11. Develops sequences of operations necessary for fabricating and assembling company's products. | | | | | | |
| 12. Estimates production capacity of machines and equipment. | | | | | | |
| 13. Interprets time study data and relates such information to production scheduling and cost analysis. | | | | | | |
| 14. Has knowledge of processing methods and procedures required to manufacture articles efficiently. | | | | | | |

| | | | | OCCUPATIONS IN PRODUCTION TECHNOLOGY | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mechanical engineering technician, steam turbine | Milling machine design | Tool designer | Tool drawing checker | Cost analysis engineer | Engineering scheduler | Machine-load control-planner | Process description writer | Production estimator | Production planner | Specifications writer, airplanes | Standard-practice man | Tool planner | Tool project man |
| G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
| ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
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reports suggesting modifications in designs and layouts to assist engineers in final design and development of such products.

Plans initial methods and procedures required to build and test complete prototypes of rocket engines and combined systems such as activators and feed and generator systems. Prepares detailed drawings or sketches to scale when requesting fabrication by personnel of machine, wood, or sheet-metal shops. Assembles and installs rocket engine components on laboratory test stand. Checks entire assemblies consisting of valve fittings, hydraulic and pneumatic lines, and electronic instrumentation, to assure proper assembly, installation, and conformance to specifications, using such instruments as gages, micrometers, and calipers. Exercises extreme care in handling cylinders of high pressure gases such as helium and nitrogen.

Conducts "dry run" tests of engine assemblies and supporting systems for leakages and overall functioning, preparatory to developmental field testing with actual fuel. Operates test equipment to simulate actual operating conditions for testing entire rocket engine assemblies, applying air, water, and oil pressures in sections of assemblies to observe functional operation and to detect leaks and malfunctioning. Modifies designs and makes adjustments to engines or system components such as in wiring, tube routing, or mechanical clearances.

Prepares scale sketches of complete units as developed and tested, indicating exact dimensions, clearances, circuit elements, and component specifications, making minor changes on drawings which will result in improved performance of product or elimination of causes of malfunctioning.

Visually examines and functionally tests complete engines, systems, and components after test firing in field, using simulating equipment. Interprets test-instrument graph readings obtained during test and makes minor changes in parts configuration, circuitry, or designs. Maintains complete records of findings and adjustments for engineering reference in connection with development of improved or new equipment.

## ENGINEERING SCHEDULER--0-63.55

Plans, directs, and expedites the preparation of drawings of airplane parts. Determines drawings to be made on new models and employees to whom work is to be assigned. Estimates, by consulting previous records, the number of hours required to complete each drawing. Ascertains when specific drawings are needed by fabrication and planning department. Assigns starting and completion dates for drawings, and personnel required by each group. Prepares charts showing schedule for drawings, progress of work, deviations from schedules, and assignment of personnel. Makes use of charts in demonstrating reasons for deviations from schedules, and expedites completion of drawings by checking progress of work and stressing adherence to schedules. Keeps records and prepares reports to be utilized as guides in future planning.

## LABORATORY TECHNICIAN AND TESTER, FLOWMETERS--0-67.45

Plans and conducts laboratory tests of newly designed and modified standard flowmeters. Analyzes and evaluates performance and test results, determining causes of failures. Suggests modifications in meter design and construction. Designs fixtures and tools used for machining and assembling parts of meters and prepares sketches or drawings for tools, special parts, and test devices.

Writes detailed plans for conducting experimental tests on newly designed disk, turbine, and compound water meters; on newly developed subassemblies and parts of modified standard production models; and on allied products such as lubrication grease meters or their electrical controls. Prepares sketches of test setups indicating arrangements of test meters, experimental parts or subassemblies, and test equipment.

Develops experimental test setups involving (a) attaching to standard production models, mockups of new parts to be tested such as rubber disks and propellers, copper screens, bronze housing, bushings, gaskets, and gears, or subassemblies such as meter registers, gear trains, stuffing boxes, disk chambers, and propeller cages, or (b) assembling complete newly designed meter models. Prepares sketches to be used by others in fabricating parts for test setups.

Varies test setups according to parts or types of tests such as for (a) testing electrical controls, (b) measuring noises, vibrations, and pressure losses, (c) measuring capacity for withstanding extreme environments including frost and corrosion, and (d) determining the point at which failures occur due to prolonged flows, pressures, and strains.

Conducts tests according to standard procedures or specially developed test plans. Observes performance of models under test, noting conditions under which failures occur, detecting leakages, and recording test instrument readings at set intervals. Examines components of model for causes of failures or undue wear. Measures each part with devices such as micrometers, calipers, and height and depth gages, and compares measurements with original dimensions to determine degree of wear. Prepares report of test activities describing conditions under which breakage or wear occurred, listing such data as test plans, procedures, techniques used; test setups, test equipment and measuring devices used; test readings and findings; and analyses of test results. Presents findings or conclusions regarding test results in charts, graphs, or tables (using algebraic formulas to extend data to practical and theoretical limits), or in sketches showing broken or worn parts.

Analyzes engineering and test data to determine problems involved and possible solutions, e.g., if parts must be redesigned, materials or parts changed, or parts or subassemblies rearranged. Reworks part or assembly drawings performing algebraic, geometric, or trigonometric calculations to determine strength of material specifications and new size, shape, location, dimension, or operating characteristics of critical parts. Relates changes to operation of entire models to insure that design changes will not adversely affect operation or functioning. Completes design modifications by preparing new designs and detail drawings of parts or subassemblies showing changes made, or arranges for drawings to be made from sketches.

Prepares detailed drawings for use in casting, machining, and assembling of fixtures and tools. Confers with engineering and shop personnel regarding designs of fixtures and tools as they relate to the machines, shapes of parts, machining operations intended, and tolerances to be maintained. Prepares process and material specifications showing dimensions and composition of materials and parts to be purchased, machine tool operations, tolerances, finishes, and heat treating to be used in fabrication.

## MACHINE-LOAD-CONTROL PLANNER--0-68.51

Estimates production capacity of machine shop equipment. Studies previously established production records. Using his knowledge of machine capacities, operations necessary for manufacturing various aircraft parts, working properties of aircraft metals, and machine-shop methods, determines production factors such as need for additional machinery, possibility of accepting orders from other firms, or need for contracting with outside firms for manufacture of specific parts. Prepares written reports of findings for use of production planner.

## MECHANICAL ENGINEERING TECHNICIAN, STEAM TURBINE--0-67.46

Develops new or modified steam turbine components to meet new specifications and to solve problems in production, installation, and operation; utilizes an overall knowledge of design, construction, and operation of steam turbines. Makes plans, sketches, or scale drawings of designs for drafting room or shop use. Interprets drawings and specifications to solve problems in shop fabrication of models or test fixtures. Conducts tests to evaluate functional adequacy and power efficiency, redesigning components until specifications are met. Makes special studies to improve design and stress standards of steam turbines.

## MILLING MACHINE DESIGNER--0-48.82

Plans, sketches, and draws parts of milling machine and calculates strength of materials, specifications, and other technical data. Computes, using handbook formulas, the magnitude, direction and point of application of significant tension, and compression and bending loads to conceive geometric shapes that avoid stress or load concentrations. Calculates, from accumulated engineering data or standard references, information needed to make decisions relative to moving parts, such as speed of shafts, spindles or gears, direction of rotation of moving parts, and pitch of gear teeth, to establish part and subassembly dimensions. Evaluates test result data concerning tool cutting characteristics and physical breakdown of machine parts. Suggests remedial action such as new part design or rearrangement of parts based on test results.

## PROCESS-DESCRIPTION WRITER--0-68.68

Prepares descriptions of work methods and processes to be followed in an industrial establishment. Studies written specifications for finished product, manuals on components, and other technical information to become familiar with production requirements. Observes plant operations, and consults foremen and technicians to determine operating procedures. Writes work methods and process descriptions based on findings for use in production operations. May supervise workers engaged in duplication and distribution of descriptions. May edit and standardize process descriptions prepared by foremen or other operating personnel (Standard-Practice Man). Applicants are usually selected on basis of specific training or experience in production operations of industry in which job occurs.

## PRODUCTION ESTIMATOR--0-68.57

Estimates manufacturing costs of firearms such as small arms and artillery pieces, and the procurement and manufacturing costs of tools, jigs, and fixtures used in the production of firearms. Calculates unit and job-lot manufacturing costs involving factors such as lay-out, forging, machining, heat treating, inspecting and handling, using blueprints, manuals, and other specifications. Estimates tool and fixture costs guided by use to which they are put, his knowledge of tool design machine operations, and the material involved. May specialize according to the product or according to one phase of the work such as tool costs, material cost, or specification writing.

## PRODUCTION PLANNER--0-68.50

Plans production schedules for the manufacture of industrial products: consults production blueprints and plant capacity data. Schedules work for individual departments and operations in proper sequence. Plans flow of work through plant, considering available raw materials and shipping dates of finished products. Directs department supervisors in maintaining smooth flow of production. Expedites operations that delay schedules, and alters schedules to meet unforeseen conditions. Reports major difficulties to Production Engineer II. (Assistant Engineer) Prepares production reports.

## SPECIFICATION WRITER, AIRPLANES--0-68.63

Prepares process and material specifications to provide plant employees and subcontractors with material and process standards. Observes and makes notes on processes such as heat treating, molding, forging, and painting. Draws rough sketches to illustrate portions of processing operations. Gathers information from publications dealing with processes and materials used in the manufacture of airplanes. Obtains permission to use information incorporated in specifications prepared by other aircraft companies and by Government agencies. Writes descriptions of processes and of physical and chemical properties of materials, explaining how materials are used. Supervises preparation of finished drawings from rough sketches and arranges to have photographs made to illustrate specifications.

## STANDARD-PRACTICE MAN--0-68.68

Standardizes and edits records of descriptions of processes, formulas, specifications, and other technical information essential to the normal operation of a plant in order to provide supervisory personnel with accepted procedures and pertinent data. Reviews write-ups of existing procedures such as those prepared by process-description writer, foreman, or other operating personnel for completeness, style, and terminology; and routes copies of edited standards to heads of department concerned.

Writes formal approval of authorized changes in standard procedure in form of statement containing description of deviation, limitations, and expiration of change. Obtains information concerning raw materials from production departments and compiles specifications. Compiles new standards, using procedures originated by research department and corrections submitted by department heads after actual production testing of research procedures, and submits new standards to department concerned for approval.

## TOOL DESIGNER--0-48.41

Designs special tools and fixtures such as boring bars and milling-machine tools. May do drafting (Draftsman, Tool Design). Frequently is a machinist, using types of machines for which he is designing tools. May be designated according to type of tool designed, such as broach designer, cutting-tool designer, spindle designer.

## TOOL-DRAWING CHECKER--0-48.40

Examines airplane tool-drawings made by tool designer for inaccuracies of detail and to determine production feasibility of designs. Visually compares design of jig, fixture, or tool with drawing of airplane parts, matching coordinating points for accuracy of fit. Examines drawing details such as dimensions, angles, allowances, and shop notes for errors, guided by specifications on engineering drawing and his knowledge of mathematics and drafting. Verifies size and quantity of materials and methods of fabrication. Notes corrections on drawings.

## TOOL PLANNER--0-68.52

Determines tools, fixtures, and equipment required and sequence of operations necessary for fabrication and assembly of airplane assemblies and airplane and automobile parts. Studies engineering blueprints and, using his knowledge of functions and procedures of various departments and capacities of machines, determines tool requirements and establishes sequences of operations necessary to fabricate and assemble airplane and automobile parts. Prepares reports of data for use by production planner in determining complete production operations. May plan tool and operation sequences for only one department. May designate kind of material to be used in construction of tools.

## TOOL-PROJECT MAN--0-68.53

Coordinates and directs tooling work in a department, following plans formulated by tool planner. Analyzes problems of tool lay-out and of fabrication to determine procedures necessary to comply with production requirements. Rearranges tool fabrication schedules to eliminate work stoppage. Makes changes in tooling specifications and submits suggested changes to engineering department for consideration. May be assigned to one type of tooling development such as jigs and fixtures or hand-and-machine tools and dies.

## CHAPTER IV

## TRAINING REQUIREMENTS

If the purpose of a technical training program is to prepare workers for a single occupation, the content for such a program is derived from the analysis of that specific job. However, inasmuch as most training programs for a specific technology are designed to prepare workers for a cluster of occupations, the content should be derived from analyses of all the jobs in the cluster. In the latter case, it is necessary to assemble the occupational data gathered during the job analysis study; compare the elements or characteristics of the various jobs; determine the elements that are common to the several jobs in a group; ascertain the skills and knowledges required for their performance; and develop a reasonably complete list of the skills and knowledges needed for all the jobs in the cluster. From this list, the specific courses of study which make up the curriculum are developed. It should be recognized that instruction for a specific occupation within a given cluster may require greater depth and emphasis on certain aspects of the training than that required for a cluster-based curriculum. This highly specialized training may be given through extension courses after the individual has entered employment and has gained some experience and understanding in his field of work.

The job definitions contained in chapter III of this publication, augmented by the information gathered through the individual job analyses made by State or local personnel, should provide much of the data needed for determining the training requirements. Each job description should be in two parts. The first part should describe the work performed, i.e., what this worker does and why he does it. The second part should cover performance requirements and provide information about the skills, knowledge, and abilities required of the worker in performing the job duties.

The Training Requirements Analysis Form on page 22 illustrates a method for recording the technical knowledge and ability required for each of the clusters of related jobs. The subheadings on the form--"Mechanical Design Technology" and "Production Technology"--are the major groupings or fields of work for which training is required.

The first column lists the subject-matter areas discovered through job analysis as basic in a training program for occupations in each field of work. It is conceivable that other subject-matter areas will be found which belong in these two fields of work since the requirements of these occupations vary from plant to plant, among industries, and in different parts of the Nation. The determination of the subject matter required for successful performance in the various occupations of a cluster of related jobs depends upon the adequacy of the source data obtained through job analysis and the ability of the person preparing the form to interpret these data.

If the job descriptions resulting from the job analyses indicate that a knowledge or skill in a certain area is essential, the letter "E" should be entered. If it is not absolutely essential but advisable, the letter "A" should be entered.

The nature of the work and the industry in which the job under study is found usually suggests to an experienced analyst other subjects which might be helpful to a worker in one of the fields of work. In some cases, it may be found that industry supplies training in these areas, and in other instances the limited demand for such skills in the employment market or lack of facilities in the school makes it inadvisable for the school to set up special courses. The completed form serves the following purposes:

1. Indicates the technical knowledge and abilities needed by workers to perform the duties of various occupations in a given field of work.

2. Identifies the subject-matter areas that are common to the several jobs in a cluster of related jobs within each technology.

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

## TRAINING REQUIREMENTS ANALYSIS FORM

### SUBJECT-MATTER AREAS REQUIRED

Symbols: E--Essential
A--Advisable

| | MECHANICAL TECHNOLOGY | |
|---|---|---|
| | Design | Production |
| **MATHEMATICS--Applied** | | |
| Arithmetic including shop mathematics | E | E |
| Algebra through quadratic equations | E | E |
| Trigonometry (right & oblique triangles) | E | E |
| Logarithms & slide rule usage | E | E |
| Descriptive geometry | E | |
| Analytical geometry | E | |
| **SCIENCE--Applied** | | |
| Electricity & magnetism | E | E |
| Heat | E | |
| Hydraulics | E | |
| Mechanics | E | E |
| Strength of materials & metallurgy | E | E |
| **GENERAL** | | |
| Communications | E | E |
| Industrial relations | E | E |
| Technical report writing | E | E |
| **DESIGN TECHNOLOGY** | | |
| Tool & die design | E | |
| Machine design | E | |
| Basic mechanisms | E | A |
| Mechanical drafting | E | E |
| Foundry practices & welding techniques | E | A |
| **PRODUCTION TECHNOLOGY** | | |
| Plant layout & materials handling | | E |
| Manufacturing processes | | E |
| Production cost analysis | | E |
| Statistical quality control | | E |
| Process & production planning | | E |
| **ADDITIONAL KNOWLEDGES & UNDERSTANDINGS** | | |
| Machine Shop Operations & Practices | E | E |

NOTE: This form illustrates a technique for recording subject-matter areas that should be considered in developing a curriculum and it is not intended as a curriculum guide.

# CHAPTER V

## DEVELOPING THE CURRICULUM

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

A curriculum may be defined as a systematic group of courses of study designed to prepare persons for a cluster of jobs or for a specific occupation in a given field of work. It is an organized body of content for the training program--all that the school offers for reaching desired educational goals.

Curriculums can be developed in several ways. The simplest method 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 was satisfactory for the original institution, that it may not fit into the conditions of the setting where it is to be used. For example, each institution has specific entrance requirements which vary from State to State and from one institution to another. A second method is to study a number of curriculums from other institutions and to develop from them a composite curriculum embodying the best points of all of them. The difficulty sometimes encountered with this method is that the resultant program is made up of a group of subjects which may not constitute a complete, integrated curriculum.

Probably the most effective method is to use the approach outlined in this pamphlet: the development of a curriculum based upon up-to-date analyses of the occupations with which the program is concerned. As a check against this method, it is usually helpful to study other curriculums for structure and content.

In undertaking the construction of a curriculum based upon job analyses, the first task is to prepare a composite list of all of the knowledges and skills needed for effective performance in the occupations making up the cluster. In the preceding chapter the technique for developing a list of subject-matter areas has been prepared (Training Requirements Analysis Form). The job descriptions in chapter III represent typical occupations found in these two fields of work and are not meant to be all-inclusive. Therefore, the fields should be explored further to ascertain what other jobs should be included in the clusters. All of the jobs should then be analyzed and the findings checked against the present lists to determine whether additional subject-matter areas are necessary. Thus, a reasonably complete list of items for the proposed curriculums is assured.

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

In theory, one might take the content revealed by the occupational analyses, organize the content into courses, select the methods to be used for instruction, list the equipment needed, plan the space required, set up standards for student admission and for the instructional staff, and determine the length of the program without regard to details of the setting in which the program is to operate. But, it does not work out that way in practice. There are many factors which must be taken into account. For example, the program may be one of several given by a large institution which has established admission standards, a predetermined length of school year and day, available space which may or may not lend itself well to the proposed program, a limited budget, and many other conditions which affect the curriculum planning. Therefore, the curriculum builder may have to compromise in order to adapt the desired elements of the curriculum to what is available. In any case, the curriculum should be sufficiently complete to provide adequate preparation for effective entry into any of the occupations identified as belonging to a specific technology.

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

This chapter reviews curriculum designing rather briefly, assuming that the reader is familiar with pedagogical practice and with curriculum building in other areas of education. It also points out some broad aspects of curriculum development as it relates to technical training.

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

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

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

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

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

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

6. Mathematics and the physical sciences are key disciplines in all technical study. Therefore, the various areas of mathematics or science should be integrated so that the application of mathematical or scientific principles will supplement and support the specific course work in these areas. In doing this a high degree of coordination is required. This coordination involves the teaching of mathematics or science by application in technical courses concurrent with the more formal instruction in the mathematics or science classes.

7. The relative emphasis to be placed on each subject and the time that should be allotted to each subject should be carefully analyzed so that the courses of instruction are properly integrated and the total curriculum is in balance.

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

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

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

The techniques in this publication, together with the charts and forms provide basic information regarding techniques that can be used in organizing curriculums which will meet specific technical training needs in the mechanical and production technologies.

# BIBLIOGRAPHY

The job descriptions in chapter III were taken from Volume I and Supplement 1 of the Dictionary of Occupational Titles and Technical Occupations in Research Design and Development, BES No. E-194.

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


U.S. Department of Labor, Bureau of Employment Security. Dictionary of Occupational Titles, Volume I, Definition of Titles. Washington: Superintendent of Documents, Government Printing Office, March 1949. 1518 p. $5.25.

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

U.S. Department of Labor, Bureau of Employment Security. Dictionary of Occupational Titles, Second edition, Supplement 1. Washington: Superintendent of Documents, Government Printing Office, March 1955. 341 p. $1.

Contains 2,260 new and revised definitions and 1,322 code numbers arranged alphabetically according to job titles, and supersedes all releases to the Dictionary issued since the second edition was published in March 1949.

U.S. Department of Labor, Bureau of Employment Security. Technical Occupations in Research Design and Development. BES No. E-194. Washington: Superintendent of Documents, Government Printing Office, February 1961. 113 p. 50 cents.

Study is limited to those technical occupations that could be identified as being concerned with research, design, and development activities and considered directly supporting to engineers and physical scientists. It describes a total of 65 general and specific job activities found in about 85 establishments in various parts of the country.

U.S. Department of Labor, Bureau of Employment Security. Reference Manual for In-Plant Manpower Planning. Washington: Superintendent of Documents, Government Printing Office, April 1951. 53 p. 45 cents.

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



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