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CHEMICAL TECHNOLOGY, A SUGGESTED 2-YEAR POST HIGH SCHOOL CURRICULUM.
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OFFICE OF EDUCATION, WASHINGTON, D.C.
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THE PURPOSE OF THIS CURRICULUM GUIDE IS TO HELP ADMINISTRATORS, SUPERVISORS, AND TEACHERS PLAN, DEVELOP, AND EVALUATE PROGRAMS. BOTH THE BASIC MATERIALS, BY AN INDIVIDUAL FOR THE CONNECTICUT STATE DEPARTMENT OF EDUCATION, AND THE INFORMATION ON FACILITIES AND COST, BY AN INDIVIDUAL, WERE PREPARED PURSUANT TO U.S. OFFICE OF EDUCATION (USOE) CONTRACTS. THE FINAL DRAFT WAS PREPARED BY USOE PERSONNEL. THE GUIDE CONTAINS GENERAL REQUIREMENTS (PROGRAM), THE CURRICULUM, COURSE OUTLINES, LIBRARY FACILITIES, LABORATORIES AND PHYSICAL FACILITIES FOR TEACHING CHEMISTRY, AND A BIBLIOGRAPHY. THE COURSE OUTLINES INCLUDE HOURS REQUIRED, DESCRIPTION (COURSE), MAJOR DIVISIONS (OUTLINE), LABORATORY (TIME AND EXPERIMENTS), TEXTS AND REFERENCES, AND VISUAL AIDS. TEACHERS SHOULD BE TECHNICALLY COMPETENT AND HAVE INDUSTRIAL EXPERIENCE. STUDENTS SHOULD -- (1) BE PROFICIENT IN MATHEMATICS, BASIC PHYSICS, AND CHEMISTRY, (2) UNDERSTAND MATERIALS AND PROCESSES, (3) HAVE AN EXTENSIVE KNOWLEDGE OF CHEMICAL APPARATUS, AND (4) HAVE WELL-DEVELOPED COMMUNICATIONS SKILLS. ILLUSTRATIONS OF EQUIPMENT AND REPRESENTATIVE STUDENT EQUIPMENT LISTS ARE GIVEN. THIS DOCUMENT IS AVAILABLE AS GPO NUMBER FS 5.280--80031 FOR 75 CENTS FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (EM)

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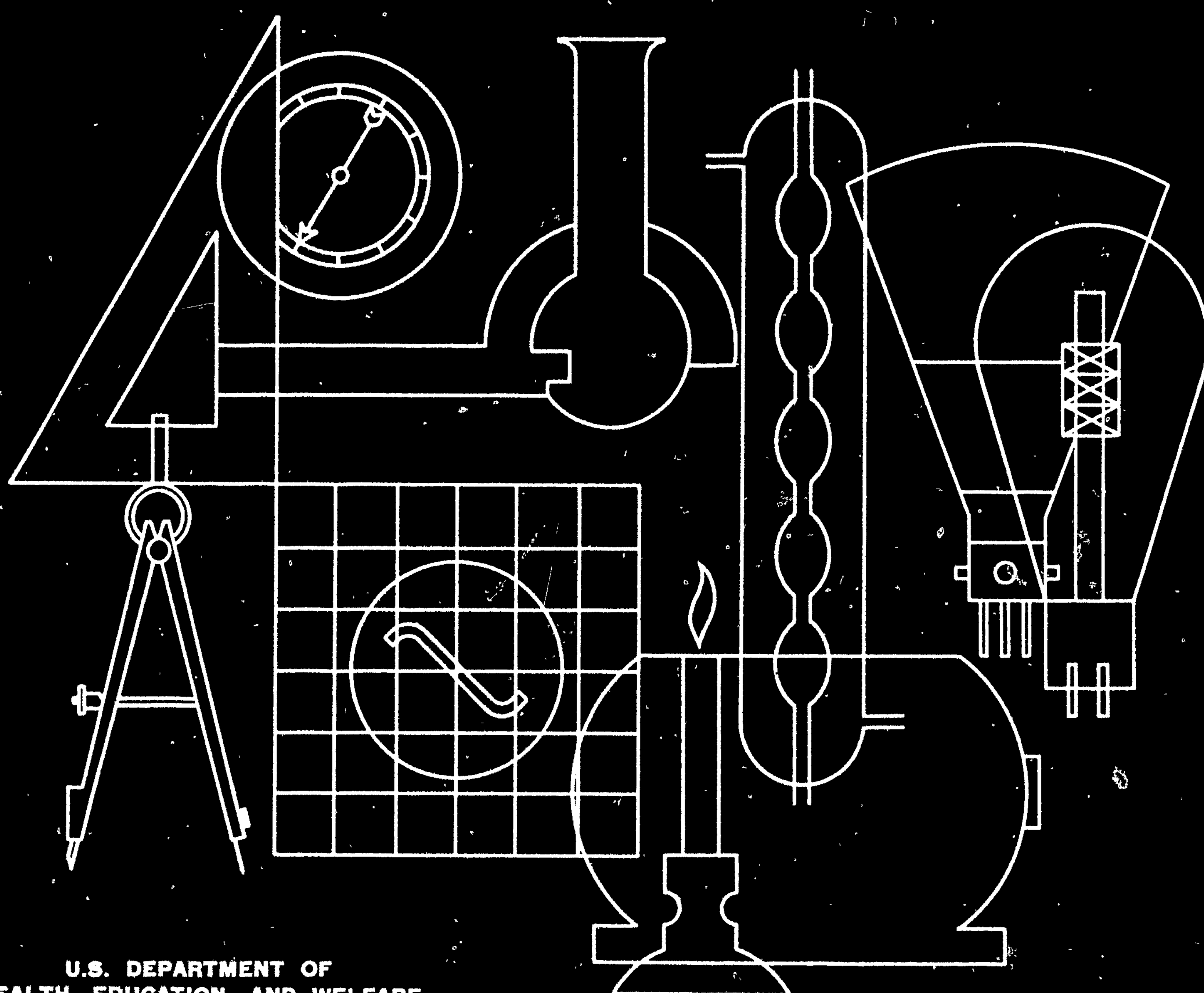
TECHNICAL EDUCATION PROGRAM SERIES NO. 5

Chemical Technology

A Suggested 2-Year Post High School Curriculum



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

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CHEMICAL TECHNOLOGY

A Suggested 2-Year Post High School Curriculum

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE . . . . ANTHONY J. CELEBREZZE, *Secretary*

Office of Education . . . . FRANCIS KEPPEL, *Commissioner*

Foreword

THE CHANGES brought about in modern living through chemistry are almost universal, but often overlooked. Before World War I, this Nation's chemical industry was relatively undeveloped. Today, the United States is among the leaders in the development and production of fuel, pharmaceuticals, and new materials.

Applied chemical science has influenced the materials that touch every aspect of our lives. Chemical analysis of natural raw materials precedes their refinement. Chemical research discovers and continues to develop new combinations of substances with which to produce many specialized materials and devices unknown two decades ago. These, in turn, allow man to control the environment; to explore the unknowns of space, polar regions, and ocean depths; and to probe the mysteries of life, growth, and health.

Fuels used in the past quarter of a century shifted primarily from coal to oil to natural gas; and in the case of missiles, to solid chemical fuels and nuclear reaction. A whole new family of textile materials starting with nylon has been invented. Developments in plastics have improved packaging, paints, floor coverings, molding materials, and adhesives. Among pharmaceuticals, penicillin, the Salk vaccine, and antibiotics stand out as examples of the hundreds of new drugs and compounds developed to fight disease. Closely related to drugs are DDT and the organometallic fungicides to control parasites and plant diseases.

Work in the chemical industry may be classified in two general areas: research of new and improvement of known products and production of chemicals and allied products. Chemical technicians are needed in chemical research and production to assist the chemist, engineer, or plant supervisor in process development, design and operation of equipment, and product control. Many such technicians may be women.

This suggested curriculum guide was prepared to aid in planning and developing programs for educating highly skilled chemical technicians. It is a 2-year curriculum with course outlines, laboratory layouts, and lists of textbooks and references. Special attention is given to chemical laboratory facilities because of the need for control of chemical fumes and solutions and the need for careful planning of chemical teaching facilities and their costs. Library facilities, content, and use are emphasized.

The indicated level of instruction in this suggested curriculum is post high school, but the sequence of course work may start at any grade level where students have the prerequisite background and understanding.

This guide should be of assistance to school administrators, supervisors, and teachers who are planning and promoting new programs of chemical technology. It may be used, too, in evaluating existing programs.

The basic materials included herein were prepared by Robert Pachaly for the Connecticut State Department of Education, and the information on facilities and costs was prepared by E. Rexford Billings, pursuant to contracts with the U.S. Office of Education. Many useful suggestions were offered by special consultants and by administrators and teachers in schools of technology. Although all suggestions could not be incorporated, each was considered carefully in the light of the publication's intended use. In view of this it should not be inferred that the curriculum is completely endorsed by any one institution, agency, or person.

The final draft was prepared under the direction of Robert M. Knoebel, Acting Director, Technical Education Branch, by Walter J. Brooking, assisted by Alexander C. Ducat and Clarence E. Peterson.

The technical accuracy of the curriculum materials is due largely to the work of six outstanding chemists and educators who thoroughly reviewed these materials in conference with the staff of the Technical Education Branch in the U.S. Office of Education.

WALTER M. ARNOLD
Assistant Commissioner for
Vocational and Technical Education

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[1] Private educational institution.

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Contents

Chemical Technology Program

General Requirements

THIS SUGGESTED CURRICULUM GUIDE is designed to provide an intensive 2-year full-time program of study for students of chemical technology. The courses in the plan of study are designed and organized to provide the chemical, physical, and mathematical theories combined with the procedural and technical skills involved in their application to the problems encountered in the broad field of the chemical and allied industries.

The chemical manufacturing industry is one of the five largest industries in the United States. It is a complex industry based on the application of chemistry and related science and engineering to produce thousands of chemicals and compounds. A partial list of chemical products includes chemical raw materials, chemical intermediates, fuels, plastics, drugs, food compounds or preservatives, synthetic fibers, packaging materials, and pharmaceuticals. The use of chemicals of some sort or in some form touches almost every phase of our lives. Chemical processes are involved in mining; metal production; food processing; petroleum refining; paper, rubber, plastics, and paint-making; and in most other industrial processing. Chemical research and development of products and processes have grown rapidly, presently engaging more than one-third of the scientists and engineers employed by the chemical industry.

Chemical technicians are an essential part of the scientific and management team working either in research or pilot-plant operations growing out of research or in the production of chemicals and allied products. The team is comprised of professional chemists, usually with doctor's or master's degrees, chemical engineers, chemical technicians, members of the supervisory staff of the organization for which they work, and skilled chemical production or laboratory workers.

The technician performs a special and indispensable role as a member of the scientific team in chemical research, pilot-plant operation, or production. His special knowledge of the principles of chemistry, physics, and mathematics as applied in the chemical industry, combined with his broad knowledge of laboratory techniques, chemical processes, and the techniques of chemical analysis and control provide a basis for his working closely with the chemical scientists and chemical engineers. His specific task usually is to obtain laboratory or pilot-plant test data which prove or disprove the possibility of new processes or systems proposed by the scientists and engineers for developing new products or improving production methods. Under the supervision of the chemist or chemical engineer and with the assistance of skilled chemical production workers or laboratory assistants, the technician assembles the apparatus and conducts the tests, makes the measurements, and records and reports the data which form the basis for decisions as to whether the new concepts are workable. If the new concepts are found to be workable in some degree, continued variation of tests, changes in apparatus and equipment, further analysis of results, and comprehensive and detailed reports of such activities are prepared by the technician.

When new or improved processes are developed to the point where they should be tried on a semicommercial scale in a pilot-plant, the technician works with the chemical engineers and the scientists, plant supervisors, skilled chemical workers, and other assistants in developing, assembling, and operating the scaled-up models of the laboratory equipment. Frequently the technician, under the supervision of the chemical engineer and/or the theoretical scientist, is in full charge of the operation and evaluates the process and the product of the pilot-plant operation. He records, analyzes, and reports the data; confers with the engineers and scientists; and may suggest modifications of the equipment, if necessary, to improve its performance in the pilot-plant stage. Often he is expected to train chemical workers in the operation of such equipment.

At the point of transition from pilot plant to full-scale production, the technician continues his role as assistant in the design and installation of the final equipment; supervises or "troubleshoots" the operation of the new equipment; and trains chemical operators in the essential steps of the operation and the control of the new plant process. He helps to evaluate the product, process, and functioning of the equipment, and compiles the reports of its performance. Often he establishes the methods and apparatus for routine analysis, and trains chemical operators in the procedures for the control of the process and the quality of the final product.

Special Abilities Required[1]

Special abilities required of chemical technicians as they perform their essential part of the work in the research laboratory, pilot plant, or chemistry production organization may be listed as follows:

1. Facility with mathematics; ability to use algebra and trigonometry as tools in the development of ideas that make use of chemical and related principles; an understanding of, though not necessarily facility with, higher mathematics according to the requirements of the application.
2. Proficiency in the application of the basic concepts and laws of physics and chemistry.
3. An understanding of the materials and processes commonly used in the chemical and allied industries.
4. An extensive knowledge of chemical apparatus, equipment, procedures, and techniques; and competency in applying the knowledge in the various production, research, or control activities in the chemical field. The degree of competency and the depth of understanding should be sufficient to enable the individual to establish rapport with professional chemists, chemical engineers, and related scientists with whom he works; and to enable him to perform a variety of detailed scientific or technical work in the chemical field as outlined by general procedures or instructions, but requiring individual judgment, initiative, and resourcefulness in the use of techniques, handbook information, and recorded scientific data.
5. Communication skills that include the ability to interpret, analyze, and transmit facts and ideas graphically, orally, and in writing.

Activities Performed[1]

A list of generalized activities, some combination of which a chemical technician is prepared to perform, follows:

1. Applies knowledge of chemistry, physics, and mathematics extensively in rendering direct technical assistance to chemists or engineers in chemical or related research and experimentation.
2. Designs, develops, or plans modifications of new products, techniques, and processes under the supervision of chemists or engineers in applied chemical or related research, design, and development.

[1] Adapted from *Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs.* OE-80015; U.S. Office of Education, Washington, D. C., 20202.

3. Plans and inspects the installation of complex equipment and control systems used in the chemical or allied industries.
4. Advises or recommends procedures or programs for the operation, maintenance, and repair of complex equipment used in extensive control systems.
5. Plans production as a member of the management unit responsible for efficient use of manpower, materials, and machines in chemical or allied production.
6. Advises, plans, and estimates costs as a field representative of a manufacturer or distributor of chemical or allied equipment, services, and/or products.
7. Is responsible for performance tests of chemical apparatus or equipment used in chemical research or production; the determinations, tests, and analyses of substances in the chemical or allied fields; and the preparation of appropriate technical reports covering the tests.
8. Prepares or interprets chemical engineering plans or sketches for chemical research or production systems, or writes detailed specifications or procedures for operation, analysis, or control of work related to chemical or allied research or production.
9. Selects, compiles, and uses technical information from references, such as engineering standards, procedural outlines, handbooks, and technical digests of research findings.
10. Analyzes and interprets information obtained from precision measuring and recording instruments or tests, using highly specialized techniques; and makes evaluations upon which technical decisions are based.
11. Analyzes and diagnoses technical problems that involve independent decisions.
12. Deals with a variety of technical problems involving many factors and variables which require an understanding of several technical fields.

The versatility required of a chemical technician is a characteristic that relates to breadth of understanding, the antithesis of narrow specialization. In applying these criteria the importance of technical training in providing a broad background should be appraised. It is this educational background that provides versatility in those activities where experience alone cannot include the wide-range knowledge required.

Some of the occupational titles associated with chemical technicians' work follow:

Chemical Production Technician
Chemical Research Technician
Chemical Pilot-Plant Technician
Assistant Research Chemist
Chemical Process Analyst or "Trouble Shooter"
Laboratory Experimentation Specialist
Chemical Sampler and Analyst
Plant Control Chemist
Chemical Process Supervisor
Chemical Product Analyst
Pilot-Plant Supervisor
Pilot-Plant Operator
Chemical Product Salesman
Chemical Product Serviceman
Chemical Equipment Salesman
Chemical Equipment Serviceman

The functions of the chemical technician clearly place him in a semiprofessional position. He is an essential member of the chemistry research and production team. His performance of duties clearly distinguishes him from the skilled chemical production worker or chemical laboratory asssistant.

The work done by chemists, engineers, and chemical technicians in the industries using their skills may be divided into two main groups based upon the objectives of each.

Research chemists have the principal objective of performing laboratory experiments with the purpose of making new chemical (or allied) products, or of discovering new processes or modifying and improving known processes for making chemical products.

The work of this group is centered around laboratory activities in which new ideas are generated from known theoretical chemistry and allied science. Laboratory experiments to explore and develop these ideas are conceived, the equipment and materials assembled, the experiment conducted, the products analyzed, and the ideas evaluated in light of the test data. Often a great number of variations on equipment and procedure must be tried and the results compared before a new product or novel (or improved) process is developed. The work is laboratory-oriented, but may approach plant operation when research discoveries are tried out in a production pilot plant.

Pilot-plant operations are becoming an increasingly important area for the use of highly trained chemical technicians. The tasks of designing, planning, assembling, and erecting the equipment; making the tests; collecting and recording the data; analyzing the results; and reporting them to the professional chemists or chemical engineers with suggestions or recommendations are tasks which are increasingly being delegated to technicians as research projects progress successfully to the point of being scaled up for semicommercial production tests.

Production is the principal objective of those who operate manufacturing or processing plants using chemical or related materials, operations, equipment, and controls to produce commercial products. Work done by this group is primarily centered around materials and processes, and their control. It must, therefore, involve chemical sampling and analyses either in the laboratory or in plant locations; and the use of other scientific methods of measurement to control the processing and regulate the quality of the final product. The underlying science of the chemistry and mechanics of the process as it is accomplished in the plant must be understood by those controlling it.

The underlying science used by both the research and the production chemist is the same. Each needs an understanding of the activities and methods of the other since production processes were originally developed in a research laboratory and must be conducted and controlled according to the chemical procedures developed by research. Conversely, the research chemist develops products and processes which must finally result in efficient manufacture in a processing plant; hence, the researcher will profit significantly by having knowledge of production equipment and operations.

This curriculum is designed primarily for high school graduates who have particular abilities and interests. In general, students entering the program should have completed the equivalent of 1 year of algebra, 1 year of geometry, and 1 year of physical science in their high school program. It should be recognized that the ability levels of those who do, and those who do not, meet these general requirements will vary greatly and that some students may have to take refresher courses in mathematics or English to make satisfactory progress in the program.

Girls whose interests and scholastic preparation cause them to be attracted to this program may be encouraged by the opportunities for employment for women in chemical laboratory and related work. The aptitudes and abilities of women with scientific interests and training peculiarly suit them for much of the analysis and related laboratory work in many chemical research and manufacturing or allied institutions employing chemists.

Because of the specialized nature of this curriculum, teachers must have special competencies. These competencies are based primarily on technical knowledge and industrial employment experience. Beyond this, however, an instructor of chemical technology courses must understand the educational philosophy, the objectives, and the unique organizational requirements that characterize technical education programs.[1] Instruction in the technical education program is not a matter of conducting independent classes in separate subjects; all courses are closely interrelated.

A 2-year curriculum must concentrate on primary needs if it is to prepare individuals for responsible technical positions in modern industry. It must be essentially pragmatic in its approach and must involve a high order of specialization. *The curriculum suggested in this bulletin has been designed to provide maximum technical instruction in the time that is scheduled.* To those who are not familiar with this type of educational service (or with the goals and interests of students who elect it) the technical program often appears to be inordinately rigid and restrictive. While modifications may be necessary, in certain individual institutions, the basic structure and content of this curriculum should be maintained.

[1] *Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs.* OE-80015 p. 10-17, U.S. Office of Education, Washington, D.C., 20202.

This technical curriculum has the usually recognizable five subject-matter divisions: Namely, (1) specialized technical courses in the technology (chemistry); (2) auxiliary or supporting technical courses (technical report writing and chemical technology seminar); (3) mathematics courses; (4) science (physics) courses; and (5) general education courses. The technical subjects provide application of scientific and engineering principles. *For this reason, mathematics and science courses must be coordinated carefully with technical courses at all stages of the program.* This coordination is accomplished by scheduling mathematics, science, and technical courses concurrently during the first two terms, a curriculum principle that will be illustrated at several points. General education courses constitute a relatively small part of the total curriculum. It has been found that students who enter a technical program do so because of the depth in the field of specialization that the program provides. In fact, many students who elect this type of education program will bring to it a good background of general study.

Laboratories and equipment for a chemical technology program must meet high standards of quality since the objective and the strength of the program lie in providing valid laboratory experience basic in nature, broad in variety, and intensive in practical experience. Well-equipped laboratories with sufficient facilities for all students to actually *do* laboratory work are required for these courses. In training chemical technicians, competency obtained by *doing* is required in the use of sampling devices, gravimetric balances, chemical apparatus for quantitative and qualitative analyses (both inorganic and organic), and specialized photometric, electrochemical, or other modern instrumental equipment in general use in chemical production control or research laboratories.

For the unit operations laboratory, equipment must include prototype production units which the students can use separately and in systems to learn how they work and to provide *real* problems in computing material balance, process completion, product losses, yield, and product quality.

Variety and quality of equipment and facilities are more important than quantity in equipping laboratories for teaching chemical technicians. Such equipment and facilities are a major element of the cost of such a program, but they are indispensable if the training objectives are to be met. A separate section in this curriculum guide is devoted to facilities for teaching chemistry because of special need for attention to the details of such facilities.

Safety, cleanliness, precision, and care must be taught as the underlying requisites of all chemical laboratory work. Chemicals and chemical process operations often involve potential dangers that careful procedures combined with understanding of the materials and processes can avoid. Safety is a constant preoccupation of all chemical or allied industries, and its practice must be taught continually from the beginning of the course.

Communication is an important element of technical work. The educational program should include specific instruction in graphic, written, and oral communications. In addition to these specifics, there should be a continual emphasis on written reports with rising standards of attainment as the student progresses in the program. Elements of industrial sociology, psychology, and economics, while necessarily limited by the time factor, should be considered important units of the curriculum.

The course outlines in this guide are short and descriptive. The individual instructor will have to prepare complete courses of study and arrange the curriculum material in logical order of teaching before starting instruction. Suggested chemistry laboratory layouts and equipment found under "Facilities" may be helpful to instructors preparing to teach the courses.

The material is not intended to be applied to a given situation exactly as outlined; it is presented to illustrate the form and content of a complete chemical technology program. In keeping with the form of previously published guides, it is planned as a full-time post high school preparatory program. It is expected, however, that these materials will be of use also in planning extension courses and preparatory technical programs in secondary schools.

The Curriculum

Functional competence in a broad field such as chemical technology has at least three components around which the curriculum must be structured: (1) The training should prepare the graduate to take an entry job in which he will be productive; (2) the broad, technical training, together with a reasonable amount of experience, should enable the graduate to advance to positions of increasing responsibility; and (3) the foundation provided by the training should be broad enough so that the graduate can do further study within his field of technology. This curriculum has been designed to meet these three requirements.

A 2-year technology program has certain unique requirements that influence the content and organization of the curriculum. Some of these requirements are imposed by the occupational functions that graduates must be prepared to perform; some result from the need for special courses that will maximize the effectiveness of teachers who have special competencies; and others arise because of the need to teach both technical principles and related practical applications in the limited time available. The chemical technology curriculum reflects three basic requirements: functional utility, units of instruction in specialized technical subjects, and provision for the teaching of principles by application.

Chemical Technology Curriculum

First Year

	Class hours	Laboratory hours	Outside study	Total hours
First Term				
General Chemistry I	4	4	8	16
Mathematics I	5	0	10	15
Communication Skills	3	0	6	9
Physics I (Mechanics, Heat)	4	2	8	14
Chemical Technology Seminar	1	0	2	3
Total	17	6	34	57
Second Term				
General Chemistry II	4	4	8	16
Mathematics II	4	0	8	12
Technical Reporting	2	2	4	8
Physics II (Electricity, Light)	4	4	8	16
Total	14	10	28	52

Second Year

	Class hours	Laboratory hours	Outside study	Total hours
Third Term				
Quantitative and Instrumental Analysis I	3	6	6	15
Unit Operations I	3	4	6	13
Organic Chemistry I	3	4	6	13
General and Industrial Economics	3	0	6	9
Total	12	14	24	50
Fourth Term				
Quantitative and Instrumental Analysis II	3	6	6	15
Unit Operations II	3	4	6	13
Organic Chemistry II	3	4	6	13
Industrial Organization and Institutions	3	0	6	9
Total	12	14	24	50

The sequence of the courses in a 2-year technical curriculum is as important as the content of the courses. In general, the subject matter in a technical curriculum is carefully correlated in groups of concurrent courses. This is in sharp contrast to the arrangement of professional curriculums in which basic and somewhat unrelated courses make up the first part of the study program and specialization is deferred to subsequent terms.

In technical curriculums it is mandatory that specialized technical course work be introduced in the first term. Deferring this introduction even for one term imposes serious limitations on the effectiveness of the total curriculum. Several important advantages accrue from the early introduction of the technical specialty: (1) Student interest is caught by practical aspects and if the first term consists entirely of general subjects — mathematics, English, social studies — students often lose interest; (2) by introducing technical study in the first term it is possible to obtain greater depth of penetration in specialized subjects in the latter stages of the 2-year program; and (3) maximum practice in the application of mathematics in the technical courses is obtained. The student's study in mathematics is reinforced by his appreciation of the disciplinary values obtained therefrom and the need for these values in technical study.

A chemical technician must have a comprehensive understanding of basic chemical and related physical science, and must be able to do sampling, analyses, calculations, interpretation, and reporting required in applied industrial or research chemistry.

Chemistry, physics, and mathematics courses need to be started immediately and taught intensively, since all three are interrelated. The subject matter of each should be presented in a carefully coordinated sequence so each reinforces the other. This is essential to provide maximum effective use of the limited time for learning in a 2-year curriculum. As each course builds on and reinforces the other, the student's comprehension and interest increase.

The orientation course in the first semester is designed as a working course with lectures and outside assignments. Its purpose is to provide students with a frame of reference regarding the chemical industry and how his education as a chemical technician fits him to do interesting and profitable work in the chemical or allied industries.

Laboratory courses start the first semester with greater emphasis on chemistry (4 hours per week) than on physics (2 hours per week), and continue with equal emphasis in the second semester due to the increased interrelationships of chemistry and physics after the first semester. Chemical laboratory work increases in the third and fourth semesters to give the students maximum opportunity to practice laboratory skills and apply chemical science to real problems.

In the second semester both general chemistry and qualitative chemistry are taught in class lectures and in the laboratory. The concepts and laboratory techniques of qualitative chemistry thus are incorporated early in the curriculum and accomplish the dual purpose of teaching general chemistry laboratory techniques and skills by using problems and procedures of qualitative analysis.

Quantitative analysis and unit operations course content in both the third and fourth semester places heavy emphasis on chemical calculations and mathematical computation of material balances, completeness of chemical reactions, equipment and process efficiences, and related quantitative chemical considerations. Instrument methods of analysis are emphasized and practiced in the laboratory in these courses as extensively as time and equipment allow. This allows the student to make more chemical analyses due to the more rapid determinations by instrumental methods than conventional titration, volumetric, or gravimetric methods, and allows him to learn the application of modern analytical equipment widely used in industrial laboratories. His analytical laboratory experience thus teaches him conventional methods of analysis and also allows him to study a greater variety of determinations than possible without the use of timesaving instrumental methods of analysis.

The social science courses are designed to broaden the student's concepts and perception of the society in which he lives and will be employed. These courses include broad economic and industrial concepts and sufficient emphasis on corporate structure and economics to enable the student to comprehend the terminology and recognize the motives, methods, objectives, and administrative procedures of employers.

Communications courses emphasize the mechanics of reading, writing, listening, speaking, and reporting. Instructors should establish standards of clarity, conciseness, and neatness in the beginning courses. In addition, instructors in technical courses should set increasingly high standards for student work in reporting. This is especially important in the student's laboratory, diary, and record books, which in the chemical industry become the legal basis for substantiation of discovery and process or product patents. Freedom to report on technical subjects may add reality and extra motivation for technology students. In the final phases of the 2-year program, the standards of reporting should approach those required by business organizations. At the same time, instructors should encourage individual style and initiative by allowing as much freedom as possible in reporting, consistent with established school standards.

As a part of the technical report writing course, 2 semester hours of laboratory training in graphic representation, freehand drawing, and sketching are included in addition to the 2 semester hours of class time devoted to technical report writing. The inclusion of drawing is to provide the student with a knowledge of drawing, sketching, and blueprint reading. Drawings are the "second language" of scientists and engineers. Most designs are first sketched freehand as general layouts and plans. After refinement and further study they then are formally drawn by skilled draftsmen. Chemical technicians must be able to understand drawings, piping diagrams, and electrical diagrams employing symbols commonly in use; and must be able to convey their ideas by drawings if they are to communicate effectively with chemical engineers, research chemists, or supervisors of chemical production processes or plants.

Outside study is a significant part of the student's total program. In this curriculum 2 hours of outside study time have been suggested for each hour of scheduled class time. A typical weekly work schedule for a student in the first semester of this curriculum would be: class attendance, 17 hours; laboratory, 6 hours; outside, 34 hours — a total of 57 hours per week. This is a full schedule, but not excessive for this type of program. The second year weekly schedule is 50 hours.

The course outlines shown are concise and comprehensive, intended as guides rather than as specific plans of instruction to be covered in an inflexible order or sequence. They represent a judgment on the relative importance of each instructional unit, especially where time estimates are shown for the divisions within each course. It is expected that the principles outlined in these courses will be supplemented with industrial applications wherever possible. Industrial practices should be studied and followed in drafting and report writing, and materials from industry should be utilized throughout the program wherever it is possible to do so. Field trips will add a great deal to the effectiveness of the instruction if they are carefully planned in advance and scheduled at a stage in the course where the processes observed will be understood in terms of the chemistry being applied.

Textbooks, References, and Visual Aids

Textbooks, references, and visual aids for teaching any technology must constantly be reviewed and supplemented in light of (1) the rapid development of new knowledge in the field, and (2) the results of research in *methods* of teaching and developing basic concepts in the physical sciences and mathematics. This is especially true in chemical technology. The impact of the development of whole new areas of theoretical and applied scientific knowledge is creating new textbooks, new references, new material in scientific and technical journals, and new visual aid materials.

New textbooks will reflect new methods of teaching scientific principles and applications as fast as current education research becomes applicable. Extensive research in methods of teaching chemistry and physics in recent years almost certainly will produce changes in teaching materials and methods. The research promoted by the National Science Foundation, for example, in methods and materials for teaching chemistry and physics prior to and in high school will probably influence post secondary teaching of these disciplines in the future. It is, therefore, mandatory that instructors constantly review new texts, references, and visual aid materials as they become available, and *adopt* them when they are an improvement over those here suggested or being used in present programs.

The suggested texts have been carefully selected. From the lists presented it should be possible to select suitable texts. It should not be interpreted, however, that unlisted books are not suitable — there are, no doubt, excellent ones which have not been included only because of lack of complete familiarity with them.

Before a department head or instructor undertakes a program in chemical technology, or any course contained in the curriculum, it is urged that he familiarize himself with the texts and references listed here and any new ones available. He will then be able to select the text which best serves his particular needs in providing a lucid high-level technical presentation to his students.

Visual aids can be of great help in many teaching programs. The aids which are listed have been selected from an extensive list, and represent those considered most suitable at the time the curriculum was prepared. Again, there are many which are not listed because the variety and extent of the materials make an all-inclusive listing prohibitive.

Scientific and Technical Societies

Scientific and technical societies are an important source of instructional materials. Such societies provide in their publications and in their regularly programed meetings, a continuing disclosure and discussion of the new concepts, processes, techniques, and equipment in the science and related technologies. They are probably the greatest single device by which persons engaged in applying that particular body of science keep abreast of new developments. Their data are presented in such manner as to provide a "popularizing" bridge between the creative theoretical scientists and the applied science practitioners, including the technicians.

Students of chemical technology should be made aware of the literature and services of these societies early in their study program. Student affiliate memberships are offered by some of these societies, and students should be encouraged to become such members.

The *American Chemical Society,* 1155 16th Street NW., Washington, D.C. is the largest and longest established technical society for chemists and chemical engineers numbering about 100,000 members. Among its many publications are *Chemical and Engineering News, Industrial and Engineering Chemistry, Chemical Abstracts, Colloid Chemistry,* and *Analytical Chemistry.* They offer a student affiliate membership.

The American Institute of Chemical Engineers, 50 East 41st Street, New York, N.Y. 10017, is an organization of chemical engineers numbering nearly 20,000 members. They publish *Chemical Engineering Progress* monthly; a *Year Book*; and *Transactions*, a bimonthly.

Other chemists' technical societies are listed in Appendix A.

Manufacturing Chemist's Association, Inc., 1825 Connecticut Avenue NW, Washington 9, D.C., is an organization of more than 200 chemical companies. *The Chemical Industry Facts Book* is one of its several publications.

Advisory committees can be very helpful in technical education curriculum planning for a specific community. Such committees usually are made up of knowledgeable and technically informed representatives from industry, State employment services, education, and professional or trade associations who have special knowledge of the employment needs of the community. One of the important functions of any advisory committee is to provide a medium for communication. The committee can interpret the needs of the community to the school and at the same time make the contributions of the school known to the community.

This publication is intended as a guide for program planning and development, primarily in post high school institutions. It is expected that adaptations will need to be made to suit various situations in several kinds of schools. The level of instruction indicated represents a consensus on the level of proficiency required for success in occupations in which manpower is in short supply today and threatens to be even more so in the future. The curriculum is a product of the efforts of a number of people —educators, engineers, employers, and the staff of the Office of Education's — Technical Education Branch — concerned with the improvement of public education services.

Suggested Continuing Study

A 2-year curriculum must concentrate on the primary needs of science, mathematics, and the related knowledge and skills of the technology necessary to the preparation of the student for employment upon graduation.

Obviously, such a course of study cannot in 2 years cover in depth all of the subjects which are pertinent to the technology, and some important related subjects may be only touched upon in that time.

Some form of continuation of study for graduates of technology programs is therefore mandatory. By reading the pertinent current literature related to the technology, the student can keep abreast of the technical developments of his special field, but this tends only to build on the organized technological base provided by the curriculum he studied.

Formal continuation or supplementary courses provide the most efficient and practical means for the graduate technician to add important related areas of knowledge and skill to his initial education. They have the advantages of systematic organization of subject matter, disciplined and competent teaching, class discussion, and may be scheduled for evening or Saturday hours outside of the graduate student's working day.

Some suggested continuation or extension courses for graduates of this chemical technology curriculum follow:

- Biochemistry
- Physical Chemistry
- Analyses using radioactive tracers
- Nuclear Chemistry
- Psychology and Human relations
- Elementary Metallurgy
- Chemistry of materials
- Industrial management and supervision

COURSE OUTLINES

Technical Courses

General Chemistry I

Hours Required

Class, 4; Laboratory, 4

Description

A study of fundamental principles and concepts in chemistry; atomic structure; the chemical bond; and the periodic classification of the elements. Selected laboratory experiments illustrate chemical principles and develop laboratory techniques.

Major Divisions

		Class hours
I.	Introduction and Fundamental Principles	4
II.	Atomic Structure	8
III.	Periodic Classification	7
IV.	Formulas and Chemical Equations	3
V.	Oxygen and Hydrogen	2
VI.	The Gaseous State	9
VII.	Valence and Oxidation Number	6
VIII.	Classification and Nomenclature	5
IX.	Weight and Volume Relations	6
X.	Water and the Liquid State	3
XI.	Solutions and Colloids	11

I. Introduction and Fundamental Principles

1. Introduction and historical background
2. Units of measurement
   Dimensional analysis
3. Matter and its changes
4. Laws of chemical change
5. Symbols and formulas
7. Valence, covalence
8. Molecular weight, formula weight,

II. Atomic Structure

1. Atomic theory
2. Atomic weights, equivalent weights
3. Electron, proton, neutron
4. Modern theory of atomic structure
   mole
5. Atomic numbers, mass numbers
6. Atomic structure — isotopes
7. Valence, covalence
8. Molecular weight, formula weight, mole

III. Periodic Classification

1. The periodic table
2. Relationship of modern atomic theory to the periodic table
3. Long-form periodic table
4. Ionization potential
5. Physical and chemical behavior
6. Uses of the periodic table
7. Imperfections of the table

IV. Formulas and Chemical Equations

1. Formulas
2. Chemical equations
3. Radicals
4. Types of chemical changes
5. Percentage composition

V. Oxygen and Hydrogen

1. Oxygen
   (a) History and occurrence
   (b) Preparation — laboratory, commercial
   (c) Properties and uses
2. Hydrogen
   (a) History and occurrence
   (b) Activity series
   (c) Preparation — laboratory, commercial
   (d) Properties and uses

VI. The Gaseous State

1. Atmospheric pressure
2. Pressure — volume relationship
3. Temperature — volume relationship
4. Combined gas laws
5. Standard temperature and pressure
6. Law of partial pressures
7. Kinetic theory of gases
8. Law of combining volumes
9. Gram molecular volume

VII. Valence and Oxidation Number

1. Electrovalence and atomic structure
2. Derivation of formulas
3. Derivation of valence from formula
4. Valence and formula writing
5. Covalence, polar and non-polar bonds
6. Coordinate valence
7. Oxidation number
8. Oxidation and reduction

VIII. Classification and Nomenclature

1. Acids and their properties
2. Bases and their properties
3. Salts
4. Ionic equations
5. Reaction types
6. Nomenclature
7. Amphoterism

IX. Weight and Volume Relations

1. Volume — volume relations
2. Weight — weight relations
3. Weight — volume relations

X. Water and the Liquid State

1. Properties of liquid state
2. Evaporation
3. Boiling point
4. Surface tension
5. Viscosity
6. Purification of water
7. Molecular structure of water; heavy water
8. Hydrates
9. Efflorescence and deliquescence

XI. Solutions and Colloids

1. Solutions; solute and solvent
2. Types of solutions
3. Equilibrium in solutions
4. Supersaturation
5. Solubility of solids
6. Solubility of gases in liquids
7. Effect of temperature on solubility
8. Concentration of solutions
9. Molar solutions
10. Normal solutions
11. Molal solutions
12. Boiling and freezing points
13. Osmotic pressure
14. Colloids and colloidal particles
15. Kinds of colloidal solutions
16. Preparation of colloidal solutions
17. Characteristics of colloidal solutions
18. Precipitation of colloidal particles

Laboratory

1. The Tirrill Burner and glass manipulation
2. Density and specific gravity
3. Separation of the components of a mixture
4. The Law of Definite Proportions
5. Determination of the amount of an element present in an unknown solution
6. Percentage of potassium chlorate in a mixture
7. Equivalent weight
8. Melting point and boiling point
9. Water hardness
10. Formula of a hydrate
11. Percentage of zinc in a mixture
12. Titration
13. Extraction and titration
14. Ion-exchange
15. Molecular weight by boiling-point elevation
16. The halogens and some of their compounds

Any good laboratory manual for college chemistry may be selected. Most of the manuals contain a majority of the suggested laboratory experiments which will vary somewhat depending on the manual selected.

Texts and References

One of the following books may be selected for a text. Others may be used for reference.

FREY. *College Chemistry*

KING *and others*. *Laboratory Manual for College Chemistry*

NEBERGALL *and* SCHMIDT. *Basic Laboratory Studies in College Chemistry*

NECHAMKIN. *Laboratory Problems Manual of General Chemistry*

PIERCE *and* SMITH. *General Chemistry Workbook*

RUSSELL. *Study Guide for Sienko and Plane Chemistry*

SIENKO *and* PLANE. *Chemistry*

——— *Experimental Chemistry*

SISLER *and others*. *General Chemistry — A Systematic Approach*

SORUM. *Fundamentals of General Chemistry*

WOOD *and* KENNAN. *General College Chemistry*

Audiovisual Aids

ATOMIC ENERGY COMMISSION:
Understanding the Atom (12-part series), 16 mm., black and white

MODERN TALKING PICTURES, 160 E. Grand Ave., Chicago 11, Ill.:
Valence and Molecular Structure, Pauling series, 3 films, 16 mm., 50 min., color, sound

INDIANA UNIVERSITY, Bloomington, Ind. (NET):
The Chemical Elements, Seaborg. Series of 3, 16 mm., 35 min.

STATE UNIVERSITY OF IOWA, Iowa City, Iowa:
Atomic Models, Valence and the Periodic Table, 16 mm., 44 min., color, sound

MANUFACTURING CHEMISTS' ASSOCIATION:
Catalysis (Prof. Richard E. Powell—collaborator), 16 mm., 17 min., color
Nitric Acid (Prof. Harry H. Sisler—collaborator), 16 mm., 18 min., color

MODERN LEARNING AIDS, New York, N. Y.:
Chemical Families (Dr. J. Leland Hollenberg and Prof. J. Arthur Campbell—collaborators), 16 mm., 22 min., color
Gases and How They Combine (Prof. George C. Pimentel, University of California—collaborator), 16 mm., 22 min., color
Molecular Motions (Dr. J. Arthur Campbell—collaborator), 16 mm., 13 min., color

PURDUE UNIVERSITY, Audio Visual Center, Fort Wayne, Ind.:
11 films on laboratory techniques

General Chemistry II

Hours Required

Class, 4; Laboratory, 4

Description

Includes the study of general principles as applied to reversible reactions and chemical equilibrium; descriptive chemistry of the groups of elements; corrosion; and nuclear changes. Approximately one class period per week will be devoted to the qualitative identification of the ions. The laboratory portion is concerned with qualitative analysis and is described more fully under the laboratory outline.

Major Divisions

		Class hours
I.	Chemical Equilibrium; Ionization	14
II.	Group VII–A Elements	3
III.	Oxidation and Reduction	4
IV.	Group VI–A Elements	3
V.	Group V–A Elements	5
VI.	Group IV–A Elements	3
VII.	Metals and Metallurgy	3
VIII.	Representative Metals	5
IX.	Electrochemistry	3
X.	Corrosion	2
XI.	Transition Metals	5
XII.	Nuclear Changes	4
XIII.	Qualitative Separation and Identification	10

I. Chemical Equilibrium; Ionization

1. Factors affecting reaction rates
2. Law of mass action
3. Chemical equilibrium
4. Equilibrium constants
5. Reactions which proceed to completion
6. Effect of temperature and pressure
7. Theory of ionization
8. Conductivity of solutions
9. Ionization effects
10. Neutralization reactions
11. Other reactions
12. Ionization constants
13. Common ion effect
14. Buffer solutions
15. Hydrogen ion concentration
16. Solubility product principles
17. Applications of solubility product principles
18. Hydrolysis

II. Group VII-A Elements

1. Similarities and differences
2. History and occurrence
3. Preparation
4. Properties
5. Uses
6. The hydrohalogens
7. Oxygen compounds of the halogens

III. Oxidation and Reduction

1. Oxidation
2. Reduction
3. Oxidizing and reducing agents
4. Oxidation — reduction equations
5. Balancing redox equations

IV. Group VI-A Elements

1. Sulfur
    (a) Occurrence and extraction
    (b) Physical structure
    (c) Properties and uses
    (d) Hydrogen sulfide
    (e) Oxides and acids of sulfur
2. Selenium and Tellurium

V. Group V-A Elements

1. Nitrogen
2. Nitrogen fixation
3. The inert gases
4. Ammonia and ammonium salts
5. Nitric acid and nitrates
6. Oxides of nitrogen
7. Phosphorous
8. Compounds of phosphorous
9. Arsenic
10. Antimony
11. Bismuth

VI. Group IV-A Elements

1. Carbon
    (a) Allotropic forms
    (b) Destructive distillation; fuels
    (c) Properties; uses
    (d) Carbon compounds
2. Silicon
    (a) Occurrence
    (b) Preparation, properties, uses
    (c) Compounds of silicon
    (d) Glass

VII. Metals and Metallurgy

1. Atomic structure and properties of metals
2. Physical properties
3. Alloys
4. Eutectics
5. Occurrence of metals
6. Metallurgy
7. Chemical properties
8. Activity
9. Amphoterism

VIII. Representative Metals

1. Alkali metals
2. Alkaline earth family
3. Aluminum
4. Boron
5. Other elements of Groups III-A and III-B
6. Tin
7. Lead

IX. Electrochemistry

1. Chemical change from electrical energy
    (a) Faraday's Law
    (b) Electrical units
2. Electrical energy from chemical change
    (a) Voltaic cells
    (b) Electrode potentials
    (c) The dry cell
    (d) The storage battery
3. Electroplating

X. Corrosion

1. Chemical reactions: corrosion
2. Galvanic action
3. Oxygen and water in corrosion
4. Rates of corrosion
5. Prevention of corrosion

XI. Transition Metals

1. Copper, silver, gold
2. Zinc, cadmium, mercury
3. Chromium, manganese
4. Iron and steel
5. Cobalt and nickel
6. The platinum metals

XII. Nuclear Changes

1. Radioactivity
2. Disintegration of atoms
3. Half-life periods
4. Properties of radium
5. Isotopes of lead
6. Artificial transmutation

7. Artificial radioactivity
8. Atomic energy
9. Chain reactions, atomic fission
10. Nuclear power plants
11. Atomic fusion

XIII. Qualitative Separation and Identification

1. Cation group separation
2. Separation of individual cations
3. Identification of cations
4. Separation of anion groups
5. Identification of anions
6. Methods of dissolving samples
7. Complete analyses of mixtures

Laboratory — 64 hours

The laboratory portion of this course is concerned with the qualitative identification of the ions, and it is recommended that the semimicro method using thioacetedmids be adopted. It is assumed that the theoretical background in ionic equilibrium is treated in Division I of the lecture outline above. It is suggested that in addition to the 1 hour per week of classroom work devoted to qualitative analysis, some of the laboratory time be used to discuss the techniques encountered and to point out the specific applications of theory to the laboratory work.

This course is a continuation of General Chemistry I. The following laboratory experiments, in addition to those for general chemistry, are suggested for the qualitative chemistry in the course.

1. Separation of cation groups
2. Separation of cations within each group
   (a) Physical and chemical
   (b) Effectiveness of the separation
   (c) Amount of cation remaining in given amount of solution using solubility product
3. Use of known and unknown solutions to determine the skill of the student
4. Study of difference in techniques applied anions
5. Separation of anion groups
6. Identification of individual anions
7. Methods of dissolving samples
8. Complete analyses of mixtures or simple commercial products

Texts and References

The following texts are in addition to those listed for General Chemistry I.

ARTHUR *and* SMITH. *Semimicro Qualitative Analysis*

HOGNESS *and* JOHNSON. *Introduction to Qualitative Analysis*

SORUM. *Introduction to Semimicro Qualitative Analysis*

Quantitative and Instrumental Analysis I

Hours Required

Class, 3; Laboratory, 6

Description

A course devoted to the study of the chemical methods applied in quantitative analysis; formation and properties of precipitates; theory of neutralization; basic laboratory procedures in gravimetric analysis; titrimetry.

Major Divisions

		Class hours
I.	Introduction	1
II.	The Analytical Balance and Weighing	1
III.	General Operations in Quantitative Analysis	1
IV.	Applications of Solubility Product	4
V.	Gravimetric Stoichiometry	3
VI.	Gravimetric Determination	3
VII.	Evaluation of Experimental Measurement	3
VIII.	Titrimetry: Stoichiometry	6
IX.	Theory of Neutralization Reactions	3
X.	Acidimetric and Alkalimetric Determinations	3
XI.	Theory of Precipitation and complex Ion Formation	3
XII.	Applications of Precipitation Titration and Complex Ion Formation	3
XIII.	Potentiometry of Neutralization Reactions	3
XIV.	Oxidation and Reduction	7
XV.	Applications of Redox Reactions	4

I. Introduction

1. The scope of quantitative analysis
2. Need for analytical chemistry

II. The Analytical Balance and Weighing

1. Mass and weight
2. Construction of balance
3. Types of balances
4. Sensitivity
5. Weighing operations
6. Care of the balance
7. Errors in weighing
8. Weights and their calibration

III. General Operations in Quantitative Analysis

1. The sample; preparation, storage, measurement
2. Analytical separations
3. Analytical measurements
4. Apparatus assembly, glass welding and forming
5. Tools and techniques
6. The laboratory notebook

IV. Applications of Solubility Product

1. Review of solubility product principle
2. Common ion effect
3. Limitations of solubility product principle
4. Diverse ion effect

V. Gravimetric Stoichiometry

1. Percentage from analytical data
2. Gravimetric factors
3. Factor weight samples
4. Dry basis calculations
5. Composition of mixtures of solids
6. Indirect analysis

VI. Gravimetric Determinations

1. Percent water by loss on heating
2. Determination of sulfate
3. Determination of chloride
4. Determination of silica
5. Iron by precipitation as ferric hydroxide
6. Determination of calcium
7. Determination of magnesium
8. Errors encountered

VII. Evaluation of Experimental Measurement

1. Significant figures
2. Types of errors
3. Precision and accuracy
4. Deviation
5. Confidence limits
6. Rejection of a measurement

VIII. Titrimetry: Stoichiometry

1. Standard solutions — preparation and storage
2. Primary and secondary standards
3. Normal solutions
4. Titer of solutions
5. Molar solutions
6. Equivalents, milliequivalents, millimoles
7. Factor weight solutions
8. Equipment used in titrimetric analysis

IX. Theory of Neutralization Reactions

1. Ionization of acids and bases — ionization constants
2. Ionization of water
3. Hydrogen-ion concentration and pH
4. Polyprotic acids
5. Buffered solutions

X. Acidimetric and Alkalimetric Determinations

1. Preparation of standard solutions
2. Common primary standards
3. Determination of replaceable hydrogen
4. Titration of hydroxides
5. Analysis of mixed alkalis
6. Determination of volatile bases: Kjeldahl method

XI. Theory of Precipitation and Complex Ion Formation

1. Equivalence points: equivalent weight
2. Indicators
3. Application of chemical equilibrium
4. Primary standards

XII. Applications of Precipitation Titration and Complex Ion Formation

1. Determination of chloride by Mohr method
2. Volhard method for determination of silver or chloride
3. Determination of chloride using adsorption indicator
4. Analysis of material using EDTA

XIII. Potentiometry of Neutralization Reactions

1. Changes in pH during titrations
2. Titration curves
3. Acid-base indicators
4. End point: equivalence point

XIV. Oxidation and Reduction

1. Oxidation number
2. Balancing redox equations
3. Electrochemical theory
4. Redox indicators
5. Equivalent weight in redox reactions

XV. Applications of Redox Reactions

1. Oxidizing and reducing agents used
2. Primary standards and indicators
3. Use of permanganate in determining oxalate
4. Use of permanganate in determining iron
5. Determination of iron using dichromate

Suggested Laboratory Determinations—96 hours

1. Calibration of set of weights
2. Gravimetric determination of water by evaluation
3. Gravimetric determination of sulfate
4. Gravimetric determination of chloride
5. Gravimetric determination of iron
6. Gravimetric determination of nickel by dimethylglyoxime method
7. Standardization of hydrochloric acid solution
8. Standardization of sodium hydroxide solution
9. Determination of percentage purity of soda ash
10. Determination of percentage purity of potassium biphthalate
11. An analysis of nitrogen using the Kjeldahl method
12. Standardization of silver nitrate solution
13. Standardization of potassium thiocyanate solution
14. Standardization of EDTA solution
15. Analysis for chloride using Mohr method
16. Determination of chloride by Volhard method
17. Determination of chloride by Fajan method
18. Determine hardness in water using EDTA
19. Standardization of potassium permanganate solution
20. Standardization of potassium dichromate solution
21. Determination of oxalate by permanganate
22. Determination of iron using dichromate

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

AMERICAN SOCIETY FOR TESTING MATERIALS, BOOKS OF ASTM METHODS FOR CHEMICAL ANALYSIS

AYRES. *Quantitative Chemical Analysis*

CALDWELL *and* KING. *Semimicro Quantitative Analysis*

DIEHL *and* SMITH. *Quantitative Analysis*

FISCHER. *Quantitative Chemical Analysis*

FOULK *and others. Quantitative Chemical Analysis*

HAMILTON *and* SIMPSON. *Quantitative Chemical Analysis*

PIERCE *and others. Quantitative Analysis*

WILLARD *and others. Elements of Quantitative Analysis*

Audiovisual Aids

BELL TELEPHONE LABORATORIES, 463 West Street, New York, N. Y.:
Crystals: An Introduction, 16 mm., 24 min., color, sound

F. H. REEVE ANGEL & CO., New York, N. Y.:
Principles of Chromatography

MODERN LEARNING AIDS, New York, N. Y.:
Crystals and Their Structures (Prof. J. Arthur Campbell — Collaborator), 16 mm., 21 min., color
Acid Base Indicators (Prof. J. Arthur Campbell — Collaborator), 16 mm., 19 min., color
Electric Interactions in Chemistry (Prof. J. Leland Hollenberg and Prof. J. Arthur Campbell — Collobarators), 16 mm., 21 min., color
Equilibrium (Prof. George C. Pimentel — Collaborator), 16 mm., 21 min., color
Molecular Spectroscopy (Prof. Bryce Crawford, Jr., *and* Dr. John Overend — Collaborators), 16 mm., 23 min., color

NORTH AMERICAN PHILLIPS, New York, N. Y.:
The Ultimate Structure, 16 mm., 22 min., black and white, sound

RENSSELAER POLYTECHNIC INSTITUTE, Department of Chemistry, Troy, N. Y.:
Three films on analytical techniques, including IR Spectroscopy

SUTHERLAND EDUCATIONAL FILMS, Los Angeles, Calif.:
Introduction to Reaction Kinetics and Vibration of Molecules, 16 mm., 13 min., color, sound
Vibrations of Molecules, 16 mm., 11 min., color, sound

Quantitative and Instrumental Analysis II

Hours Required

Class, 3; Laboratory, 6

Description

A continuation of the study of the chemical methods applied in quantitative analysis. Emphasis in this course is on oxidation-reduction reactions, precipitation titrimetry, and the analysis of multicomponent materials. The use of instrumental methods for performing analyses is introduced after the traditional methods have been covered. It is suggested that the student should gain experience with as many of the available instruments as possible. Emphasis should be upon application, limitations, and common errors in the methods, rather than upon the design, operation, and servicing of specific instruments.

Major Divisions

		Class hours
I.	Oxidation and Reduction	3
II.	Applications of Redox Reactions	2
III.	Electrodeposition	4
IV.	Analysis of Multi-component Materials	1
V.	Introduction to Instrumental Methods	1
VI.	Light	1
VII.	Absorption of Light	2
VIII.	Colorimetry and Spectrophotometry	7
IX.	Flame Photometry	2
X.	Other Analytical Methods Using Light Measurements	2
XI.	Electrical Conductance	3
XII.	Electromotive Force Measurements and Potentiometric Titrations	3
XIII.	Polargraphy and Amperometry	5
XIV.	Chromatography	2
XV.	X-ray Diffraction	2

I. Oxidation and Reduction

1. Half-cell reactions
2. Reference electrodes and indicator electrodes
3. Measurement of potentials
4. Potentiometric redox titrations
5. Equilibrium constant from E° value
6. Rates of redox reactions
7. Changes of E° values with pH

II. Application of Redox Reactions

1. Cereometry and perchloratoceric acid methods
2. Iodometric determination of copper
3. Determination of arsenic and antimony
4. Potentiometric detection of end points

III. Electrodeposition

1. Scope
2. Definition of terms
3. Laws of electrolysis
4. Electrode reactions
5. Compositions of electrolytes
6. Polarization, overvoltage
7. Applications of electrodeposition

IV. Analysis of Multicomponent Materials

1. Procedures in the analysis of brass
2. Procedures in limestone analysis
3. Other multi-component materials

V. Introduction to Instrumental Methods

1. Differences between classical and instrumental methods of analysis
2. Physical properties useful in analysis

VI. Light

1. Review of the nature of light
2. The electromagnetic spectrum
3. Reflection, diffraction, and diffusion of light
4. Mirrors, prisms, and diffraction of light
5. Monochromators

VII. Absorption of Light

1. How radiant energy is absorbed
2. Terms and symbols used
3. Colorimetry
4. Fundamental laws of colorimetry
5. Deviations from Beer's law

VIII. Colorimetry and Spectrophotometry

1. Visual colorimetry
2. Photoelectric colorimetry
3. Tri-stimulus colorimetry
4. Spectrophotometry
5. Data collected in photometric measurements
6. Interpretation of data

IX. Flame Photometry

1. Emission of light
2. Equipment necessary for measurement of light
3. Qualitative flame photometry
4. Quantitative flame photometry
5. Commercial flame photometers

X. Other Analytical Methods Using Light Measurements

1. Nephelometric methods
2. Turbidimetric methods
3. Fluorimetric methods

XI. Electrical Conductance

1. Measurements
2. Electrical terminology reviewed
3. Ionic mobilities
4. Other conditions affecting conductivity
5. Instruments for measurement
6. Conductivity cells
7. Applications of conductance measurements
8. Limitations of the method

XII. Electromotive Force Measurements and Potentiometric Titrations

1. The Ernst equation
2. Half-cell reactions
3. Reference electrodes
4. Indicator electrodes
5. Apparatus for measurement of e.m.f.
6. Potentiometric titrations

XIII. Polarography and Amperometry

1. Characteristics of current-voltage curves
2. Polargraphic cells and electrodes
3. Polargraphic curves
4. Factors affecting the polargraphic curves
5. Half-wave potentials; qualitative analysis
6. Wave height and quantitative analysis
7. Amperometric and coulometric titrations
8. Dead-stop titrations

XIV. Chromatography

1. Paper partition chromatography
2. Absorption chromatography
3. Electrophoresis
4. Bas chromatography

XV. X-ray Diffraction

1. Basic principles
2. Method and apparatus
3. Application
4. Limitations

Suggested Laboratory Determinations—96 hours

1. Standardization of sodium thiosulfate solution
2. Standardization of iodine solution
3. Determination of copper in copper ore
4. Analysis of antimony ore for antimony
5. Potentiometric determination involving redox
6. Analysis of brass
7. Colorimetric determination of manganese in steel
8. Colorimetric determination using filter photometer
9. Spectrophotometric determinations
10. Flame photometry
11. Turbidimetry and Nephelometry
12. Fluorimetry
13. Potentiometry
14. Polarography
15. Conductimetry
16. Amperometry
17. Chromatography
18. X-ray diffraction

Texts and References

In addition to those listed for Quantitative and Instrumental Analysis I, the following are suggested:

BAYER. *Gas Chromatography*

BLOCK *and others. Manual of Paper Chromatography and Paper Electrophoresis*

BRIMLEY *and* BARRETT. *Practical Chromatography*

DEAN. *Flame Photometry*

DELAHAY. *New Instrumental Methods in Electrochemistry*

EWING. *Instrumental Methods of Chemical Analysis*

KEULEMANS. *Gas Chromatography*

KOLTHOFF *and* LINGANE. *Polarography*

LINGANE. *Electroanalytical Chemistry*

MEITES *and* THOMAS. *Advanced Analytical Chemistry*

MELLON. *Analytical Absorption Spectroscopy*

——— *Colorimetry for Chemists*

PHILLIPS. *Gas Chromatography*

REILLEY *and* SAWYER. *Instrumental Analysis and Techniques*

WILLARD *and others. Instrumental Methods of Analysis*

Organic Chemistry I

Hours Required

Class, 3; Laboratory, 4

Description

A systematic study of the compounds of carbon and hydrogen and their substituted products. There are several approaches to the study of organic chemistry. The unified approach presents the aliphatic and aromatic compounds together and the classification is based on substituent groups. Another method is to separate the aliphatic and aromatic compounds and study each in areas of substituent groups. This outline is based on the unified approach although either approach arrives at the goal equally well. This course also studies the reaction mechanisms involved in organic chemistry as well as the uses of important compounds.

Major Divisions

		Class hours
I.	Introduction	2
II.	Hydrocarbons	11
III.	Alcohol and Phenols	6
IV.	Halogen Compounds	4
V.	Ethers	3
VI.	Aldehydes and Ketones	7
VII.	Carboxylic Acids	7
VIII.	Amines and Diazonium Compounds	4
IX.	Sulfur Compounds	4

I. Introduction

1. Definition of organic chemistry
2. Reasons for studying the compounds of carbon separately
3. Marked difference in solubility of organic and inorganic compounds
4. Reaction rates generally slower, and non-ionic in character
5. Type reactions — alcohols to aldehydes, etc.
6. Complexity of reactions and side reactions
7. Sources of organic compounds
8. Electron theories of valence applied to organic compounds
9. Acylic and cyclic compounds

II. Hydrocarbons

1. Pariffins
2. Cycloparaffins
3. Olefines
4. Acetylenes
5. Aromatic hydrocarbons
6. Hydrocarbon mixtures

III. Alcohols and Phenols

1. Primary, secondary, and tertiary alcohols
2. Monohydric and polyhydric alcohols
3. Preparation
4. Reactions
5. Phenols and aromatic alcohols
6. Uses

IV. Halogen Compounds

1. Alkyl and amyl halides
2. Nomenclature
3. Preparation
4. Reactions
5. Uses

V. Ethers

1. Nomenclature
2. Preparation
3. Reactions
4. Uses

VI. Aldehydes and Ketones

1. Nomenclature
2. Preparation
3. Reactions
4. Polymerization

VII. Carboxylic Acids

1. The carboxyl group
2. Monobasic acids
3. Polybasic acids
4. Preparation
5. Reactions
6. Uses
7. Acid Halides
8. Esters
9. Anhydrides
10. Amides and nitrites

VIII. Amines and Diazonium Compounds

1. Nomenclature
2. Reactions
3. Preparation
4. Aromatic amines and diazotization
5. Coupling
6. Sandmeyer reaction

IX. Sulfur Compounds

1. Thio compounds
2. Sulfonic acids
3. Sulfanilamides

Laboratory — 64 hours

This course is designed to familiarize the student with the methods of preparing and testing representative compounds studied in the organic chemistry lectures. The laboratory work should be so planned that the experiments in the laboratory are correlated with the class work.

Particular emphasis should be placed on proper safety procedures in setting up the apparatus and handling of the chemicals. Precautions against fire and care in the use of volatile materials should be constantly stressed. Many of the experiments can be performed without the use of open flames. Hot plates and heating mantles should be used whenever possible. Special precautions should be emphasized in handling of toxic materials.

Any good laboratory manual for organic chemistry may be selected; most of them contain a majority of the representative laboratory experiments.

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

BREWSTER *and others. Unitized Experiments in Organic Chemistry*

CASON *and* RAPAPORT. *Basic Experimental Organic Chemistry*

CHEMICAL RUBBER CO. *Handbook of Physics and Chemistry*

CRAM *and* HAMMOND. *Organic Chemistry*

ENGLISH *and* CASSIDY. *Principles of Organic Chemistry*

FERGUSON. *Textbook of Organic Chemistry*

HARTE *and* SCHULTZ. *A Short Course in Organic Chemistry*

LANGE. *Handbook of Chemistry*
MORRISON *and* BOYD. *Organic Chemistry*
VOGEL. *Elementary Practical Organic Chemistry*

Laboratory Manuals

ANDERSON *and others. Manual for the Organic Chemistry Laboratory*

CHERONIS. *Experimental Organic Chemistry*

HARTE *and* SCHULTZ. *A Laboratory Manual for a Short Course in Organic Chemistry*

ROBERTSON *and* JACOBS. *Laboratory Practices of Organic Chemistry*

WIBERG. *Laboratory Technique in Organic Chemistry*

Visual Aids

BELL TELEPHONE LABORATORIES, 463 West Street, New York:
Physical Chemistry of Polymers. 16 mm., 23 min., color, sound

HANDEL FILMS, Hollywood, Calif.:
The Riddle of Photosynthesis. 16 mm., 12½ min., black and white, sound

MODERN LEARNING AIDS, New York, N. Y.:
Mechanism of an Organic Reaction, (Prof. Henry Rapaport — Collaborator) 16 mm., 20 min., color
Synthesis of an Organic Compound, (Prof. T. A. Geissman — Collaborator) 16 mm., 22 min., color

YOUNG AMERICA FILMS, New York, N. Y.:
Techniques of Organic Chemistry

Organic Chemistry II

Hours Required

Class, 3; Laboratory, 4

Description

A continuation of Organic Chemistry I; the emphasis in this course is on some of the more complex areas of Organic Chemistry.

Major Divisions

		Class hours
I.	Carbonic Acid and Its Derivatives	6
II.	Substituted Acids	14
III.	Color and Chemical Constitution	3
IV.	Stereoisomerism	5
V.	Carbohydrates	8
VI.	Macromolecules	6
VII.	Chemistry of Heterocyclic Compounds	6

I. Carbonic Acid and Its Derivatives

1. Carbonyl chloride
2. Urea
3. Ureids
4. Isocyanates

II. Substituted Acids

1. Halogenated acids
2. Phenolic acids
3. Geometric isomerism
4. Claissen condensation
5. Amino acids

III. Color and Chemical Constitution

1. Chromophore groups
2. Auxochrome groups
3. Relation between color and molecular structure
4. Indicators, dyes, stains

IV. Stereoisomerism

1. Asymmetric crystals
2. Asymmetry in molecules
3. Resolution of mixtures
4. Meso forms

V. Carbohydrates

1. Monosaccharides
2. Disaccharides
3. Trisaccharides
4. Polysaccharides
5. Reactions and tests for the saccharides
6. Reactions of cellulose

VI. Macromolecules

1. Cellulose
2. Proteins
3. Plastics
4. Elastomers

VII. Chemistry of Heterocyclic Compounds

1. Nomenclature
2. Preparation
3. Properties
4. Occurrence

Laboratory

Continuation of Organic Chemistry I.

Unit Operations I

Hours Required

Class, 3; Laboratory, 4

Description

Designed to present the fundamental theories of chemical engineering and to acquaint the student with chemical process equipment, its use, and its applications. It focuses study on the principles, materials, systems of equipment, and some of the problems involved in chemical manufacturing and processing. Chemical plant operations are large-scale reproductions of the processes performed in miniature in laboratory experiments. The scaling-up of laboratory experimental procedures and development of the operation to an efficient production plant involves numerous problems and principles of applied physical science. Chemical technicians need some understanding of these matters, as preparation for either research laboratory or production plant work because chemical commercial processing or production problems ultimately influence the work of both.

Major Divisions

		Class hours
I.	Basic Mathematical Operations...	4
II.	Dimensional Analysis	3
III.	Basic Physical Principles	5
IV.	Fluid Flow	9
V.	Flow Measurement	4
VI.	Fluid Transportation — Pipe Fittings	4
VII.	Fluid Transportation — Pumps ..	3
VIII.	Flow of Heat	14
IX.	Alignment Charts	2

I. Basic Mathematical Operations

1. Log-log graphs
2. Equation of a line
3. Plotting equations
4. Graphical solutions of problems

II. Dimensional Analysis

1. Application of units
2. Calculation of conversion factors
3. Conversion of metric and English units

III. Basic Physical Principles

1. Flow equation and applications
2. Work and energy
3. Gas laws
4. Derivation of formulas from basic principles

IV. Fluid Flow

1. Fluid behavior (gases and liquids)
2. Friction losses
3. Bernoulli equation
4. Fluid statics
5. Viscosity and units of viscosity
6. Mechanism of fluid flow
7. Reynolds number

V. Flow Measurement

1. Theory
2. Instruments
3. Methods

VI. Fluid Transportation — Pipe Fittings

1. Pipe and tubing
2. Fittings
3. Joints
4. Valves

VII. Fluid Transportation — Pumps

1. Theory
2. Applications
3. Calculations

VIII. Flow of Heat

1. Theory
2. Methods
3. Calculations
4. Conductivities
5. Film coefficients
6. Overall coefficients
7. Empirical equations
8. Radiation
9. Parallel and counter current flow

IX. Alignment Charts

1. Theory
2. Construction
3. Use

Laboratory — 64 hours

During the early part of the course in unit operations, the laboratory periods may be used advantageously as work periods in which the student has an opportunity to become familiar with the preparation and use of alignment charts and graphs, and to practice on the graphical solution of problems. It is suggested that practice be given in the use of calculating machines in some of the mathematical problem-solving in this course.

1. Preparation of simple alignment charts
2. Use of graphs
3. Graphical solution of simple problems
4. Rate of response of thermometers
5. Use of manometers
6. Calibration of thermocouples
7. Reynolds number experiment
8. Preparation and calibration of an orifice
9. Determination of efficiency of pumps
10. Determination of friction in pipes
11. Performance and efficiency of a fan using pitot tube
12. Heat transfer experiment — radiation
13. Heat transfer experiment—conduction
14. Heat exchange experiment — fluid to fluid

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

BADGER *and* BANCHERS. *Introduction to Chemical Engineering*

CORCORAN *and* LACEY. *Introduction to Chemical Engineering Problems*

FOUST. *Principles of Unit Operations*

HENLEY *and* STUFFIN. *Stagewise Process Design*

HIMMELBLAU. *Basic Principles and Calculations in Chemical Engineering*

JOHNSTONE *and* THRING. *Pilot Plants, Models, and Scale-up Methods in Chemical Engineering*

LITTLEJOHN *and* MEENAGHAN. *Introduction to Chemical Engineering*

PERRY. *Chemical Engineers' Handbook*

MCCABE *and* Smith. *Unit Operations of Chemical Engineering*

PETERS. *Elementary Chemical Engineering*

SHREVE. *The Chemical Process Industries*

Visual Aids

AMERICAN CHEMICAL SOCIETY:
Introduction to Reaction Kinetics (Prof. Henry Eyring — Collaborator), 16 mm., 13 min., color

Unit Operations II

Hours Required

Class, 3; Laboratory, 4

Description

Designed to present the fundamental theories of chemical engineering and to acquaint the student with chemical process equipment, its use, and its applications. A continuation of Unit Operations I.

Major Divisions

		Class hours
I.	Evaporation	4
II.	Distillation	15
III.	Solvent Extraction	3
IV.	Filtration	8
V.	Centrifuges	1
VI.	Size Separation	3
VII.	Classification	4
VIII.	Sedimentation	1
IX.	Crushing and Grinding	3
X.	Conveying	3
XI.	Materials of Construction	3

I. Evaporation

1. Basic calculations
2. Survey of equipment
3. Theory

II. Distillation

3. Materials and energy balance
1. Raoult's Law
2. Boiling-point diagrams
4. Equilibrium diagrams
5. Continuous distillation
6. Column calculations
7. McCabe Thiele diagrams
8. Column capacity
9. Column construction
10. Packed columns

III. Solvent Extraction

1. Theory
2. Application
3. Survey of equipment

IV. Filtration

1. Theory
2. Derivation of mathematical treatment
3. Classification of equipment
4. Types of equipment and application
5. Effect of variables

V. Centrifuges

1. Theory
2. Application
3. Survey of equipment

VI. Size Separation

1. Mechanical
2. Hydraulic
3. Theory
4. Survey of equipment

VII. Classification

1. Mechanical
2. Hydraulic
3. Magnetic
4. Electrostatic and other methods
5. Theory
6. Application

VIII. Sedimentation

1. Theory
2. Application

IX. Crushing and Grinding

1. Theory
2. Application
3. Survey of equipment

X. Conveying

1. Survey of equipment
2. Use of alignment charts in calculations

XI. Materials of Construction

1. Survey of chemically resistant materials and their application

Laboratory — 64 hours

1. Distillation experiment — continuous
2. Distillation experiment — batch
3. Extraction: solid liquid
4. Filtration and washing — filter press
5. Screen analysis and sampling procedures
6. Size-reduction studies:
   (a) Crushing
   (b) Impact
   (c) Shears
7. Laboratory-library project involving the use of *Thomas Register* and similar references

Texts and References

Same as for Unit Operations I.

Mathematics and Other Science Courses

Mathematics I

Hours Required

Class, 5; Laboratory, 0

Description

The choice of topics and the order in which they are presented integrate mathematics with the technical courses in the curriculums to their mutual benefit. Thus, the basic slide-rule operations are introduced early in the course so that the student can use this tool to advantage in other courses. As the various topics are introduced, the meaning and underlying principles of each and the role each plays in chemical technology should be considered before the subject proper is explored. Practical problems following the exposition of each major topic will help to motivate the student and will strengthen his understanding of the principles involved.

Prerequisites: 1 year each of high school algebra and geometry, or equivalent.

Major Divisions

		Class hours
I.	Arithmetic Review	3
II.	Basic Slide Rule	3
III.	Fundamental Algebraic Operations	7
IV.	Equations and Formulas	12
V.	Applied Problems in Plane and Solid Mensuration	6
VI.	Introduction to Analytic Geometry and Graphing	8
VII.	Simultaneous Equations	8
VIII.	Exponents, Radicals, and Complex Numbers	8
IX.	Quadratic Equations in One Unknown	7
X.	Ratio, Proportion, Variation	3
XI.	Logarithms	10
XII.	Introduction to Trigonometry	5

I. Arithmetic Review

1. Number systems
   (a) Decimal
   (b) Binary
2. Fundamental operations
   (a) Integers
   (b) Fractions
   (c) Decimals
   (d) Changing fractions to decimals
3. Percentage
4. Dimensional analysis

II. Basic Slide Rule

1. Types of slide rules and calculators
2. Multiplication and division
3. Powers of ten
4. Combined multiplication and division
5. Squaring and square root

III. Fundamental Algebraic Operations

1. Positive and negative numbers
2. Review of addition, subtraction, multiplication, and division
3. Review of factoring
4. Review of fractions

IV. Equations and Formulas

1. Meaning and underlying principles of equations
2. Solving first-degree equations in one unknown
3. Formula rearrangement and evaluation
4. Significant figures and approximate computation

V. Applied Problems in Plane and Solid Mensuration

1. Area and volume of common figures and solids
2. Relations in triangle, quadrilateral, and circle
3. Applied problems in geometry

VI. Introduction to Analytic Geometry and Graphing

1. Rectangular coordinate system
2. Meaning of function in mathematics
3. Graphing a function
4. Graphing technical data
5. Equation of the straight line
6. Concept of slope

VII. Simultaneous Equations

1. Linear systems in two unknowns
2. Linear systems in three unknowns
3. Solution by determinants
4. Illustrative practice technical problems

VIII. Exponents, Radicals, and Complex Numbers

1. Review of laws of exponents
2. Relationship between fractional exponents and radicals
3. Meaning of the complex number
4. Basic operations with complex numbers

IX. Quadratic Equations in One Unknown

1. Standard form $ax^2 + bx + c = 0$
2. Formula solution — completing the square
3. Solution by factoring
4. Graphical solution
5. Applied problems

X. Ratio, Proportion, Variation

1. Meaning of ratio and proportion
2. Slide-rule solution of proportion problems
3. Meaning of direct, inverse, and inverse square variations
4. Technical use of these concepts

XI. Logarithms

1. Logarithmic meaning and notation
2. Relation between logarithmic and exponential form
3. Laws of logarithms
4. Tables of logarithms
5. Computation; products, quotients, powers, roots
6. Solution and rearranging of exponential and logarithmic equations
7. Natural logarithms
8. Logarithmic scale: slide-rule graphing

XII. Introduction to Trigonometry

1. Purpose of trigonometry
2. Definitions of six functions of an acute angle
3. Trigonometric tables
4. Solution of right triangles
5. Applied problems in right triangles

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference:

ALLENDOERFER *and* OAKLEY. *Fundamentals of Freshman Math*

ANDRES *and others. Basic Mathematics for Science and Engineering*

CHEMICAL RUBBER PUBLISHING COMPANY. *C.R.C. Handbook of Mathematics Tables*

FISHER *and* ZIEBUR. *Integrated Algebra and Trigonometry*

HEMMERLING. *Mathematical Analysis*

JUSZLI *and* RODGERS. *Elementary Technical Math*

KRUGLAK *and others. Basic Math for the Physical Sciences*

REES *and* SPARKS. *Algebra and Trigonometry*

RICE *and* KNIGHT. *Instructor's Guide*

——— *Technical Mathematics*

SPITZBART *and* BARDELL. *College Algebra and Plane Trigonometry*

Visual Aids

KNOWLEDGE BUILDERS, Visual Education Center Bldg., Floral Park, N. Y.:

Areas. 16 mm, sound, 12 min.

Circle. 16 mm, sound, 10 min.

Ratio and Proportion. 16 mm, sound, 11 min.

NORWOOD FILMS, 926 New Jersey Ave., NW., Washington 1, D. C.:

The Slide Rule: The "C" and "D" Scales. 16 mm., black and white, sound, 21 min.

The Slide Rule: Proportion, Percentage, Squares, and Square Roots. 16 mm., black and white, sound, 24 min.

Demonstration slide rule.

Models and mock-ups illustrating some practical uses of mathematics in the solution of problems in Chemical Technology.

Mathematics II

Hours Required

Class, 4; Laboratory, 0

Description

Trigonometry, analytic geometry, and algebra are continued and expanded to more advanced phases as required in the technology. Graphical analysis is used wherever possible. Practical problems in all major topics illustrate the principles involved and the utility of mathematics in technical study. Calculus is incorporated in a manner emphasizing concept and principle rather than facility in manipulation.
Prerequisite: Mathematics I.

Major Divisions

		Class hours
I.	Solution of Right Triangles	9
II.	Trigonometric Functions for any Angle	6
III.	Solution of Oblique Triangles	8
IV.	Solution of Triangles: Applied Problems	4
V.	Trigonometric Identities and Equations	4
VI.	Trigonometric Graphing	7
VII.	Complex Numbers and Vectors	7
VIII.	Analytic Geometry	7
IX.	Introduction to Calculus	7
X.	Graphic Calculus	5

I. Solution of Right Triangles

1. Definitions of trigonometric functions
2. Trigonometric ratios in triangle solution
3. Slide rule in computation
4. Logarithms in computation

II. Trigonometric Functions for Any Angle

1. Generalized definition of six functions
2. Graphs of functions: sine, cosine, tangent
3. Numerical values of functions
4. Radian system of measurement

III. Solution of Oblique Triangles

1. Right triangle method and scaling
2. Sine law method
3. Cosine law method
4. Further methods: tangent and half-angle laws

IV. Solution of Triangles: Applied Problems

1. Review solution of triangles: right and oblique
2. Simple vector problems
3. Problems from technology

V. Trigonometric Identities and Equations

1. Identities vs. conditional equations
2. Reciprocal, ratio, and Pythagorean identities
3. Two-angle, half-angle, and double-angle identities
4. Proofs of identities
5. Solving conditional trigonometric equations

VI. Trigonometric Graphing

1. Review of sine, cosine, and tangent graphs
2. General sine equation: $Y = K \sin(x + \ominus)$
3. Sine wave generation by rotation
4. Sine wave harmonics and harmonic addition
5. Lissajous figures

VII. Complex Numbers and Vectors

1. Meaning and basic operations of complex numbers
2. Graphical representation of complex numbers
3. Vector addition and multiplication
4. Vector subtraction and division

VIII. Analytic Geometry

1. Simple graphs and properties: circle, ellipse, parabola, and hyperbola
2. Graphical solution of simultaneous quadratic equations
3. Polar coordinate loci
4. Exponential functions

IX. Introduction to Calculus

1. Calculus and technical work
2. Rate of change
3. Graphical determination of rate of change
4. Review of function concept

X. Graphic Calculus

1. Graphic integration
   - (a) Increments by blocks
   - (b) Ray method of integration
   - (c) Plotting the integral
2. Graphic differentiation
   - (a) Graphic methods
   - (b) Applied problems

Texts and References

Same as for Mathematics I.

Visual Aids

JOHNSON HUNT PRODUCTIONS, 1104 Fair Oaks Ave., South Pasadena, Calif.:
Parallel Lines. 16 mm., 10 min., sound

KNOWLEDGE BUILDERS, Visual Education Center Bldg., Floral Park, N. Y.:
Congruent Figures. 16 mm., 12 min., sound
Pythagorean Theorem. 16 mm., 12 min., sound

NORWOOD FILMS, 926 New Jersey Ave., NW., Washington 1, D.C.:
Introduction to Vectors: Co-Planar, Concurrent Forces. 16 mm., 10 min., sound
Periodic Functions. 16 mm., 17 min., sound

Demonstration slide rule.

Models and mockups illustrating practical uses of mathematics in the solution of problems in chemical technology.

Physics I (Mechanics and Heat)

Hours Required

Class, 4; Laboratory, 2

Description

The objectives of this course extend beyond its immediate purpose of developing an understanding of the basic principles of mechanics and heat. Not apparent in the outline but of crucial importance is the emphasis in both laboratory and lecture upon the scientific method.

Physics and chemistry are closely interrelated. The content of this course and that of General Chemistry I will complement each other as the student studies them concurrently. Coordination of the subject matter taught by the respective chemistry, physics, and mathematics instructors will produce an optimum opportunity for student mastery of all three subjects. Emphasis should be placed upon material from the mathematics course and the use of the slide rule in computation of data in the laboratory.

Prerequisite: Concurrent registration in Mathematics I.

Major Divisions

		Class hours
I.	Basic Measurement	6
II.	Properties of Solids, Liquids, and Gases	9
III.	Statics	9
IV.	Rectilinear Motion and Momentum	4
V.	Angular and Simple Harmonic Motions	3
VI.	Work, Energy, and Power	5
VII.	Heat, Temperature, and Calorimetry	9
VIII.	Fusion, Vaporization, Critical Temperature, and Pressure	3
IX.	Heat, Work, and Heats of Formation and Combustion	5
X.	Gas Laws	3
XI.	Heat Transfer	3
XII.	Thermodynamics	5

I. Basic Measurement

1. Science and measurement: units of measurement
   - (a) The scientific method and measurement
   - (b) Dimensional analysis
   - (c) Systems of measurement
     - (1) Traditional: metric and English
     - (2) Modern: cosmic, atomic, industrial
2. Methods of measurement
   - (a) United States standards
   - (b) Aids to measurement — vernier, micrometer, planimeter, optical flats, comparators, diffraction grating

II. Properties of Solids, Liquids, and Gases

1. Structure of matter
   - (a) Atoms — the periodic table
   - (b) Elements, compounds, crystals

2. Elasticity and rigidity
   (a) Units of measure: Young's modulus, torsion
   (b) Deformation — stress, strain, fatigue
   (c) Hooke's Law
3. Hydrostatics — properties of fluids
   (a) Density, specific gravity, buoyancy
   (b) Statement and application of Pascal's and Archimedes' Law
   (c) Bernoulli's theorem and applications
   (d) Phenomena of viscosity, capillarity, surface tension
   (e) Orifice: pressure, flow, loss of head
4. Properties of gases
   (a) Bernoulli's theorem
   (b) Measurement of pressure

III. Statics

1. Composition of resolution of vectors
   (a) Definition of vector — examples
   (b) Components and composition
   (c) Resolution of vectors
   (d) Methods of handling
      (1) Graphical
      (2) Analytical: summation, trigonometry
2. Conditions of equilibrium
   (a) Forces and vector diagrams
   (b) Principle of transmissibility
3. Statics of structures, cranes, trusses
4. Friction — coefficient of friction
5. Principle of moments
6. Application of moments to members of structures

IV. Rectilinear Motion and Momentum

1. Rectilinear motion — displacement and rates of change
2. Systems of units — C.G.S., English, M.K.S.
3. Newton's second law
4. Law of universal gravitation — free-fall, spatial problems
5. Inertia of a body
6. Physical aspects of momentum
   (a) Transmission; impulse, impact, collision
   (b) Units and denominations
   (c) Jet propulsion principles
7. Motion of a projectile

V. Angular and Simple Harmonic Motions

1. Forces on bodies in motion
2. Circular motion: formulas and denominations
3. Centrifugal action
   (a) Vectors and components
   (b) Applications in centrifuge, satellites, highways, castings
4. Harmonic motion
   (a) Characteristics; amplitude, displacement, frequency, period
   (b) Equations and graphs
   (c) Types: simple and compound pendulums, spring, electronic
   (d) Vibration in structures
5. Gyroscopic action

VI. Work, Energy, and Power

1. Physical concept of work
   (a) Forces, directions, distances, and units
   (b) Positive and negative character of work and energy
2. Energy and its manifestations
3. Conservation of energy
4. Power as compared to work and energy
5. Simple machines: inclined plane, pulleys, belts, and gears
   (a) Aspects of work, energy, power, and efficiency
   (b) Mechanical advantage
   (c) Friction in machines
   (d) Power transmission

VII. Heat, Temperature, and Calorimetry

1. Definition of Heat
   (a) Energy from the sun is radiant energy (Electromagnetic)
   (b) Changes in metals in heat treating

2. Definition of Temperature
   (a) Temperature scales
   (b) Fixed points — boiling and freezing
   (c) Temperature-indicating devices
3. Expansion of solids, liquids, and gases
4. Calorimetry and Heat Units
   (a) Thermal capacity defined
   (b) Mass
   (c) Quantity of heat involved in temperature changes

VIII. Fusion, Vaporization, Critical Temperature, and Pressure

1. Fusion and the Heat Quantities Involved
   (a) Relative values of heats and fusion
   (b) Change in volume
      (1) Importance in container design
         (a) Water containers
   (c) Melting points
   (d) Cooling curves
   (e) Supercooling
2. Vaporization defined
   (a) Evaporation, effects of temperature, pressure, and area
   (b) Boiling — definition
   (c) Humidity — relative and absolute
3. Critical Points Defined
   (a) Values for different gases
   (b) Behavior of real gases
   (c) Liquefaction of gases
   (d) Fractional distillation

IX. Heat, Work, and Heats of Formation and Combustion

1. The relationship between heat and work
   (a) Numerical relationship as discovered by Joule
   (b) Applications
   (c) Conditions affecting friction
2. Heats of combustion
   (a) Solid fuels — coal
   (b) Liquid — oil and alcohol
   (c) Gaseous
   (d) Electrical
3. Heats of Formation
   (a) Relationship between heat of formation and heat of combustion
4. Nuclear Energy
   (a) Fusion
   (b) Fission

X. Gas Laws

1. Ideal Gases
2. Real Gases

XI. Heat Transfer

1. Conduction
2. Convection
3. Radiation

XII. Thermodynamics

1. Gas laws
   (a) Boyle's and Gay-Lussac's Laws
   (b) Ideal gas equation
   (c) Adiabatic expansion and compression
2. First law of thermodynamics
   (a) Relationship between heat and work
   (b) Industrial applications
3. Second law of thermodynamics
   (a) Efficiency in heat conversion to work
   (b) Heat, engine cycles: Carnot, Rankine, Diesel, Otto
   (c) The reversed cycle
   (d) Heat applied to chemical reactions

Laboratory — 32 Hours

Laboratory experiments should follow or be done concurrently with classroom study of the major divisions of the course, and should include as much of the following work as time and individual course emphasis allows:

1. Use vernier and micrometer calipers, planimeter, spherometer in measurement
2. Calculate the densities of solids and liquids
3. Determine the elastic properties of materials and become familiar with their specifications and limitations

4. Compute the modulus of rigidity of a rod
5. Measure buoyancy of liquids
6. Convert a system of concurrent forces into a vector diagram
7. Analyze a system of forces
8. Determine the coefficient of friction between simple objects
9. Determine the center of gravity of a series of forces and the reaction at supports of parallel forces.
10. Calculate internal and external moments in members of a structure.
11. Apply Newton's second law to forces in cables and hoists.
12. Specify and measure the characteristics of the motion of a projectile and free-fall object.
13. Measure one momentum of a body: ballistic pendulum.
14. Confirm the laws of centripetal force; centrifuge.
15. Confirm conservation of energy in simple machines.
16. Confirm Charles' Law using the constant volume air thermometer.
17. Calculate the coefficient of linear expansion of various materials.
18. Determine the specific heat of various solids.
19. Determine the specific heat of various liquids.
20. Determine vapor pressure of a liquid at various temperatures.
21. Measure the heats of fusion and vaporization of a substance.
22. Confirm Newton's Law of cooling.
23. Determine the mechanical equivalent of heat.
24. Measure absolute and relative humidity and relate these to industrial problems.
25. Confirm Boyle's Law.

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

BLACK *and* LITTLE. *An Introductory Course in College Physics*

CONDON. *Handbook of Physics*

DEFRANCE. *General Electronics Circuits*

HARRIS. *Experiments in Applied Physics*

——— *and* HEMMERLING. *Introductory Applied Physics*

MILLER. *College Physics*

OREAR. *Fundamental Physics*

SEARS *and* ZEMANSKY. *College Physics, Part II*

SMITH *and* COOPER. *Elements of Physics*

WEBER *and others*. *College Physics*

——— *Physics for Science and Engineering*

WHITE. *Modern College Physics*

Visual Aids

AMERICAN CHEMICAL SOCIETY, 1155 — 16th St., NW., Washington, D.C.:

Vibrations of Molecules (Prof. Linus Pauling and Prof. Richard M. Badger — Collaborators), 16 mm., 12 min., color

ENCYCLOPEDIA BRITANNICA FILMS, INC., 1150 Wilmette Ave., Wilmette, Ill.:

Galileo's Laws of Falling Bodies. 16 mm., 6 min., sound
Gas Laws and Their Application. 16 mm., 13 min., sound
Heat — Its Nature and Transfer. 16 mm., 11 min., sound
Laws of Motion. 16 mm., 13 min., sound
Simple Machines. 16 mm., 11 min., sound
Thermo-dynamics. 16 mm., 11 min., sound

MCGRAW-HILL BOOK CO., INC., 330 West 42nd St., New York 36, N.Y.:

Carnot Cycle (Kelvin Temperature Scale). 16 mm., 8 min., sound
Diesel Engine. 16 mm., 8 min., sound
Gasoline Engine. 16 mm., 8 min., sound
Uniform Circular Motion. 16 mm., 8 min., sound

MODERN LEARNING AIDS, New York:

Gas Pressure and Mollecular Collisions (Prof. J. Arthur Campbell — Collaborator), 16 mm., 21 min., black and white
Ionization Energy (Prof. Bruce H. Mahan — Collaborator), 16 mm., 22 min., color

NORWOOD FILMS, 926 New Jersey Ave., NW., Washington 1, D.C.:

Basic Hydraulics. 16 mm., 9 min., sound
Electron — An Introduction. 16 mm., 16 min., sound
Principles of Dry Friction. 16 mm., 17 min., sound
Principles of Moments. 16 mm., 23 min., sound
Principles of Refrigeration. 16 mm., 20 min., sound
Verniers. 16 mm., 19 min., sound

Physics II (Electricity and Light)

Hours Required

Class, 4; Laboratory, 4

Description

This is an introduction to electrical circuitry and equipment, and a study of light, with emphasis on the concepts of physics, oriented toward their pertinence and relationships to applied chemical science. Emphasis is placed upon electronics because it involves applied solid-state physics with significant chemical implications, and because of the increasing importance of electrical and electronic applications and controls in chemical research and processing. The increasing use of instrumental analyses using spectroscopic and photoelectric methods makes the understanding of light a necessary part of the education of chemical technologists. The section on nuclear physics is included to provide the students with an understanding of the physical science underlying the emerging use of radiographic techniques in chemical analysis and process control.

Major Divisions

		Class hours
I.	Electricity and Magnetism	3
II.	Basic Electric Circuits and Components	12
III.	Alternating Current	7
IV.	Electrical Instruments	6
V.	Basic Electronics	11
VI.	Electric Power	4
VII.	Motors and Controls	4
VIII.	Light	8
IX.	Photo Chemical Applications	3
X.	Nuclear Physics	4
XI.	Use of Radioactive Materials	2

I. Electricity and Magnetism

1. Nature of electricity — the electron theory
   - (a) Atomic structure — historical development
   - (b) Conductors — specific resistance
   - (c) Insulators — dielectric strength
2. Electrical units
   - (a) Coulomb — flowing electricity
   - (b) Ampere — current electricity
   - (c) Volts, ohms, watts
3. Nature of magnetism
   - (a) Atomic theory of magnetism
   - (b) Permanent and electromagnets
   - (c) Law of magnets and magnetic field strengths
   - (d) Hysteresis curve: permeability, retentivity, saturation
   - (e) Applications of magnets

II. Basic Electric Circuits and Components

1. Ohm's Law in DC series resistance circuits
2. Ohm's Law in DC parallel resistance circuits
3. Measurement of resistance: voltammeter, Wheatstone bridge, Ohmmeter
4. Inductance in dc circuits
   - (a) Electromagnetic induction — Lenz's Law
   - (b) Concept and units of self-inductance

(c) Rise and decay of current in an inductance
(d) Energy in inductive circuits
(e) Mutual induction — coefficient of coupling
(f) Series and parallel inductance

5. Capacitance in dc circuits
   (a) Definition and units of capacitance
   (b) Rise and decay of voltage in a capacitor
   (c) Energy in capacitive circuits
   (d) Series and parallel capacitors

III. Alternating Currents

1. Electromagnetic generation of a sine wave
2. Sine wave terminology and vector representation
3. Inductive and capacitive reactance
   (a) Definition and units of measure
   (b) Vector representation — phase angle
   (c) Impedance — vector diagrams
   (d) Resonance — vector diagrams
4. AC circuits in resistance, capacitance, and inductance
5. Measurement of alternating current
6. The electromagnetic spectrum — high frequencies
7. Electromechanical analogies
   (a) Resistance — friction; power consumption
   (b) Inductance — inertia; kinetic energy
   (c) Capacitance — potential energy
8. ac alternators and transformers

IV. Electrical Instruments

1. Ammeters — types and uses
   (a) Moving coil, permanent magnet
   (b) Solenoid
   (c) Movable iron
   (d) Electrodynamometer
   (e) Shunts and range-extension devices, use and calculation of capacity
2. Voltmeters — types and uses
   (a) Voltmeters — single range, multirange switch types
   (b) Vacuum tube voltmeter
   (c) Potentiometer
   (d) Shunts and range-extension devices, use and calculation of capacity
3. Wheatstone Bridge
   (a) Principles and function
   (b) Modifications for various applications
      (1) Capacitance
      (2) Inductance
4. Oscilloscopes — types and uses
   (a) Principles and function
   (b) Frequency spectrum and high frequency phenomena
   (c) Oscilloscopic measurement applications
5. Application of instruments to industrial processes
   (a) Temperature
   (b) Acidity-alkalinity (pH)
   (c) Speed
   (d) Strain
   (e) Pressure
   (f) Thickness
   (g) Vibration

V. Basic Electronics

1. Controlling electric current: historical development; rheostat, vacuum tube, transistor
2. The diode tube
   (a) Thermionic emission
   (b) Characteristic curves
   (c) Rectification — principles and use
3. The Triode tube
   (a) Grid control — electrostatic fields
   (b) Characteristic curves
   (c) Concept of amplification
   (d) Applications
4. Solid state devices
   (a) Sophistication of solid-state conduction
   (b) Mechanism of conduction in semiconductors

5. Chemistry of solid-state devices
   (a) Nature of materials
   (b) Effect of impurities
   (c) Effect of physical flaws
   (d) Resistance to heat, shock, chemical action
6. Electronic measuring instruments
   (a) Measuring devices
   (b) Applications
7. Applications of electronics
   (a) Communications
   (b) Industrial processing and control
   (c) Applications in chemical research
   (d) Applications in chemical production systems

VI. Electric Power

1. Sources of electric power
   (a) Electrical generators and alternators
      (1) The electromotive series
      (2) Thermocouple — application and uses
      (3) Chemical heat cells
   (b) Photoelectricity
      (1) Kinds of photoelectric cells
      (2) Emerging use of solar cells
   (c) Chemical action
      (1) Primary cells
      (2) Secondary cells
      (3) Edison, cadmium, lead, and other batteries
2. Power in DC and AC circuits
3. Physical uses of electric power
   (a) Heat and light — principles of common devices
   (b) Electric (resistance) furnace; chemical industry uses
   (c) Electric arc — uses in furnacing, refining, welding of metals
   (d) Electron beam — use in melting and welding metals
4. Chemical uses of electricity
   (a) Electrolysis — principles and applications
      (1) Chlorine — caustic soda production
   (b) Electrodeposition and electrorefining of metals
      (1) Refinement of copper, lead, zinc
      (2) Electroplating
   (c) Electric conversion
      (1) Manufacture of silicon carbide

VII. Motors and Controls

1. Operating characteristics of direct current motors
   (a) Shunt
   (b) Series
   (c) Compound
2. Direct-current motor controllers
3. AC motor types and characteristics
4. Control and protection of ac equipment

VIII. Light

1. The electromagnetic spectrum
   (a) Measurement units of wave length
   (b) Light spectrum from ultraviolet to infrared
2. The nature of light
   (a) Speed
   (b) Energy
   (c) Doppler effect
   (d) Emission, interference, and absorption of light
3. Reflection and refraction of light
   (a) Lenses
   (b) Systems of lenses in scientific equipment
   (c) Reflection
   (d) Refraction — prismic refractions and refractive index
   (e) Spherical and chromatic aberration
4. Diffraction of light
   (a) Diffraction of gratings
   (b) Power of resolution
   (c) X-ray diffraction
   (d) Electron microscope
   (e) White- and dark-line spectra
5. Polarization of light
6. Lasers — description and use

7. Sources of light
   (a) Quanta
   (b) Cavity radiators
   (c) Planck's radiation formula
   (d) Photoelectric effect
   (e) Photon theory
   (f) Relationship of matter, energy, and light

IX. Photochemical Applications

1. Photography
2. Spectroscopic analyses
3. Spectrophotometry
4. Refractometry
5. Polarimetry
6. X-ray diffraction applications

X. Nuclear Physics

1. Atomic structure
   (a) Early interpretation
      (1) Nucleus and electron
      (2) Periodic arrangement of the elements
      (3) Chemical implications of outer shell of atom
   (b) Present interpretation
      (1) Protons, neutrons
      (2) Isotopes
   (c) Other nuclear particles — neutrons, beta particles, positrons (positive electrons), alpha particles, deuteron, triton, gamma-ray.
   (d) Nuclear physicist's table of the elements
      (1) Nuclides
      (2) Chemical compared to nuclear reactions
2. Radioactivity
   (a) Natural radioactivity — decay of complete nuclei of heavy elements
   (b) Induced radioactivity by nuclear reactions — alpha, beta, gamma radiation
   (c) Radiation shielding
      (1) Radiation units
      (2) Half-life of isotopes
      (3) Half-thickness of shielding
      (4) Radiation-detection devices
   (d) Nuclear reactions
      (1) Fission
      (2) Fusion
      (3) Elements of an atomic energy powerplant

XI. Use of Radioactive Materials

1. Areas of use
   (a) Medical — diagnostic and therapeutic
   (b) Industrial — radioactive isotope-tracer analyses, gamma-ray applications
2. Radiographic tracer techniques
   (a) Materials used
   (b) Equipment and apparatus used
   (c) Laboratory procedures peculiar to radiography

Laboratory — 64 hours

Laboratory experiments should follow or be done concurrently with classroom study of the major divisions of the course, and should include as much of the following work as time and individual course emphasis allows:

1. Verify the laws of electrostatics and electrostatic induction; sketch of electrostatic fields.
2. Confirm the law of magnets and sketch magnetic fields using permanent and electromagnets.
3. Problems in series and parallel resistive dc circuits.
4. Measure direct current in series, parallel, and combination circuits.
5. Plot the rise and decay of voltage across a capacitor in a dc circuit. Calculate time constant.
6. Electromagnetic generation and transmission equipment.
7. Demonstrate and calculate ac circuit constants using vector analysis.
8. Demonstrate use of various types of ammeters.

9. Extend the range of an ammeter of calculated amount.
10. Demonstrate use of various types of voltmeters.
11. Use of Wheatstone bridge to measure resistance.
12. Determine the high-frequency wave length using an oscilloscope.
13. Determine the amount of electric current from a thermocouple in an oxidizing flame and in a reducing flame.
14. Determine the pH of a 1/10 normal solution of magnesium chloride using a pH meter.
15. Measure relative humidity and calculate the amount of water in the system.
16. Demonstrate the use of strain gauge, and calculate magnitude of strain.
17. Measure the thickness of various pieces of carbon steel strips by means of magnetic flux.
18. Measure the characteristics of a diode and observe its action as a rectifier on an oscilloscope.
19. Measure and calculate the amplification factor of a triode tube.
20. Demonstrate electronic control equipment.
21. Measure speed-load and torque characteristics of dc and ac motors.
22. Make field trips to industrial installations.
23. Demonstrate industrial control equipment.
    (a) Spot welders
    (b) Induction heating units
    (c) Instrumentation
24. Demonstrate the spectrum from sunlight.
25. Demonstrate polarization of light.
26. Demonstrate strain concentrations in transparent plastic material using polarized light.
27. Demonstrate several lenses and confirm the mathematical description of their characteristics.
28. Determine the index of refraction of a substance.
29. Demonstrate diffraction gratings.
30. Demonstrate white- and dark-line spectra.
31. Demonstrate the Fraunhofer lines in a sodium flame.
32. Demonstrate a laser lightbeam.
33. Demonstrate an X-ray defraction.
34. Use a Geiger counter and calculate radiation per unit mass of a substance.
35. Demonstrate shielding and calculate thickness of shield for a given radiation.
36. Demonstrate use of a tracer isotope in a fluid flow system to check rate of flow through the system.

Visual Aids

ENCYCLOPEDIA BRITANNICA FILMS, INC., 1150 Wilmette Ave., Wilmette, Ill.:
- *Series and Parallel Circuits.* 16 mm., 11 min., sound
- *What Is Electricity.* 16 mm., 13 min., sound
- *Electro-Dynamics.* 16 mm., 11 min., sound
- *Magnetism.* 16 mm., 16 min., sound

NORWOOD FILMS, 926 New Jersey Ave., NW., Washington 1, D.C.:
- *Capacitance.* 16 mm., 31 min., sound
- *Diodes: Principles and Applications.* 16 mm., 17 min., sound
- *Ohm's Law.* 16 mm., 19 min., sound
- *RCL — Resistance Capacitance.* 16 mm., 34 min., sound
- *Voltaic Cell, Dry Cell, and Storage Battery.* 16 mm., 18 min., sound

U.S. ATOMIC ENERGY COMMISSION (Obtainable from any regional office):
- *The International Atom.* 16 mm., 27 min., sound

Auxiliary or Supporting Technical Courses

Chemical Technology Seminar

Hours Required

Class, 1; Laboratory, 0

Description

This course is designed first to orient the beginning student in a post high school educational program at the beginning of the course. A brief introduction to the new type of learning situation is followed by an explanation of the objectives of the course and how they will be accomplished in the seminar. The remainder of the course is devoted to giving the student occupational and professional orientation by means of student panel reports and class discussion on pertinent topics. These topics should be assigned to panel groups at the first or second meeting of the class, with emphasis on the principle that the student groups are responsible for preparing a report and leading class discussion on the topics assigned. Students should be given topics of their choice within the scope of the course, as far as possible.

By preparing themselves and leading the class discussion under the instructor's guidance, the students become informed by active involvement in the development of the topics studied. The student panels can be expanded by including guest panelists from industry or the professions. The class should be encouraged to question the panel members and even to take issue if controversial subject matter is under discussion. The discussion of the library scientific method and the practice of safety in chemistry are intended to provide the student with an insight into important attitudes necessary to his success as a chemical technician. The exploration of job opportunities in the chemical field and educational preparation for them stimulates student curiosity and interest.

Panel reports should be written and sources documented prior to oral presentation to the class for discussion. A notebook should be required, made up of the student's part of the panel report for which he is responsible and complete class notes.

Major Divisions

		Class hours
I.	The Student and the School....	1
II.	The Library and Its Use	1
III.	The Scientific Method — Its Effect on Technician's Attitude	1
IV.	The Practice of Safety in Chemistry	2
V.	Types of College Education	1
VI.	Technical Personnel	2
VII.	Opportunities in the Chemical Field	1
VIII.	Types of Jobs in Chemistry ...	2
IX.	Industries Employing Chemists and Technicians	2
X.	Employment Opportunities Other than Industrial	1
XI.	Technical Subjects in Relation to General Education	1
XII.	Summary Discussion of Seminar Topics	1

I. The Student and the School

1. Physical facilities, regulations, academic requirements
2. How to plan use of time
   (a) for study
   (b) for student activities
3. Seminar objectives and plan of operation
4. Notebook — required content
5. Assignment of topics and schedule for panel reports

II. The Library and Its Use

1. Why technicians need a library
2. Library organization and facilities
3. Services of the library staff
4. How to use the library

III. The Scientific Methods — Its Effect on Technician's Attitude

1. Elements of the scientific method
2. Scientific observation and intellectual honesty
3. Chemical laboratory work record books
   (a) Need for accuracy and completeness
   (b) Legal record for process or product patents
4. Need for ethical standards in light of responsibility for confidential and important work

IV. The Practice of Safety in Chemistry

1. Chemical fires and their control — demonstrate types of extinguishers
2. Hazards in chemical reactions and operations — use of showers and eyewash fountains
3. Hazardous chemicals — labeling, storage, handling

V. Types of College Education

1. Comparison of objectives, costs, time, effort, starting salary, promotion opportunities of:
   (a) 2-year preparation for employment
   (b) 2-year transfer program (Liberal Arts)
   (c) Traditional 4-year programs
   (d) Graduate programs

VI. Technical Personnel

1. Occupational levels and qualifications
2. The engineering team — scientists or engineers, technicians, skilled craftsmen
   (a) Relationship of the engineer, scientist, and skilled craftsman to the technician
3. The chemical technician
   (a) Need for constant study to maintain technical "up-to-dateness"
   (b) Technical societies
   (c) Formal supplementary study

VII. Opportunities in the Chemical Field

1. Size and importance of chemical industry
2. Stability and growth of chemical industry
3. Expanding demand for trained chemical personnel
4. Expanding need for qualified chemical technicians (few programs, chemist shortage makes for upgrading, concept of 3 or 4 technicians to each scientist)
5. Trends in technician salaries

VIII. Types of Jobs in Chemistry

1. Production, quality control, analytical
2. Research assistant — experimental chemical preparation, analytical methods
3. Pilot plant, development work—analytical, operator, supervisor
4. Production — operator, supervisor
5. Sales and marketing
6. Sales service, customer troubleshooter

IX. Industries Employing Technicians

1. Chemicals and allied products
2. Petroleum and related products
3. Rubber and plastic products
4. Paper and allied products
5. Food and kindred products
6. Mining and mineral production
7. Primary metal industries
8. Fabricated metal products
9. Stone, clay, and glass manufacturing
10. Electrical equipment manufacturing
11. Machinery manufacturers
12. Pharmaceuticals and drugs
13. Instruments and related products
14. Others

X. Employment Opportunities Other Than Industrial

1. Federal Government, food and drug, military, aerospace development, agricultural research
2. State and local public health, sanitation, water, air pollution, meteorology
3. Teaching — high school, technical institute, vocational-technical school, junior college, university
4. Research foundations

XI. Technical Subjects in Relation to General Education

1. Communications: oral communication and technical reporting
2. Economics
3. Industrial and labor relations
4. Human relations
5. Need for general education knowledge and skills to obtain growth and promotion into supervisory positions

XII. Summary Discussion of Seminar Topics

1. Review of topics
2. Analysis of values

Texts and References

This course is an ideal approach to library assignments which require the students to search for pertinent information on the topics studied. Since this is a working seminar in which most of the classwork will be presentation of organized reports by small panels of students, it is suggested that the instructor, upon assignment of topics, advise the students to seek their own references for a written and documented report which should be a part of their panel's presentation. Therefore, no texts or references are listed here except the following on safety:

AMERICAN CHEMICAL SOCIETY. *Industrial and Engineering Chemistry*

GENERAL SAFETY COMMITTEE, MANUFACTURING CHEMISTS' ASSOCIATION, INC. *Guide for Safety in the Chemical Laboratory*

LEWIS. *Laboratory Planning for Chemistry and Chemical Engineering*

MANUFACTURING CHEMISTS' ASSOCIATION, INC. *Chemical Safety Data Sheets*

——— *Guide to Precautionary Labeling of Hazardous Chemicals*

NATIONAL SAFETY COUNCIL. *Chemical Laboratories; Safety Practice Pamphlet No. 60*

PIETERS *and* CREYGHTON. *Safety in the Chemical Laboratory*

Audiovisual Aids

ALPHA ALPHA CHAPTER OF ALPHA CHI SIGMA, Chemistry Department, Standard University, Palo Alto, Calif.:
Glass — Handle with Care. 8 mm., silent

AUDIO VISUAL AIDS DEPT., Indiana University, Bloomington, Ind.:
Plan to Live. 16 mm., 17 min., black and white, sound

MANUFACTURING CHEMISTS' ASSOCIATION, INC., 1825 Connecticut Ave., NW., Washington, D.C.:
Chemical Careers Unlimited. 35 mm., 12 min., sound
Safety in the Chemical Laboratory. 16 mm., 20 min., color, sound

NATIONAL SAFETY COUNCIL, 425 N. Michigan Ave., Chicago, Ill.:
Safety in the Laboratory. 35 mm. filmstrip with recording
Current List of Safety Films. (Includes 963 motion pictures and slide films on general safety)

Technical Reporting

Hours Required

Class, 2; Laboratory, 2

Description

A natural and vital extension of Communication Skills intended to help the student achieve greater facility in his use of the language, both spoken and written. Using the basic skills previously acquired, the student is introduced to the practical aspects of organizing information, preparing reports, and communicating within groups. The use of graphs, charts, sketches, diagrams, and drawings to present ideas and clearly significant points is an important part of the course. Emphasis is upon techniques for collecting and presenting scientific data by means of informal and formal reports, and special types of technical papers. Forms and procedures for technical reports are studied and a pattern is established for all reports to be submitted in this and other courses.

Major Divisions

		Class hours
I.	Reporting	2
II.	Writing Technical Reports	10
III.	Use of Technical Sketching and Drawing	1
IV.	Use of Pictorial Drawings	1
V.	Use of Diagrammatic Representation	1
VI.	Graphical Presentation of Data	1
VII.	The Research Paper	8
VIII.	Group Communication	8

I. Reporting

1. Nature and types of reports
2. Objective reporting
3. Primary recording of data — Importance of retention
4. Analysis of data and reporting only significant points
5. Critical evaluation of a report

II. Writing Technical Reports

1. The scientific method
   - (a) Meaning of the method
   - (b) Characteristics of the scientific method
   - (c) Essentials of scientific style
   - (d) The problem concept
2. The techniques of exposition
   - (a) Definitions
   - (b) Progression
   - (c) Use of illustrative diagrams, photographs, graphs, and sketches
   - (d) Elements of style
   - (e) Analysis of examples
3. The report form
   - (a) Characteristics
   - (b) Functions
   - (c) Informal reports
   - (d) The formal report
   - (e) Special types of papers

III. Use of Technical Sketches and Drawings

1. Techniques of freehand sketching
2. Theory of projection
3. Multiview drawing
4. Sectional views
5. Dimensioning of drawings

IV. Use of Pictorial Drawings

1. Isometric drawings
2. Oblique drawing
3. Perspective

V. Use of Diagrammatic Representation

1. Chemical process flow diagrams
2. Electrical diagrams and symbols
3. Piping diagrams and symbols
4. Instrumentation diagrams

VI. Graphical Presentation of Data

1. Types of graph paper
2. Proper scaling of paper
3. Points and lines — their meaning
4. Use of data from graphs

VII. The Research Paper

1. Subject and purpose
2. Source materials: bibliographical tools, periodical indexes, the library
3. Organizing the paper
   (a) A working bibliography
   (b) Notes and the outline
   (c) The rough draft
   (d) Quoting and footnoting
   (e) The final paper
4. Oral and written presentation of the paper

VIII. Group Communication

1. The problem-solving approach
   (a) Stating and analyzing the problem
   (b) Proposing solutions
   (c) Selecting and implementing a solution
2. Participating in group communication
   (a) The chairman — duties and qualifications
   (b) Rules of order
   (c) The panel discussion and symposium
   (d) Group investigation

Laboratory — 32 Hours

Laboratory work in this course is devoted to learning and practicing different types of drawing and sketching, and the use of diagrammatic and graphical presentation of important data. These methods of communication are sometimes referred to as "the second language of engineers, scientists, and technicians," hence, proficiency in their use is essential to the chemical technician. Laboratory exercises in these skills should begin immediately, and should be used in the classwork throughout the course.

1. Make freehand sketches of single units of chemical laboratory apparatus, chemical processing, or laboratory equipment, to develop skill in representing distances, proportions, relative sizes, and relationships.
2. Construct multiview sketches of mechanical parts requiring simple dimensions and shop notes.
3. Construct freehand sketches of sectional views of a piece of chemical laboratory equipment, and show the significant dimensions.
4. Make isometric drawings of a piece of laboratory or chemical processing equipment.
5. Make an oblique drawing of an item similar to 4 (above).
6. Make a perspective drawing of a small building or piece of chemical processing equipment.
7. Make a schematic chemical process flow diagram, labeling all elements.
8. Make a schematic electrical wiring diagram for a chemical process unit, using electrical diagramming symbols
9. Make a schematic piping diagram for a chemical process using piping diagramming symbols.
10. Using correct symbolism, make a schematic and a wiring diagram for a simple electronic instrumental control system for a chemical process.

11. Plot and obtain information from the following types of graphs:
    (a) rectilinear
    (b) polar
    (c) semi-log
    (d) log-log
    (e) trilinear
12. Prepare graphs, charts, diagrams, and sketches to be used in a technical report covering a chemical or physics laboratory experiment.

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

AMERICAN STANDARDS ASSOCIATION. *American Drafting Standards Manual — ASA-Y14*

——— *Graphic Symbols — ASA-Y32*

BAER. *Electrical and Electronics Drawings*

BLICKE *and* HOUP. *Reports for Science and Industry*

BUCKLER *and* MCAVORY. *American College Handbook of English Fundamentals*

CROUCH *and* ZETLER. *A Guide to Technical Writing*

DEAN *and* BRYSON. *Effective Communication*

DEVITIS *and* WARNER. *Words in Context: A Vocabulary Builder*

FRENCH *and* VIERCK. *Engineering Drawing*

GERBER. *The Writer's Resource Book*

GRACHINO *and* BEUKEMP. *Drafting and Graphics*

HARWELL. *Technical Communications*

HICKS. *Successful Technical Writing*

HOELSCHER *and* SPRINGER. *Engineering Drawing and Geometry*

INSTRUMENT SOCIETY OF AMERICA. *Recommended Practice — Instrumentation Flow Plan Symbols — ISA-RP 5.1*

KEGEL *and* STEVENS. *Communication: Principles and Practices*

LEVENS. *Graphics — With An Introduction to Conceptual Design*

MARDER. *The Craft of Technical Writing*

MCCRORIE. *The Perceptive Writer, Reader, and Speaker*

PERRIN *and* SMITH. *Handbook of Current English*

RHODES. *Technical Report Writing*

ROGET. *New Roget's Thesaurus of the English Language*

SCHUTTE *and* STEINBERG. *Communication in Business and Industry*

SOUTHER. *Technical Report Writing*

STEWART *and others*. *Business English and Communications*

THOMPSON. *Fundamentals of Communication*

WATERMAN *and others*. *Process Characterization*

ZETLER *and* CROUCH. *Successful Communication in Science and Industry*

Visual Aids

MCMURRY-GOLD PRODUCTIONS, 139 South Beverly Dr., Beverly Hills, Calif.:
- *Person to Person Communication*, 16 mm., 13 min., sound

NATIONAL EDUCATION TELEVISION FILM SERVICE, Audio-Visual Center, Indiana University, Bloomington, Ind.:
- Language in Action Series (16 mm. films)
  - HAYAKAWA. *Experiences as Give and Take*, 16 mm., 29 min., sound
  - ——— *Talking Ourselves Into Trouble*, 16 mm., 29 min., sound
  - ——— *Words That Don't Inform*, 16 mm., 29 min., sound

NATIONAL SAFETY COUNCIL, 425 N. Michigan Ave., Chicago, Ill.
- *It's an Order*, 16 mm., 12 min., sound

PENNSYLVANIA STATE UNIVERSITY, University Park, Pa.:
- *According to Plan: Introduction to Engineering Drawing*, 16 mm., 9 min., sound
- *Drawing and the Shop*, 16 mm., 15 min., sound
- *Freehand Drafting*, 16 mm., 15 min., silent
- *Shop Drawings*, 16 mm., 22 min., sound

General Courses

Communication Skills

Hours Required

Class, 3; Laboratory, 0

Description

This course is designed to enhance the student's skill in reading, writing, listening, and speaking. Topics for student oral and written reports are chosen from material discussed in their technical courses. The course material correlates and integrates the basic communication skills with practical industrial situations instead of treating them as discrete topics. The practical aspect of communication problems dominates the course.

Major Divisions

		Class hours
I.	The Idea of Communication: A Point of View	8
II.	Investigating and Designing the Composition	14
III.	Developing the Composition — Oral and Written	14
IV.	Process Explanation	6
V.	Grammatical Convention	6

I. The Idea of Communication: A Point of View

1. Analysis of the communication process
2. Examination of the problems involved in the effective use of the basic communication skills
3. Relationship of language and maladjustment
4. Dynamics of language
   (a) Changes by time, place, and environment
   (b) Levels of usage
   (c) View toward grammatical conventions
5. Meaning and value in words and phrases

II. Investigating and Designing the Composition

1. Choosing the subject
2. Limiting the subject
3. Determining the purpose
4. Gathering, selecting, and organizing the material
5. Examining the forms of discourse: argumentation, description, narration, persuasion
6. Using aids: dictionary, thesaurus, library, note-taking, outlining

III. Developing the Composition: Oral and Written

1. Being specific (words, ideas)
   (a) Defining terms
   (b) The process of definition
   (c) Types of meaning — connotative and denotative
2. Methods of presentation
3. Organization
4. Developing the central idea: forming, stating, supporting
5. Composing the sentence, the paragraph, the whole composition — oral and written

IV. Process Explanation

1. The nature of expository composition
2. Planning the explanation
3. Presenting the explanation

V. Grammatical Convention

1. Forms, mechanics, and usage
2. Troublesome problems
   (a) The sentence fragment and run-together sentence
   (b) Commonly misspelled words and penmanship
   (c) Verb-subject agreement, tense
   (d) Paragraphing — stating and developing a main idea
   (e) Punctuation and capitalization

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

BEARDSLEY. *Thinking Straight*

BUCKLER *and* MCAVORY. *American College Handbook of English Fundamentals*

DEAN *and* BRYSON. *Effective Communication*

DEVITIS *and* WARNER. *Words in Context: A Vocabulary Builder*

GERBER. *The Writer's Resource Book*

HARWELL. *Technical Communications*

KEGEL *and* STEVENS. *Communication: Principles and Practices*

LEE. *Language Habits in Human Affairs*

MARDER. *The Craft of Technical Writing*

MCCRORIE. *The Perceptive Writer, Reader, and Speaker*

PERRIN *and* SMITH. *Handbook of Current English*

ROGET. *New Roget's Thesaurus of the English Language*

SCHUTTE *and* STEINBERG. *Communication in Business and Industry*

STEWARD *and others*. *Communication in Business and Industry*

STRUNK *and* WHITE. *The Elements of Style*

THOMPSON. *Fundamentals of Communication*

TRACY *and* JENNINGS. *Handbook for Technical Writers*

ZETLER *and* CROUCH. *Successful Communication in Science and Industry*

Visual Aids

NATIONAL EDUCATION TELEVISION FILM SERVICE, AUDIO-VISUAL CENTER, Indiana University, Bloomington, Ind.:

Language in Action Series, (16 mm. films):

HAYAKAWA, S. I. *How to Say What You Mean*, 16 mm., sound, 29 min.

———. *The Task of the Listener*, 16 mm., sound, 29 min.

———. *What Is the Meaning?* 16 mm., sound, 29 min.

Language in Linguistics Series, (16 mm. films):

SMITH, HENRY LEE. *The Definition of Language*, 16 mm., sound, 29 min.

———. *Dialects*, 16 mm., sound, 29 min.

———. *Language and Writing*, 16 mm., sound, 29 min.

General and Industrial Economics

Hours Required

Class, 3; Laboratory, 0

Description

A study of economics designed to impart a basic understanding of the principles of economics and their implications; to develop the ability to follow an informed personal finance program; to aid in the development of intelligent consumption; and to provide an understanding of the underlying relationship of cost control to success in industrial enterprise. The programs or problems worked upon by a chemical technologist in either research or production ultimately must be measured by a cost analysis. To be aware of this fact, and to have a knowledge of elementary economics prepares the student for the cost-conscious environment of his future employment. It is suggested that the instruction in this course be based on this pragmatic approach and that students be encouraged to study examples from the chemical industry as they learn about industrial cost analysis, competition, creation of demand, economic production, and the related aspects of applied economics.

Major Divisions

		Class hours
I.	Introduction	2
II.	Economic Forces and Indicators	3
III.	Natural Resources — The Basis of Production	3
IV.	Capital and Labor	3
V.	Business Enterprise	7
VI.	Factors of Industrial Production Cost	8
VII.	Price, Competition, and Monopoly	5
VIII.	Distribution of Income	2
IX.	Personal Income Management	2
X.	Insurance, Personal Investments, and Social Security	3
XI.	Money and Banking	3
XII.	Government Expenditures, Federal and Local	3
XIII.	Fluctuations in Production, Employment, and Income	2
XIV.	The United States Economy in Perspective	2

I. Introduction

1. Basic economic concepts

II. Economics Forces and Indicators

1. Economics defined
2. Modern specialization
3. Increasing production and consumption
4. Measures of economic activity
   (a) Gross national product
   (b) National income
   (c) Disposable personal income
   (d) Industrial production
   (e) Employment and unemployment

III. Natural Resources — The Basis of Production

1. Utilization and conservation of resources
2. Renewable resources
3. Nonrenewable resources
4. Future sources

IV. Capital and Labor

1. Tools (Capital)
   (a) The importance of saving and investment
   (b) The necessity for markets
2. Large-scale enterprise
3. Labor
   (a) Population characteristics
   (b) Vocational choice
   (c) General education
   (d) Special training
   (e) Management's role in maintaining labor supply

V. Business Enterprise

1. Forms of business enterprise
   (a) Individual proprietorship
   (b) Partnership
   (c) Corporation
2. Types of corporate securities
   (a) Common stocks
   (b) Preferred stocks
   (c) Bonds
3. Mechanics of financing business
4. Plant organization and management

VI. Factors of Industrial Production Cost

1. Buildings and equipment
   (a) Initial cost and financing
   (b) Repair and maintenance costs
   (c) Depreciation and obsolescence costs
2. Materials
   (a) Initial cost and inventory value
   (b) Handling and storage costs
3. Processing and Production
   (a) Methods of cost analysis
   (b) Cost of labor
   (c) Cost of supervision and process control
   (d) Effect of losses in percentage of original product compared to finished product (yield) in chemical operations
4. Packaging and shipping
5. Overhead costs
6. Taxes
7. Cost of selling
8. Process analysis, a means to lower costs
9. Profitability and business survival

VII. Price, Competition, and Monopoly

1. Function of prices
2. Price determination
   (a) Competitive cost of product
   (b) Demand
   (c) Supply
   (d) Interactions between supply and demand
3. Competition, benefits, and consequences
   (a) Monopoly and oligopoly
   (b) Forces that modify and reduce competition
   (c) History of government regulation of competition
4. How competitive is our economy?

VIII. Distribution of Income

1. Increasing real incomes
2. Marginal productivity
3. Supply in relation to demand
4. Incomes resulting from production
   (a) Wages
   (b) Interest
   (c) Rents
   (d) Profits
5. Income distribution today

IX. Personal Income Management

1. Consumption — the core of economics
2. Economizing defined
3. Personal and family budgeting
4. Analytical buying
   (a) Applying quality standards
   (b) Consumer's research and similar aids
5. The use of credit
6. Housing — own or rent

X. Insurance, Personal Investments, and Social Security

1. Insurance defined
2. Life insurance
   (a) Group, industrial, and ordinary life policies
   (b) Types of policies — their advantages and disadvantages
3. Casualty insurance
4. Investments
   (a) Savings accounts and Government bonds
   (b) Corporation bonds
   (c) Corporation stocks
   (d) Annuities
   (e) Pension plans
5. Social Security
   (a) Old-Age and Survivors Insurance
   (b) Unemployment Compensation

XI. Money and Banking

1. Functions of money
2. The Nation's money supply
3. Organization and operation of a bank
   (a) Sources of deposits
   (b) The reserve ratio
   (c) Expansion of bank deposits
   (d) Sources of reserves
4. The Federal Reserve System
   (a) Service functions
   (b) Control of money supply
5. Federal Deposit Insurance Corporation

XII. Government Expenditures — Federal and Local

1. Economic effects
2. Functions of Government
3. Analysis of Government spending
4. Future outlook
5. Financing Government spending
   (a) Criteria of sound taxation
   (b) Tax revenues in the United States
   (c) Federal and State personal income taxes
   (d) Corporate income tax
   (e) Property tax
   (f) Commodity taxes

XIII. Fluctuations in Production, Employment, and Income

1. Changes in aggregate spending
2. Output and employment
3. Other factors affecting economic fluctuations
   (a) Cost-price relationships
   (b) Fluctuations in demand for durable goods
   (c) Involuntary fluctuation of supply of commodities
   (d) Economic effects of war
   (e) Inflation and deflation of currency value
   (f) Economic effects of inventions and automation
4. Means of implementing fiscal policy
5. Government debt
   (a) Purposes of Government borrowing
   (b) How burdensome is debt?
   (c) Problems of debt management

XIV. The United States Economy in Perspective

1. Recent economic changes
   (a) Increased productivity and well-being
   (b) Effects of war and depression
   (c) New products and industries
   (d) Increase in governmental controls
2. Present economic problems of U.S. Economy
   (a) The world market — a community of nations
   (b) International cooperation
   (c) Maintenance of prosperity and progress
   (d) Economic freedom and security
3. Communism
   (a) Nature and control by Soviet State
4. Fascism
5. Socialism
6. Problems common to all economic systems
7. Special economic problems of the United States

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

ARIES, *and* NEWTON. *Chemical Engineering Cost Estimation*

BLODGETT. *Comparative Economic Systems*

DONALDSON *and* PFAHL. *Personal Finance*

GORDON. *Economics for Consumers*

POND. *Essential Economics: An Introduction*

SAMUELSON. *Economics: An Introductory Analysis*

Business Week Magazine

Consumers' Research Report

Consumers' Union Reports

Visual Aids

MCGRAW-HILL BOOK CO., INC., 330 West 42nd Street, New York, N. Y.:

Basic Economic Concepts, 35 mm., filmstrip-set of 4 filmstrips, average 40 frames each

Savings and Investment, 35 mm., filmstrip

Supply and Demand, 35 mm., filmstrip

Money, Prices, and Interest, 35 mm., filmstrip

Business Cycles and Fiscal Policy, 35 mm., filmstrip

Industrial Organizations and Institutions

Hours Required

Class, 3; Laboratory, 0

Description

A description and analysis of the roles played by labor and management in the economy of the United States are presented. Approximately one-half of the classroom time is devoted to labor-management relations, including the evolution and growth of the American labor movement and the development and structure of American business management. A study is made of the legal framework within whicl labor-management relations are conducted and the responsibilities of each in a democratic system of government. The second half of the course pertains to labor-economics as applied to the forces affecting labor supply and demand, problems of unemployment reduction and control, and wage determination on the national, plant, and individual levels. Emphasis centers upon current practical aspects of our industrial society with historical references intended only as background material to interpret trends and serve as points of departure.

Major Divisions

		Class hours
I.	Labor in an Industrial World	9
II.	Management in an Industrial Society	9
III.	The Collective Bargaining Process	12
IV.	Dynamics of the Labor Market	8
V.	Wage Determination	7
VI.	The Balance Sheet of Labor-Management Relations	3

I. Labor in an Industrial World

1. The nature and scope of the Industrial Revolution
   - (a) The factory system
   - (b) Occupational trends
   - (c) Mechanisms of adjustment
2. The evolution of American labor unions
   - (a) Nature of early unions: basic system of craft unions
   - (b) Organizations by unions for solving problems
   - (c) Emergence of "business" unionism
   - (d) The changing role of Government
3. Structure and objectives of American unions
   - (a) Objectives in collective bargaining
   - (b) Political objectives and tactics
   - (c) Structure of craft and industrial unions
   - (d) Movement toward unity — the AFL-CIO merger

II. Management in an Industrial Society

1. The rise of big business
   - (a) Economic factors
   - (b) Dominance of the corporate firm
   - (c) Government, public policy, and big business

2. The "Managerial Revolution"
   (a) Changing patterns of ownership and management
   (b) "Scientific" management
   (c) Twentieth Century trends
3. Structure and objectives of American Industry
   (a) Production for profit: an "Affluent Society"
   (b) Structure of industry-organizational forms
   (c) Ethics in a competitive economy

III. The Collective Bargaining Process

1. Legal framework
   (a) Common law provisions
   (b) The growth of statute laws
      (1) The antitrust laws: aid to emergence of collective bargaining
      (2) The Addamson and LaFollette Laws
      (3) Norris-LaGuardia
      (4) Wagner Act
      (5) Taft-Hartley
      (6) Landrum-Griffin and beyond
2. Management and collective bargaining
3. Bargaining procedures and tactics, including conciliation and mediation process
4. Issues in collective bargaining
   (a) Security issues
   (b) Working conditions
   (c) Safety provisions and safety education
   (d) Money matters
5. Strikes and lockouts: tactics and prevention
6. Evaluation of collective bargaining

IV. Dynamics of the Labor Market

1. Labor supply and the market
   (a) Level and composition of the labor force
   (b) Changing patterns of employment
   (c) Some questions about labor supply and the market
2. Reduction and control of unemployment
   (a) Types of unemployment
   (b) Proposed schemes of employment stabilization
   (c) Continuing problems
3. Labor mobility
   (a) Types of labor mobility
   (b) Deterrents to labor mobility
   (c) Suggested programs to improve labor mobility

V. Wage Determination

1. Wages, process, and employment
   (a) Meaning of wages
   (b) Wages and the productive process
   (c) The problem of inflation
2. Wages and the national income
   (a) Concepts of measurement and productivity
   (b) Determinants of productivity
   (c) The distribution of national income
3. Wage structures
   (a) Occupational differences
   (b) Geographic patterns
   (c) Industry patterns
   (d) Wage determination: plant level, individual wages

VI. The Balance Sheet of Labor-Management Relations

1. The control and elimination of poverty in a modern industrial State
   (a) The extent of poverty
   (b) The attack on poverty
   (c) Trends and portents
2. Justice and dignity for all in an industrial democracy
   (a) The worker — status and goals
   (b) Management — rights and responsibilities
   (c) The future of capitalistic society

Texts and References

One of the books on the following list may be selected for a text. Others may be used for reference.

BLOOM *and* NORTHRUP. *Economics of Labor Relations*

CHAMBERLIN. *The Economic Analysis of Labor Union Power*

DULLES. *Labor in America*

ELLS. *The Meaning of Modern Business: An Introduction to the Philosophy of Large Corporate Enterprise*

FAULKNER. *American Economic History, 8th ed.*

GEARY. *The Background of Business, 2d ed.*

GREGORY. *Labor and the Law, 2d ed.*

GRIMSHAW *and* HENNESSEY. *Organizational Behavior — Cases and Readings*

KERR *and others*. *Industrialization and Industrial Man*

LEISERSON. *American Trade Union Democracy*

LINDBLOM. *Unions and Capitalism*

MCGREGOR. *The Human Side of Enterprise*

MORTON. *Trade, Unionism, Full Employment, and Inflation. American Economic Review*, XL, p. 13-39

PFIFFNER. *Administrative Organization*

PHELPS. *Introduction to Labor Economics*

REYNOLDS. *Labor Economics and Labor Relations*

RICHBERG. *Labor Union Monopoly, A Clear and Present Danger*

SLICHTER, HELAY, *and* LIVERNASH. *The Impact of Collective Bargaining on Management*

SULTAN. *Labor Economics*

TAFT. *Economics and Problems of Labor*

U.S. DEPARTMENT OF LABOR. *The American Worker Fact Book*

———. BUREAU OF LABOR STATISTICS. *Interim Revised Projection of U.S. Labor Force*

Visual Aids

THE BROOKINGS INSTITUTION, Washington, D.C.:
Big Enterprise in the Competitive System. 16 mm., color, sound, 40 min.

CORONET FILMS, INC., Coronet Bldg., Chicago:
Labor Movement: Beginnings and Growth in America. 16 mm., sound, 13½ min.

ENCYCLOPEDIA BRITANNICA FILMS, INC., 1150 Wilmette Ave., Wilmette, Ill.:
Productivity — Key to Plenty. 16 mm., sound, 22 min.
Working Together (A Case History in Labor-Management Cooperation). 16 mm., sound, 24 min.

MCGRAW-HILL BOOK CO., INC., New York:
Internal Organization. 16 mm., sound, 10 min.
Job Evaluation and Merit Rating. 16 mm., sound, 13 min.

TEACHING FILM CUSTODIANS, 25 West 43rd St., New York, N. Y.:
Bargaining Collectively. 16 mm., sound, 10 min.

UNIVERSITY OF INDIANA, Bloomington, Ind.:
Decision: Constitution and the Labor Union. 16 mm., sound, 29 min.

Library Facilities and Content

DYNAMIC DEVELOPMENTS causing rapid changes in technological science and practice make it imperative that the student of any technology learn to use a library.

In any evaluation of a technology teaching program the qualifications of the librarian, the physical facilities, the quality, quantity, pertinency of content, and the organization of the library give a tangible indication of the strength of the program.

Instruction for students in technologies should be library-oriented so they learn the importance of knowing where they can find information relative to any of the various courses which they are studying. They should learn the use of a library and form the habit of using it as a tool in the learning process. This helps to develop the professional attitude in the student, and further assists him to depend on libraries as a means of keeping abreast of the new developments in a rapidly changing technology.

Instructors of all courses should constantly keep the student aware of the extent to which a library contains useful information which can be helpful and is a part of the study in his curriculum. Planned assignments of library projects calling for the student to go to the library and prepare information on pertinent subjects in his courses enable him to understand the resources available in libraries and how they relate to his technology. Open-book examinations requiring the use of the library provide excellent and objective experience for students where they work under the incentive of the examination and the limited time available. Their understanding of their own competency in library skills becomes realistically clear to each student.

The growth and success of the graduate technician will depend in large measure on his ability to keep abreast of changes in his field. Libraries are information source agencies with trained personnel who classify source data and assist those seeking it to find pertinent information quickly.

For these reasons a central library under the direction of a professional librarian is important to the success of the teaching of technology curriculums. Most instructors have private libraries in their offices from which they may select books of special interest in their personal conferences with students and thereby stimulate interest in related literature. However, a central library under the direction of a professional librarian insures the acquisition and cataloging of the library content according to an accepted library practice, and provides the mechanics for location of reference materials by the use of systematic card files. It also provides the mechanics for lending books to students in a controlled and orderly manner typical of libraries which he should encounter in the course of solving problems in his employment after leaving school wherever he may be.

Study space with suitable lighting and freedom from outside distractions should be provided in the library for short-term study of reference data; and provisions for checking out of reference materials for out-of-library use should be systematic and efficient.

Library Staff and Budget

The head librarian usually reports to the top administrative officer of the school and has full faculty status.

American Library Association standards state that "two professional librarians are the minimum number required for effective service in any junior college with an enrollment up to 500 students (full-time equivalent). In addition, there should be at least one nonprofessional staff member. The larger the institution, the more appropriate it will be to employ a higher proportion of nonprofessional staff members. Great care should be taken that professional staff members do not spend their time doing work that is essentially clerical, because this is not only wasteful but also demoralizing."

The library staff of one well-established technical institute providing eight full-time technology programs consists of a head librarian, an assistant librarian, and two junior librarians — all holding masters degrees in Library Science; a full-time secretary; a part-time clerk; and a limited number of student library assistants.

According to the American Library Association, the library budget should be determined in relation to the total budget of the institution for educational and general purposes, but the amount to be allocated to the library should be based upon a program of optimum library service in support of the school's goals. The execution of the library program as it is outlined in their standards normally requires a minimum of 5 per cent of the total educational and general budget. This minimum percentage is for a well-established library with an adequate collection. It would have to be augmented if there is a rapid increase in the student body or in course offerings; it would again need to be increased if the library is responsible for an audiovisual program. The library budget for a newly organized institution should be considerably higher than 5 percent.

Another criterion for the library budget, approved by the American Library Association, is that the funds for acquiring new library material should equal or exceed the cost of the total library staff. This is for established libraries; and the expenditure for new acquisition of materials should be substantially greater for libraries which are just starting or when major additions of curriculums are being made.

Library Content

The content of a library must adequately provide the literature containing the knowledge encompassed by all subjects in a curriculum and extending somewhat beyond the degree of complexity or depth encountered in classroom activities. Literature dealing with unusually highly specialized aspects of a subject may be acquired as needed, or may be borrowed by the librarian from more comprehensive libraries.

The library content should meet the needs of both full-time students and those of part-time students pursuing supplemental educational courses designed to upgrade or update their occupational knowledge and skills. In addition, it should serve the day-to-day needs of the instructional staff as they keep their own technical knowledge abreast of the new developments pertinent to their special field of applied science.

In view of the highly specialized nature of library content for chemical technology, it is recommended that the department head or chief instructor in the chemical technology division be a part of a library committee and be responsible for providing or finally approving the reference material for chemistry and related courses. The librarian, as chairman of such a committee, may be expected to take the initiative in assisting the head of the chemistry department to keep informed of new literature and library materials which become available. The librarian should also take the initiative in calling meetings or informally consulting with the head of the chemistry department so that within the limitations of the budget and the overall consideration of total library needs, the chemistry department will acquire its appropriate library content.

The library content may be classified into basic encyclopedic and reference index material, reference books pertinent to the technology, periodicals and journals, and visual aids. Each will be discussed separately.

Encyclopedic and Reference Index Material

This portion of the library content is basic in that it contains the broadly classified and organized cataloging of all available knowledge pertinent to the objectives served by the library and the program which it supports.

The following list of reference material under this classification is found in a publicly controlled technical institute enrolling about 1,700 full-time students. Chemical technology is one of eight technologies taught by the institution. Though many are general, all of these references have some bearing on chemical technology. It is suggested that some or all of these might appropriately be a part of the library which supports a chemical technology. This list is not represented to be complete since there are other references and indexes which appropriately might support a chemical technology. It is presented as an example. It is suggested that upon ordering any of these references for a library collection the latest edition be specified.

American College Dictionary; Random House Inc., 457 Madison Avenue, New York 22, N. Y.

Applied Science & Technology — Industrial Arts Index; H. W. Wilson Co., New York, N. Y.

ASTM Standards; American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Bibliography Index, The; H. W. Wilson Co., New York, N. Y.

Business Periodicals Index; H. W. Wilson Co., New York, N. Y.

Chemical Abstracts; American Chemical Society, 1155 16th Street NW., Washington, D.C.

Chemical Industry Facts Book, The; Manufacturing Chemists Association, Inc., 1825 Connecticut Avenue, Washington 9, D.C.

Collier's Encyclopedia; Collier-Macmillan Library Division, 60 Fifth Avenue, New York 11, N. Y.

Commercial Atlas and Mailing Guide; Rand McNally & Co., New York, N. Y.

Cumulative Book Index; H. W. Wilson Co., New York, N. Y.

Dictionary of Applied Chemistry; J. Thorpe, John Wiley & Sons, Inc., 440 Park Avenue South, New York, N. Y.

Encyclopedia Americana, The; Americana Corporation, New York, N. Y.

Encyclopedia Britannica; Encyclopedia Britannica Inc., Chicago, Ill.

Encyclopedic Dictionary of Physics; J. Thawles, The Macmillan Co., New York, N. Y.

Encyclopedia of Chemical Reactions; C. A. Jacobson *and* Clifford A. Hampel, Reinhold Publishing Co., New York, N. Y.

Encyclopedia of Chemistry, The; Clark *and* Hardy, Reinhold Publishing Co., New York, N. Y.

Encyclopedia of Microscopy, The; George L. Clark, Reinhold Publishing Co., New York, N. Y.

Encyclopedia of the Social Sciences; The Macmillan Co., New York, N. Y.

Engineering Index; Engineering Index, Inc., 29 West 39th Street, New York 13, N. Y.

Engineering Materials Handbook; Charles L. Mantel, McGraw-Hill Book Co., New York, N. Y.

Handbook of Chemistry and Physics; Chemical Rubber Publishing Co., 2310 Superior Avenue NE., Cleveland, Ohio

International Critical Tables; McGraw-Hill Book Co., New York, N. Y.

International Dictionary of Physics & Electronics; D. Van Nostrand Co., Inc., Princeton, N. J.

Labor Policy and Practice; Bureau of National Affairs, Washington, D. C.

Library of Congress Catalog; U.S. Library of Congress, Washington, D.C.

Manual for Process Engineering Calculations; McGraw-Hill Book Co., New York, N. Y.

McGraw-Hill Encyclopedia of Science and Technology; McGraw-Hill Book Co., New York, N. Y.

Metals Handbook; American Society for Metals, Metals Park, Novelty, Ohio

Moody's Industrial Manual; Moody's Investor's Service, 65 Broadway, New York, N. Y.

Nuclear Science Abstracts; U. S. Atomic Energy Commission, Washington, D. C.

Oxford English Dictionary; Oxford University Press, Amen House, London, England

Poor's Register of Corporations, Directors, and Executives; Standard and Poor's Corporation, 345 Hudson Street, New York 14, N. Y.

Reader's Guide to Periodical Literature, The; H. W. *Wilson Co., New York, N. Y.*

Research and Development Abstracts; U.S. Atomic Energy Commission, Washington, D.C.

School and Library Atlas of the World; Geographical Publishing Co., Cleveland 16, Ohio

Scientific and Technical Societies of the United States and Canada; National Academy of Sciences, National Research Council, Washington, D.C.

Statistical Abstract of the U.S.; U.S. Department of Commerce, Washington, D.C.

Sweet's Industrial Construction File; Sweet's Catalog Service, F. W. Dodge Corp., 119 West 40th Street, New York 14, N. Y.

Temperature — Its Measurement and Control in Science and Industry; American Institute of Physics, 335 East 45th Street, New York 17, N. Y.

Thomas Register; Thomas Publishing Co., 461 Eighth Ave., New York 1, N. Y.

Van Nostrand's Scientific Encyclopedia; D. Van Nostrand Co., Inc., Princeton, N. J.

Webster's International Dictionary; G. & C. Merriam Co., Springfield, Mass.

Welding Handbook; American Welding Society; 33 West 39th Street, New York 18, N. Y.

Technical Journals, Periodicals, and Trade Magazines

The importance of this portion of the library content has previously been emphasized. These publications represent the most authoritative, most recent, and complete presentation of new knowledge and new applications of principles to a given specific area of applied science. It is essential that both instructors and students make frequent and systematic use of such literature to keep their technological information up to date.

It is suggested that careful selectivity be exercised in retaining and binding, or in microfilming, these periodicals for permanent library use. Some represent important reference material which may be used for many years. However, some, especially the trade journals, should not be bound for permanent reference material because the really important material which they contain will usually become a part of a handbook or textbook or be presented in a more compact and usable manner within a year or two.

The following list shows the technical journals, periodicals, and trade magazines which are received and available in a publicly controlled technical institute enrolling approximately 1,700 full-time students, and which teaches eight different technologies. This list is given as an example which may suggest appropriate publications to those who are concerned with this type of content for a library supporting a chemical technology teaching program.

Aerospace Management; Clinton Co., Chestnut and 56th Street, Philadelphia 39, Pa.

Air Conditioning, Heating and Ventilating; Industrial Press, 93 Worth Street, New York 13, N. Y.

American Ceramic Society Bulletin; American Ceramic Society, Inc., 4055 North High Street, Columbus 14, Ohio

Analytical Chemistry; American Chemical Society, 1155 16th Street NW., Washington, D.C.

Battelle Technical Review; Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio

Bell Laboratories Record; Bell Telephone Laboratories Inc., 463 West Street, New York 14, N. Y.

Chemical & Engineering News; American Chemical Society, 1155 16th Street NW., Washington, D.C.

Chemical Engineering; McGraw-Hill Publishing Co., 330 West 42d Street, New York 36, N. Y.

Chemical Engineering Progress; American Institute of Chemical Engineers, 25 West 45th Street, New York 36, N. Y.

Chemical Week; McGraw-Hill Publishing Co., 330 West 42d Street, New York 36, N. Y.

Chemistry; American Chemical Society, 1155 16th Street NW., Washington 6, D.C.

Clinical Chemistry; (American Association of Clinical Chemists), Paul B. Hoeber, Inc., 49 East 33d Street, New York 16, N. Y.

Engineering & Mining Journal; McGraw-Hill Publishing Co., 330 West 42d Street, New York 36, N. Y.

Glass Industry; Ogden Publishing Co., 446 Lexington Avenue, New York 36, N. Y.

Hydrocarbon Processing & Petroleum Refiner; Gulf Publishing Co., Box 2608, Houston 1, Tex.

Industrial and Engineering Chemistry; American Chemical Society, 1155 16th Street NW., Washington 6, D.C.

Industrial Bulletin; Industrial Bulletin Inc., 450 East Ohio Street, Chicago 11, Ill.

Industrial Equipment News; Thomas Publishing Co., 461 Eighth Avenue, New York 1, N. Y.

Industrial Gas; Moore Publishing Co., Inc., 48 East 38th Street, New York 18, N. Y.

Industrial Heating; National Industrial Publishing Co., Union Trust Building, Pittsburgh 19, Pa.

Instrumentation; Minneapolis-Honeywell Regulator Co., Wayne and Windrim Avenue, Philadelphia 44, Pa.

Iron Age; Chilton Co., Inc., Chestnut and 56th Streets, Philadelphia, Pa.

Iron & Steel Engineer; (Association of Iron and Steel Engineers), Empire Building, Pittsburgh 22, Pa.

Journal of American Ceramic Society; American Ceramic Society, Inc., 4055 North High Street, Columbus 14, Ohio

Journal of American Chemical Society; 1155 16th Street NW., Washington, D.C.

Journal of American Concrete Institute; American Concrete Institute, 22,400 West Seven Mile Road, Detroit 19, Mich.

Journal of Applied Physics; American Institute of Physics, 335 East 45th Street, New York 17, N. Y.

Journal of Chemical Education; American Chemical Society, 1155 16th Street NW., Washington, D.C.

Journal of Research, (National Bureau of Standards)—Part A Physics & Chemistry; U.S. Government Printing Office, Washington 25, D.C.

Lubrication; Texas Co., 135 East 42d Street, New York 17, N. Y.

Materials in Design Engineering; Reinhold Publishing Co., 430 Park Avenue, New York 22, N. Y.

Materials Research & Standards; American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Metal Progress; American Society for metals, Metals Park, Novelty, Ohio

Metals Review; American Society for Metals, Metals Park, Novelty, Ohio

Missiles and Rockets; American Aviation Publications, 1001 Vermont Avenue NW., Washington 25, D.C.

Modern Plastics; Modern Plastics Inc., 575 Madison Avenue, New York 22, N. Y.

Nucleonics; McGraw-Hill Publishing Co., 330 West 42d Street, New York 36, N. Y.

Physics Today; American Institute of Physics, 335 East 45th Street, New York 17, N. Y.

Plastics Technology; Hill Brothers Publishing Corp., 630 Park Avenue, New York 17, N. Y.

Popular Photography; Ziff-Davis Publishing Co., 1 Park Avenue, New York 16, N. Y.

Popular Science Monthly; Popular Science Publishing Co., Inc., 355 Lexington Avenue, New York 17, N. Y.

Precision Metal Molding; Telenews Production, Inc., 812 Huron Road, Cleveland 15, Ohio

Product Engineering; McGraw-Hill Publishing Co., 330 West 42d Street, New York 36, N. Y.

Production; Bramson Publishing Co., Box 1, Birmingham, Mich.

Review of Scientific Instruments; American Institute of Physics, 335 East 45th Street, New York 17, N. Y.

Science News Letter; Science Service Inc., 1719 N Street NW., Washington 6, D.C.

Scientific American; Scientific American Inc., 415 Madison Avenue, New York 17, N. Y.

Society of Plastics Engineers Journal; Society of Plastics Engineers, 65 Prospect Street, Stamford, Conn.

Technical Education News; McGraw-Hill Book Co., 330 West 42d Street, New York 36, N. Y.

Technology Review; Alumni Association of Massachusetts Institute of Technology, Cambridge 39, Mass.

Tool & Manufacturing Engineering; American Society of Tool Engineers, 5400 Good Hope Road, Milwaukee 1, Wis.

Welding Engineer; Welding Engineer Publications, Inc., Morton Grove, Ill.

Welding Journal; American Welding Society, 33 West 39th Street, New York 18, N. Y.

Wood and Wood Products; Vance Publishing Corp., 59 East Monroe Street, Chicago 3, Ill.

Wood Preserving News; C. Miles Burpee, ed., 111 West Washington Street, Chicago, Ill.

The Book Collection

The *American Library Association* states that "a 2-year institution of up to 1,000 students (full-time equivalent) cannot discharge its mission without a carefully selected collection of at least 20,000 volumes, exclusive of duplicates and textbooks. Institutions with broad curriculum offerings will tend to have larger collections; an institution with a multiplicity of programs may need a minimum collection of 2 or 3 times the basic figure of 20,000 volumes. The book holdings should be increased as the enrollment grows and the complexity and depths of course offerings expand. Consultation with many junior college librarians indicates that for most, a convenient yardstick would be the following: The bookstock should be enlarged by 5,000 volumes for every 500 students (full-time equivalent) beyond 1,000."

At the initiation of a chemical technology program it is recommended that the head of the chemistry department and the librarian review the current pertinent reference books available and select a list to be placed in the library as regular reference material. A recommended policy is to place in the library only those reference books which are not a part of the regular textbook material for the various chemistry courses.

It is suggested that *at the beginning of a chemical technology program, the library should contain at least 200 to 300 reference books on various aspects of chemistry and its related fields, particularly the field of chemical engineering.* Beyond the initial 200 to 300 textbooks there should be regular and systematic additions to the reference materials in the library supporting the chemical technology from year to year; and eventually a weeding out of those references which have become obsolete.

Visual Aids

The same procedure is suggested for placing the visual aids content in the library as is outlined above for the acquisition of books pertinent to the chemical technology. Both the librarian and the head of the chemistry department should review and evaluate visual aids materials as they become available; and those which are deemed appropriate should be borrowed for special use, or purchased for regular use.

In view of current research in methods of teaching the fundamental knowledge and theory of the atomic structure and other scientific principles, it is probable that many new visual aid materials may become available in the future.

In addition to the visual aids for teaching physical science and chemical principles, there are and probably will continue to be valuable films and other pertinent materials showing chemical research or production which should be used selectively in teaching chemical technology.

Laboratories and Physical Facilities for Teaching Chemistry

PHYSICAL FACILITIES for teaching chemistry require careful and technically informed planning because chemical reactions involve active solids, solutions, or gases which must be controlled, confined, and systematically conveyed to final disposal.

The active solutions and vapors generated in a chemistry laboratory or in classroom demonstrations require control of all associated environmental facilities; hence, the need for development of comprehensive and detailed specifications for all such facilities.

Poorly planned chemical laboratory facilities can cause serious environmental, maintenance, and service problems, and heavy expense to the institutions operating them, whereas well-planned facilities can be relatively problem-free. To yield to the pleasure or temptation to accept equipment which seems cheaper, but which would be short-lived or costly to service or maintain, usually results in an expensive disappointment in service.

For these reasons, a detailed consideration of recommended facilities for teaching the chemistry in this curriculum guide follows. The facilities described are considered to be the practical ideal for such a program. Many variations are possible and an attempt is made to discuss alternatives in important aspects so that the reason for the recommended choice is evident.

Chemistry Building Location, General Planning and Arrangement

The chemistry department ideally should be located in a separate builing or separate wing of a single-story building. This arrangement isolates fumes and possible fires or explosions from the rest of the school buildings, and avoids unnecessary student and other personnel traffic through the area. The building should be located on the downwind side of the rest of the school facilities, leeward of the prevailing wind, if possible, to prevent irritating and unpleasant fumes from being drawn into classrooms, offices, and cafeterias. Parking lots should not be located near the chemistry department exit, partly to avoid unnecessary student traffic and partl, to avoid exposing automobile finishes to possible action by chemical fumes.

The footings for the building should extend down to bedrock, if possible, under the instrument room and balance room to minimize vibration; and, under the unit operations laboratory, where units of operating equipment should have a solid floor as a base.

It is desirable to locate in a one-floor layout with no rooms above and crawl space below. Such an arrangement involves short fume exhaust stacks; permits location of exhaust fan units on the roof, if desired; permits the drain lines containing corrosive chemicals to be as short as possible; and allows emergency doors to be provided in the outside walls.

Floor, Wall, and Ceiling Coverings — 100 percent vinyl floor covering has given excellent service in chemical laboratories. This material is resistant to chemicals, is easy to clean, resists wear, is attractive in appearance, and is less fatiguing to stand on for long periods than a concrete floor.

A hardened concrete surface, which will not dust, is often used in laboratories. It can be painted and is probably the most durable floor available, but will require frequent painting. Plastic floor coverings, and asphalt tile are easily ruined by certain chemicals commonly used in chemical laboratories.

Glazed tile coverings for walls are expensive, but because the surface is resistant to chemical fumes, can be cleaned easily, and require no maintenance. Concrete blocks or similar material are often used but require frequent painting. Chemical-resistant paint should be used on walls and ceiling. Lead paints turn dark quickly in the presence of hydrogen sulfide or other sulfur fumes.

Ceilings in chemical laboratories should be finished without exposed metal beams or framework. This minimizes the accumulation of dust and dirt and the corrosion of metal beams with the resultant rust which eventually loosens and may fall into and contaminate chemical determinations.

Lighting — Chemical laboratories and lecture demonstration rooms should be well lighted. For evening classes and on dark days, it is necessary to have lighting equivalent to 50-foot candles[1] at the bench tops. Since many chemical experiments require color matching or involve color changes, the Analytical Laboratory is best located on the north side of the building away from bright sunlight because many color changes are easier to detect in a north light than in bright sunshine. Sometimes the instrument laboratory must be darkened, so it is recommended that light-tight curtains be provided for this area. Since the balance room must be located so sunshine does not strike any of the analytical balances, it is suggested that the instrument room and balance room be located adjoining the analytical laboratory on the north side of the building, if possible.

Disposal of Waste Liquids—Laboratory liquid waste disposal needs special planning for chemistry teaching facilities. At times, the liquids being fed into the laboratory draining system may be more concentrated in acid or alkali content than desirable for immediate disposal. It is, therefore, recommended that the layout of the chemistry building be such that effluent from the chemistry laboratories be fed into the school sewer system so it can be diluted by waste water from the building before it flows into the final exit sewer system.

It is recommended that adequate crawl space be provided under the laboratory facilities. This permits dropping waste liquids into glass lines directly from the sinks before connecting with the sewer. It is desirable to bring all chemical waste together in a main glass line before discharging it into the sewer, because it helps to dilute the wastes from various laboratories and permits visual inspection of the glass lines under the floors to locate possible leaks or stoppages.

The materials used in the liquid disposal collection system and disposal lines for chemistry laboratories is especially important due to problems of corrosion. Either glass or durion collection and disposal pipelines may be used because both are satisfactorily corrosion-resistant.

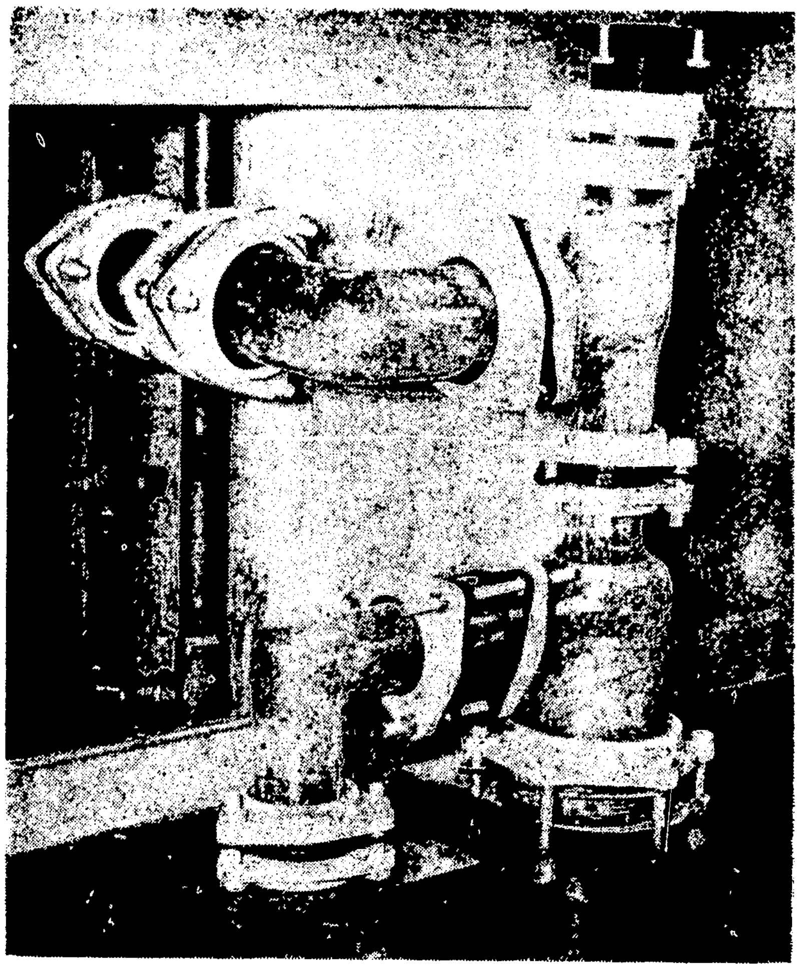
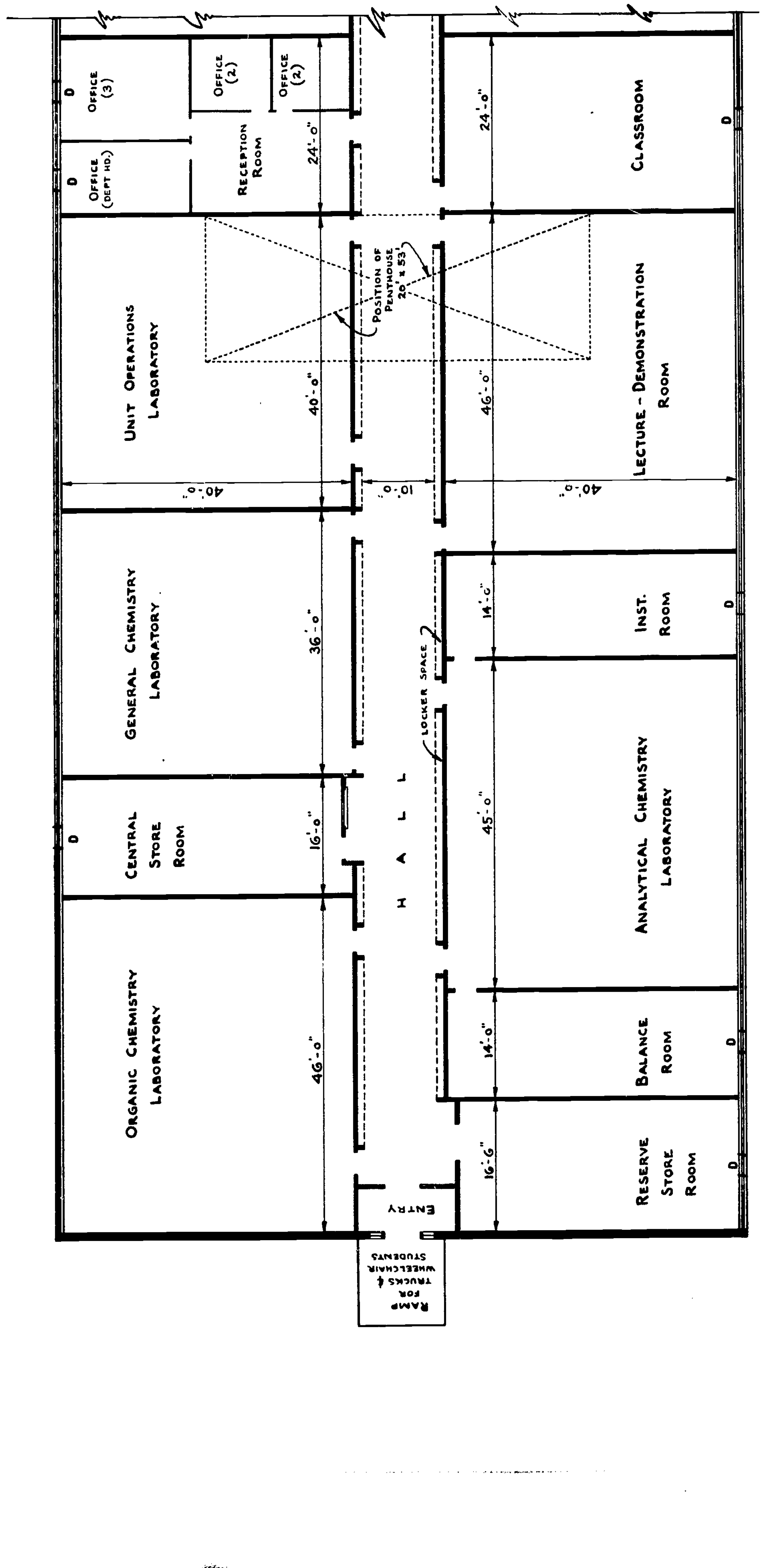


Figure 1. — Chemical Laboratory Waste Lines: Pyrex glass — flange connections.

Glass piping, such as shown in figure 1, costs more than durion when initially installed, but has the significant advantages in service and maintenance of allowing quick location of plugged lines by visual inspection and easy unplugging because its bolted connections can be easily uncoupled with a simple open-end wrench, the foreign materials removed and the pipe recoupled. Durion piping, in contrast, being opaque, must, on occasion, be flame-cut with a torch in several places to locate a plugged portion, and then must be repaired using leaded joints and patches. This process is much more laborious, costly, and hazardous than a similar

[1] Lewis, Harry F. *Laboratory Planning for Chemistry and Chemical Engineering.* 1962. New York, N.Y., Reinhold Publishing Co., p. 60.



Suggested Floor Plan for Chemistry Program

Approx size - 165' x 95'

D-Emergency Door

Figure 2

problem using glass lines, and involves an additional material weakness — that of using lead. Lead joints, patches, or linings in chemistry laboratory sinks, traps, or lines are exposed to chemical corrosion which eventually dissolves them and requires expensive repairs and cleaning up of the leakage. Such failures can occur within a very short time if metallic mercury is spilled and comes in contact with the lead.

Permanent strainers made of chemical-resistant plastic (teflon or equivalent) should be cemented into openings of all sinks or drains leading into the piping. Such strainers prevent the usual broken tubing, stoppers, pencils, pieces of glass rods, filter paper, and other foreign objects that usually cause pipe stoppages from entering the system. The strainers should be inspected periodically, and recemented, if necessary, since plastic cements may be affected on long exposure to some chemicals, especially organic solvents.

Laboratory bench tops and sinks may be stone, stainless steel, or plastic. Stainless steel and plastic sinks have the advantage of being less massive (than stone), and are single-unit structures with contoured corners which are easy to keep clean, whereas the stone sinks are made of several pieces cemented together with a cement that may fail after long exposure to chemical wastes.

Cup sinks in modern smooth-top chemistry laboratory benches may be made of glass, durion, plastic, or stainless steel. The contoured design of the plastic, glass, and stainless steel cup sinks provide the advantage of permitting easy cleanout at the end of each laboratory period.

Fume Disposal.—Fumes generated in chemical laboratories must be collected and exhausted. The method most commonly used to accomplish this is through the fume hoods by providing them with sufficient capacity to draw fumes from the laboratory through the hood and exhaust them directly into the atmosphere a short distance above the roof. This arrangement eliminates the need for auxiliary exhaust equipment to provide a fume-free working atmosphere. In such a system the fume hoods usually have sliding doors that can be raised or lowered to regulate the exhaust air to the amount needed to provide a fume-free working atmosphere. Ducts for such hoods should be lined with transite or other noncorrosive material to avoid early failure due to chemical corrosion.

In such an exhaust system, provision must be made for replacement air which normally is supplied by a positive pressure warm-air system. In localities which periodically experience very cold weather the normal heating and ventilating system may need to be supplemented with unit heaters because when all fume hoods are running to provide a fume-free atmosphere a very large volume of air is being exhausted and must be replaced with air heated to room temperature. Compliance with local air-pollution ordinances must be assured before plans for fume exhausting are finalized.

Schematic Layout for a Chemistry Department

The floor plan of a chemistry teaching department's facilities suggested in figure 2, has been considered from cost and practical teaching points of view.

It is a simple one-floor arrangement isolated in a separate building or separate wing of a building. It is compact, functional, and arranged so utility installation costs may be kept to a minimum with short fume stacks, short drain lines, and a minimum of service lines hidden in partitions or located in inaccessible areas.

The reception room and offices for the staff, a classroom, and the lecture-demonstration room are located in one end of the building as much removed as possible from the three main chemistry laboratories (general chemistry, analytical, and organic). This tends to avoid student traffic through the laboratory area, and is a convenient arrangement for the instructional staff.

The central storeroom is used primarily to provide materials to the General Chemistry, Organic, and Analytic Chemistry laboratories, hence, is located as centrally to them as possible. This makes it possible for students to obtain storeroom service only a few feet from the laboratory in which they are working, and makes it easy for instructors to check with the storeroom manager without going far from their laboratory class.

The reserve storeroom is located as close to the outside door as possible. A ramp has been suggested so that trucks may deliver materials to the reserve storeroom with a minimum of lifting and handling. The ramp would also provide for wheelchair entry to the building. The reserve storeroom is planned not only as a receiving area but as an area where quantity lots of chemicals and apparatus can be stored until needed. Case lots of beakers and similar supplies could be kept in this area and taken to the central storeroom in small quantities as needed.

A full-time laboratory manager who does not teach classes is recommended. He should be a technically trained person who can be responsible for laboratory condition, maintenance, safety precautions, ordering material, operation of central stores, stores inventory, and other related tasks.

The lecture-demonstration room is located relatively near the central storeroom because most of the demonstrations will require apparatus and materials from the storeroom which can be prepared by the stockroom clerk and delivered to the demonstration room as needed. Demonstration models, mockups, and other materials can be stored in the central storeroom and thus be easily available for lecture room use.

The balance room is used exclusively by students from the analytical laboratory. It should be on footings which extend to bedrock to eliminate as much vibration as possible. It is desirable to provide air-conditioning in this room as analytical balances are sensitive to temperature changes. Balances of a less sensitive type are sufficient in the general chemistry and organic chemistry laboratories and it is recommended that such balances be provided as permanent equipment in those laboratories to avoid the students, in both general and organic chemistry, having to use the equipment in the balance room.

The instrument room is also used almost exclusively for analytical purposes, usually as a part of the course in quantitative analysis, and, therefore, is located adjacent to the analytical laboratory. In performing analyses by means of instrumentation it is almost always necessary to dissolve the sample or chemically to prepare it before making the final measurement with an instrument. This should be done in the analytical laboratory and the instrument room should be used only for the final measurement. This keeps the atmosphere in the instrument room noncorrosive, and reduces injury to expensive instruments from corrosion to a minimum. The instrument room should also have automatic temperature and humidity control.

The plan shows the penthouse near to the end of the wing. If the laboratory facilities were connected to a main building it might be desirable to have the office and classroom spaces within the main building. This would place the laboratory wing and the penthouse directly against the main building. Thus, if hot water, gas, compressed air, steam, and electricity were available in the main building these lines could be brought directly into the penthouse without duplicating facilities.

It is desirable to have penthouse space which partially overlays the unit operations laboratory and partially overlaps another area. Removable grating floor should be installed in that portion of the penthouse overlapping the unit operations laboratories, where such an arrangement provides extra ceiling height for special pieces of equipment to be installed. The area of the penthouse which overlaps areas other than the unit operations laboratory can house other pieces of equipment. This can include the unit for making distilled water to be distributed by gravity to all laboratories. A small auxiliary steam generator, a low-pressure air supply unit, and other such equipment may also be located in the penthouse if such units are needed.

Water, Steam, Distilled Water, Air, and Fuel Gas Services

General Considerations.—Utility service pipelines to chemical laboratories should be planned for the shortest length of piping consistent with laboratory arrangement. They should be hidden as far as practicable, but control points should be planned for safety, accessibility, and ease of maintenance. It is recommended that *each lab-*

oratory have a master control panel which has a shut-off valve for each utility, such as gas, water, and steam. This master control panel should have a door with a lock so that all utilities can be turned off at a central point and locked to prevent someone turning them on without authorization. In addition to a shut-off valve in the master control panel for each utility, it is advisable to have a shut-off valve for water, gas, steam, etc., in each bench. In case of a leak or need for repair, the utility can then be shut off at the bench without shutting off the supply to other portions of the laboratory. These shut-off valves at each bench should be located at the end under a sink unit to be easily and quickly accessible.

In chemical laboratory piping installations there are many connections for water, gas, etc., as well as many connections to drain lines. Each of these is a potential trouble spot that can develop leaks, become clogged, or cause other maintenance problems. Most are hidden in the laboratory benches or hood bases or lockers. In designing laboratory benches and individual lockers it is well to plan to have removable backs in order to provide easy access to hidden service lines for maintenance and repair. If removable backs are not provided, it is necessary to dismantle the entire laboratory bench in order to work on such piping.

Pipe and Fittings for Utility Piping.—Control valves, faucet valves, and exposed piping in chemical laboratories are subjected to a corrosive atmosphere. In planning the design of a laboratory, materials should be used which will corrode as little as possible. Chromium-plated pipe and fittings, brass, most aluminum alloys, and carbon steel soon become unsightly and eventually fail due to corrosion when exposed to certain chemical atmospheres, as shown in figure 3. Recently a chemical bronze has become available which seems to be moderately resistant to strongly corrosive chemical laboratory atmospheres. The additional cost of chemical bronze over chrome plating for the metal fixtures in the laboratory is not prohibitive, and probably would be the more economical in the service life of the installation. The control valves for fume-exhaust hoods should be located outside of the hood so they are not exposed to the concentrated corrosive atmospheres which are frequently found inside the hood.

Figure 3 — Chemical Laboratory Fume Hood: Steam bath on left, chromium plated, corrosion after 2 years. Gas connection on right, chem-bronze finish, no sign of corrosion.

Hot and cold water is needed in all laboratories at the worktable and sinks, at the table in the lecture-demonstration room, and in the central storeroom. Special planning should be exercised to provide pipelines with sufficient capacity, especially to the analytical laboratory where it is common practice to have an aspirator located at each student's work-station (a possible total of 30 aspirators). In many analytical determinations all students may be using aspirators at one time. This will cause a drop in water pressure in an undersized line, with a resulting low vacuum from the aspirator. It is therefore suggested that the cold-water lines be of a suitable size so that pressure drops can be avoided.

Steam is necessary for several of the laboratories in a chemistry department. The largest requirement for steam is usually the unit operations laboratory for operating various pieces of equipment on a pilot-plant scale. This is an intermittent use. A small amount of steam also is necessary in the organic laboratory. Usually none will be required in the general chemistry or analytical laboratories. Because of the intermittent use of steam, it is suggested that a small capacity boiler be located in the penthouse above the chemistry department and operated independently of the heating system. A boiler of 10- to 15-horsepower capacity probably would be adequate for the unit operations laboratory and the small amount of steam needed in the organic laboratory. The steam lines to the various laboratories should be operated through the master control panel so it will be possible to shut off the supply of steam to the entire laboratory with a single valve.

Distilled water must be supplied to all laboratories in the chemistry department. It is suggested that an electrically operated distilling unit and storage tank be located in the penthouse, with supply lines distributing distilled water to the various laboratories by gravity. The capacity of the storage tank should normally be from 100 to 200 gallons, and it is suggested that the capacity of the still be approximately 5 gallons per hour. The storage tank for distilled water should be specially constructed of block tin or other material to prevent chemical contamination of the water by the tank. Similarly, distribution lines should be of block tin, certain alloys of aluminum, or such other material that contamination of water as it flows to the various laboratories is minimal. These lines should be as short as possible.

Distilled water for laboratory use is relatively expensive. Since *de-ionized* water can be used for some experiments where pure distilled water is not a requirement, it is suggested that de-ionizing units should be considered. If such units would save enough distilled water usage to more than pay for the cost, de-ionizing units should probably be installed in each laboratory.

Compressed air for all laboratories is a necessity. It is suggested that the air pressure for all laboratories, except the unit operations laboratory, be kept relatively low; probably in the range of 5 to 15 pounds per square inch, to minimize the probability of accidents resulting from air pressure buildup in glass containers .

In the unit operations laboratory compressed air pressures higher than 5 to 15 lbs per square inch are needed at times. For such occasions the main air-pressure line valve at the master control panel in the unit operations laboratory may be closed, and an auxiliary compressor connected to the air supply-line system in the unit operations laboratory. This makes it possible to boost the pressure in the unit operations laboratory to the required higher pressure without affecting the air pressure in the other laboratories. When a lower air-pressure is again sufficient for the unit operations laboratory, the compressor can be disconnected, the main air-control valve in the master panel reopened, and the unit operations laboratory again may use the main low-pressure air supply.

Fuel gas is required in all laboratories, with outlet valves at all student worktables, lecture demonstration tables, and fume-hood installations. Gas lines should be installed with care, and should be hidden as far as possible to minimize the possibility of their being broken or caused to leak. Gas leaks are a fire and safety hazard, and must be minimized as far as possible.

Electrical Services

It is suggested that 110- and 220-volt single-phase electrical service be provided to all laboratories and to the demonstration lecture hall. Most equipment used in the laboratory requires 110 volts; however, occasionally 220-volt single-phase current is required in the analytical laboratory, the organic laboratory, and the general chemistry laboratory.

In connecting the electrical service to the various laboratory benches, it is suggested that each be connected to a separate circuit breaker, so that when a large number of students in the laboratory are using heaters or other electrical apparatus, the lines will not become overloaded. In designing the electrical lines for the analytical laboratory, provision should be made for the many hot plates, service furnaces, and drying ovens which are sometimes used continuously.

These units should be on separate circuit breakers and wiring should be installed with sufficient capacity to provide safely for their electrical requirements. If the water-distilling unit in the penthouse is operated by electricity, a special heavy-duty line should be installed to meet the specifications of the manufacturer of the still.

The unit operations laboratory requires a 220-volt, 3-phase current in addition to the 110- and 220-volt single phase service.

Each laboratory should have a separate master distribution control panel for the electrical circuits in the room, preferably located near a door, but installed a safe distance from the emergency shower, which also should be near the exits.

Laboratory Benches and Bench Tops

The materials used for laboratory benches is very important because they are subjected to corrosive action of many different chemicals. Laboratory bench cabinets may be made of metal or well-varnished wood; the latter often are less expensive than metal and more resistant to corrosion to which they will be subjected in service.

The material for laboratory bench tops is of special importance because it is exposed to extreme chemical corrosion in the normal processes of chemical laboratory work. Table tops may be made of wood, various types of stone, and a variety of other materials.

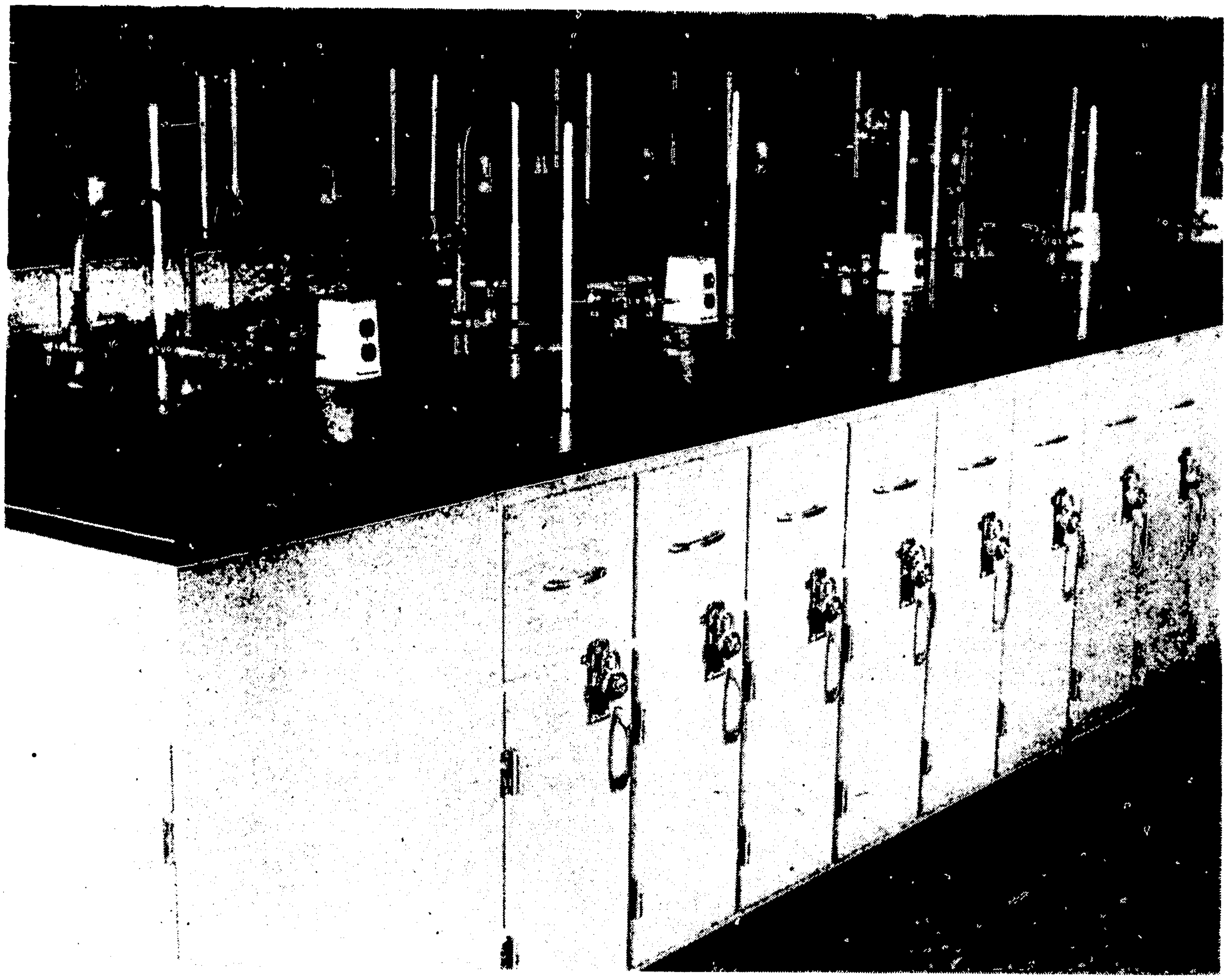


Figure 4. – General Chemistry Laboratory: Smooth top laboratory benches: chemrock bench tops; chembronze fixtures; removable ring stands; individual lockers with hasps and padlocks.

Stone materials specially treated under temperature and pressure with acid- and alkali-resisting materials are recommended because they seem to withstand the usual corrosive action of chemicals better than most materials. Untreated soapstone which has been ground smooth and polished usually gives good service for ordinary chemical laboratory use, but repeated exposure to strong acids and alkalis tends to corrode and soften it with the result that within a few years such bench tops may be pitted.

Plain or laminated wood materials, even if specially treated, are not recommended because they burn easily and strong acids soon ruin the surface. Any type of stone benchtop must be uniformly supported by the frame of the bench under its entire length because the stone material will not support any appreciable weight. It is, therefore, very important that the benches be permanently leveled before the tops are put on to avoid leaving part of the stone top unsupported. Weight put on top of an area that is not supported may cause the top to break.

A smooth-topped laboratory bench, such as is shown in figure 4, with cup sinks placed at suitable intervals is recommended because the piping for the various utilities, i.e., gas, cold water, hot water, electricity, and air, as well as the drain lines, can be run through the section between the cabinets and be completely hidden from view, with the necessary outlets brought through the stone surface at intervals as needed. This provides a neat-appearing laboratory which is easy to keep clean and in good condition.

A common design for laboratory benches is to install a lead-lined trough down the center, with several pipes above the trough carrying air, hot water, cold water, gas, etc., with valves and hose connections coming from them at intervals. Generally a reagent rack for bottles and other miscellaneous glassware is constructed above the piping. Such a design is not recommended. Lead-lined troughs develop leaks rapidly, especially if mercury is spilled in them. This results in conditions which tend to rot or corrode cabinets from the inside. In addition, the troughs are catchalls for filter paper, matches, bits of broken glass, etc., and are difficult to keep clean. The exposed utility pipes are dirt-catchers, become rusted and corroded, and are a problem to keep clean. Such a design is not recommended.

Instead of shelves over the top of laboratory benches, side cabinets are recommended for reagents or solutions. Only those chemicals normally used regularly should be available in the laboratory. The unusual or seldom-used materials can be obtained from the central storeroom as needed. This type of installation is much easier to maintain, looks better, and is efficient for teaching laboratory work when properly planned.

Laboratory Storage Cabinets

For any given course in the laboratory, it is suggested that the commonly used chemicals, such as sulfuric, hydrochloric, and nitric acids, and sodium and ammonium hydroxide be available on each laboratory bench in concentrated form at all times. Wooden cabinets built along the wall of chemical laboratories, each having appropriate shelves and detachable sliding doors, are recommended for storage of most of the additional chemicals and supplies needed in that laboratory.

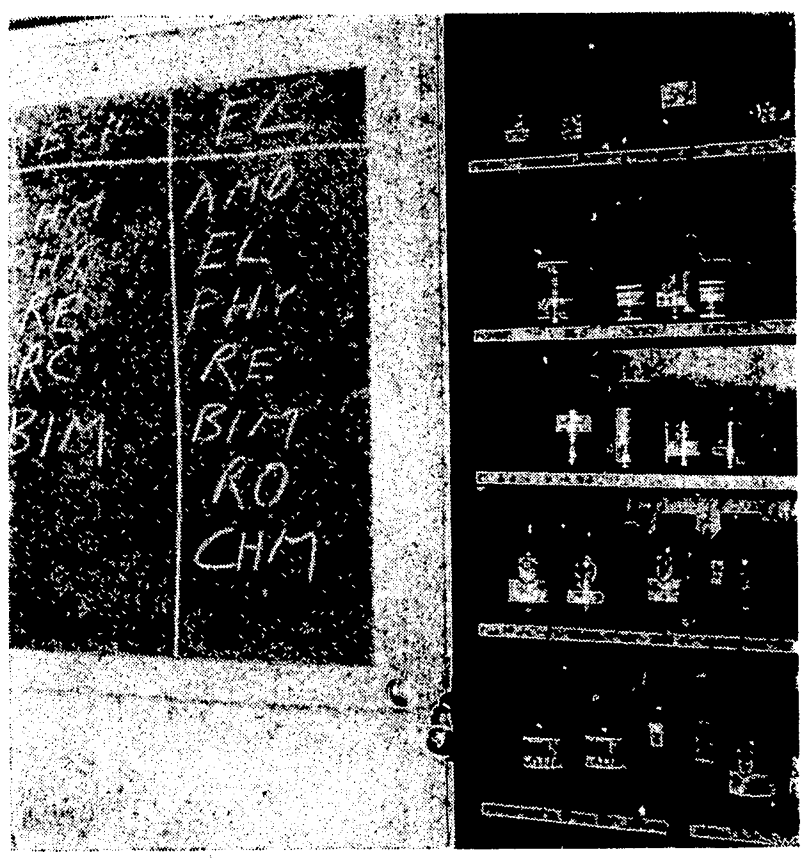


Figure 5. — Storage Cabinet with Chalkboard Doors: Contents not visible.

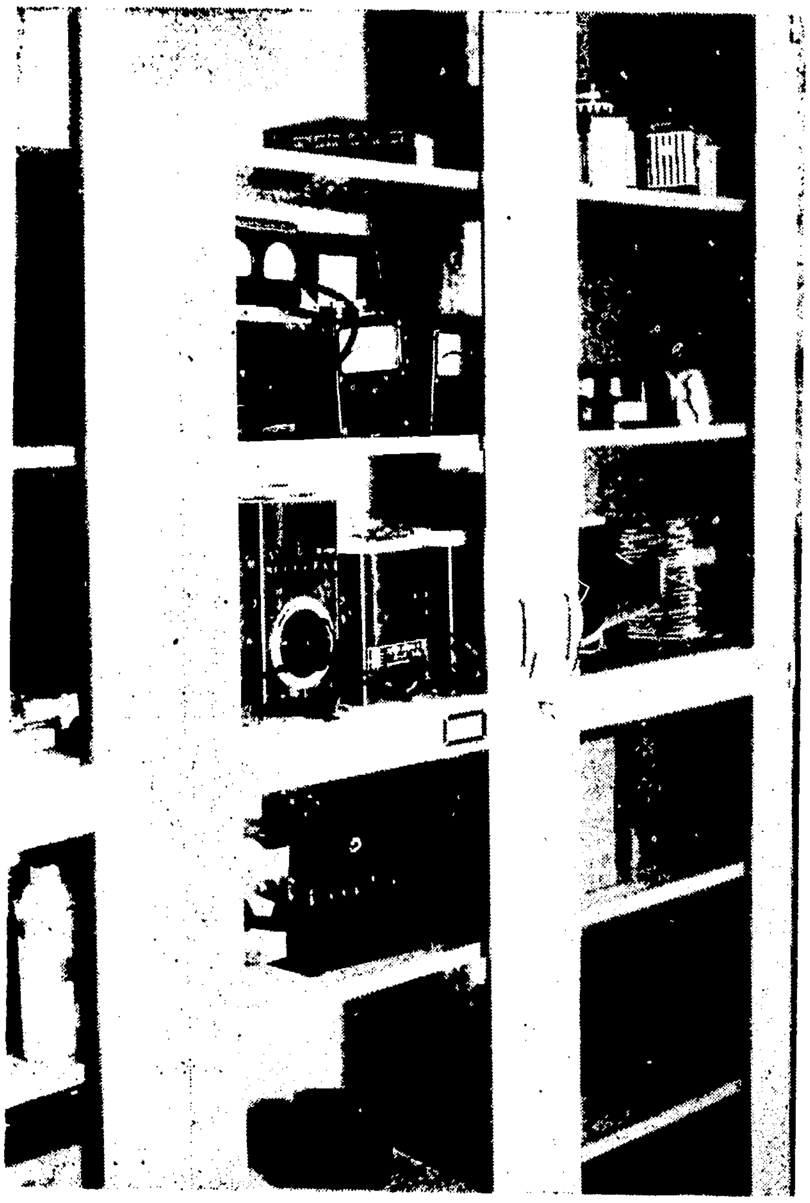


Figure 6. — Storage Cabinets with Glass Doors: Contents visible.

The use of chalk board in place of glass panels for cabinet doors, as shown in figure 5, has several advantages — first, glass panels in cabinet doors, such as shown in figure 6, usually become covered with fume residue from the laboratory, are unsightly, and difficult to keep clean. Secondly, the chalkboard, in addition to hiding contents of the storage cabinet, prevents deterioration of light-sensitive chemicals while in storage. At the same time, it can be used for laboratory tests, instructions, and appropriate notices to students.

The use of sliding doors which are easily removable is recommended if the laboratory is used in one period for general chemistry and in another set of periods for organic chemistry. The sliding doors can be opened for whichever class is using it at the time and closed and locked for the other group. It is generally desirable that organic chemicals *not* be available to general chemistry students whose unauthorized experimentation with them might involve unnecessary safety hazards.

Student Lockers in Chemical Laboratory Benches

Chemistry laboratory work benches should be designed with individual lockers to contain most of the apparatus used by the student in a given course. Items, such as beakers, burettes, test tubes, flasks, burners, and glass tubing, usually represent the largest inventory value and storage-space consumer in a chemistry program. To use the individual student lockers for the management and storage of such items is an important phase of the planning and management of a chemistry teaching program; it allows the central storage of items and materials which must be used intermittently or issued as supplies and replacements as the programs in each laboratory proceed.

In the beginning of any course, each student locker in a laboratory should have a complete stock of the standard list of apparatus required for the course. (See representative list, Appendix B). The contents of the locker should have been checked by the stockroom manager, and when the locker is assigned, the student should check the contents and sign an inventory list. The apparatus in each locker should include sufficient equipment to allow the student to complete most of the experiments in the course without checking out additional apparatus from the storeroom. Special pieces of apparatus that students need for only a short time can be obtained from the stockroom by signing it out and returning it at the end of the period.

Having apparatus permanently assigned to the student locker saves valuable time for both instructor and students. It permits the student to report to the laboratory and start work almost immediately, with a minimum of time required to check their locker lists and a minimum of traffic and last-minute attention at the central storeroom. Some additional supply of all items in the lockers must be available in the storeroom to make up for breakage or normal attrition.

Finally, the operation of the laboratory is most efficient, if at the end of the course the instructor has each student restock the locker to exactly the items that appear on a standard list of materials for the locker. The list of items checked out of the storeroom to complete the locker inventory at the end of the course represents the student's breakage, loss, or use during the course.

It is strongly recommended that padlocks and hasps be used on all student lockers. Many manufacturers of laboratory benches prefer to furnish the student locker with a built-in lock and set of keys. Experience shows that this type of lock may corrode from chemical fumes and not be usable after a period of service. Another reason for hasps and padlocks is that it permits the locks to operate with a master key. This allows the instructor to open any locker when necessary and permits the student to have access only to his locker. This is important since chemistry students in most programs are required to make a laboratory deposit to cover broken apparatus. Unless lockers are locked and students can be confident that they alone can open the locker, the procedure for accounting for lost or broken apparatus during the course breaks down upon final accounting at the end of the course. It is suggested that the locks in a laboratory be rotated at the end of each course to insure access to a given locker only to the student to whom it is assigned.

Safety

Planned safety for chemistry teaching facilities costs very little. Some safety suggestions which should be considered in designing a chemical laboratory area follow.

Every laboratory should have at least *two exits* and two alternate routes for evacuation. If a work area should catch fire due to flammable materials it is possible that the fire could shut off one exit, thus two exits are an absolute must for all chemical work areas.

Each laboratory should have a *master control for all utilities*. In case of fire at any point in the laboratory the instructor or someone else can close the master control, stopping the gas flow for the entire laboratory and thus minimize damage and danger to occupants. It is well to have this master control for the utilities near an exit so that the person who is shutting off the master control can do so and get out of the laboratory if necessary. It is suggested that the master control panel be enclosed in a cabinet, so it is possible to turn off all utilities in the laboratory and lock the cabinet door. This avoids the possibility of utilities being turned on while repair work is being done. However, the master control panel should *not* have the door locked for normal operation.

Two *emergency showers* with quick acting valves should be installed in each laboratory area and at least one in each storeroom area. These emergency showers should be located as near an exit as possible so that in case a fire ignites a person's clothing, he can immediately use the emergency shower, and when the fire is extinguished he can leave the area.

The electrical control panel for controlling the electrical outlets in each laboratory should be located on a wall well removed from the emergency shower area so they cannot be flooded in case of shower use.

Eye-wash fountains should be installed in each laboratory to provide immediate relief to anyone who splashes acid or other injurious materials in his eyes. At least one eye-wash fountain should be available in each laboratory, except perhaps in the unit operations laboratory and the instrument room. Eye-wash fountain installations should have a low-pressure flow of water to avoid damage to eyes from a high-pressure water jet.

Fire extinguishers should be installed and made easily available in all chemical laboratory areas.

Because of the varying nature of chemical fires requiring different types of fire extinguishers to extinguish them safely, it is suggested that some person who has had professional training in this aspect of firefighting be consulted — possibly an expert from a local chemical plant. In any event, local codes for fire prevention must be maintained. Fire extinguisher types and locations should be planned when the building is designed; and extinguishers should be in places where, in case of fire, a man in any room can reach a fire extinguisher and fight his way out of the fire and room.

Gas masks should be located in all main laboratories, and students should be instructed in their use at the beginning of the first semester.

Fire blankets should be installed in each laboratory. Special fire blanket units are available in metal containers which are easily operated. They are made to be installed so the person needing the blanket can simply grasp a strap and wrap the blanket firmly and quickly around himself by turning around once. Fire blankets should be located near each exit of all working areas.

An explosion-proof refrigerator should be provided for storage of certain volatile and highly flammable organic reagents, such as butane or ether. Special explosion-proof refrigerators are available. Ordinarily household refrigerators generally are not explosion-proof due to the electric light and master control switches inside of them, however, they may be modified to be explosion-proof, but only by an expert. There have been numerous cases of explosions in refrigerators where ether was stored, and several bad accidents have been recorded.

Safety glasses should be worn by everyone working in a chemical laboratory. It is an almost universal practice in chemical laboratories to require the chemists and technicians to wear safety glasses at all times. Therefore, safety regulations at a school laboratory should require all students who take a course in chemistry to purchase a set of safety glasses and to wear them at all times when they are in the laboratory.

Safety regulations should be posted in each laboratory and should be called specifically to the attention of all students and workers at the beginning of their work there. Most accidents in chemical laboratories are caused by lack of attention to safety precautions, "horseplay," or some other unnecessary act. Chemical personnel must constantly be aware of and practice safety precautions.

Specific Laboratories and Related Facilities

In the following discussion, the diagrams are intended to show suggested equipment arrangement and space for laboratories, storerooms, and offices. They are not intended to be complete. Such items as janitor's closets and student and staff toilet facilities, for example, are not shown, but must be provided in a complete plan of facilities for teaching chemistry.

The chemistry laboratory benches, hoods, and cabinets shown in the diagrams and drawings are representative of those available from several chemistry laboratory equipment suppliers. When a chemistry department is being planned in detail, it is suggested that the engineering services of such suppliers be obtained. Suppliers will usually provide complete drawings and specifications for an entire laboratory or department in such form that they may be used to obtain competitive bids. Such engineering services usually are provided free of charge; and the supplier's experienced engineers provide alternate plans and detailed suggestions which promote efficient arrangements and economical use of space and funds for the facility.

Most of the basic chemistry laboratory work benches, cabinets, and hoods can be built on the spot. *This is not usually recommended.* To build them is not economical in most instances because of the required specialized materials and items, such as sinks, work-bench tops, fume-hood mechanisms, and special fittings. The standard unitized equipment available from chemistry laboratory equipment suppliers are well engineered, efficient in service, and are probably most economical when purchased and installed under contract.

Demonstration and Lecture Hall

Seats in the demonstration and lecture hall should be so arranged that the view of the demonstration tables is good both from the rear and the front of the room. The suggested plan, figure 7, with seats elevated as they approach the rear has been found to be a good arrangement. The hall should be equipped with a lecture demonstration table and should have an outlet for a portable fume exhauster. The drawing indicates a seating capacity of 128 for the demonstration and lecture hall. However, if the chemistry department offers chemistry service courses to other departments, a demonstration and lecture

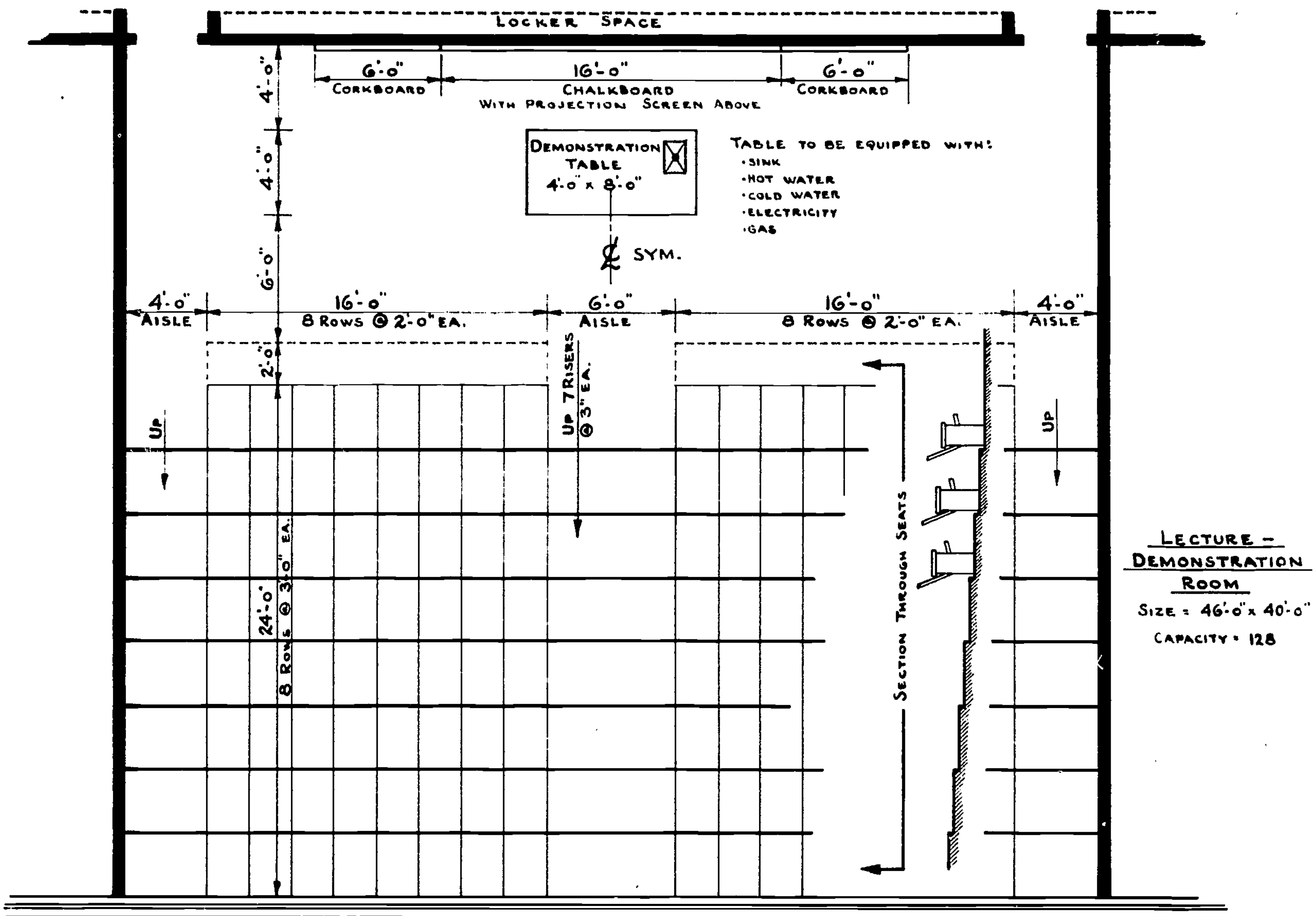


Figure 7

hall seating up to 200 should be considered. This permits the combining of groups for lecture and demonstration purposes.

The demonstration room should be located near the stockroom. This allows the technical person who operates the stockroom to prepare visual aids and demonstration materials, and to deliver them expeditiously to the teacher in the demonstration room. No attempt should be made to stock demonstration apparatus and supplies in the lecture hall, but they should be delivered from the stockroom whenever they are needed.

A large chart of the chemical elements permanently mounted in the demonstration room is a valuable teaching aid. There should be one or more blackboards of the portable type in the room. An overhead projector which will permit the teacher to write at desk level and have his writing projected onto the screen over his head is recommended because of its usefulness in chemical lecturing and demonstrations, particularly to illustrate chemical equations. It is desirable that 8-millimeter projection equipment be available to make use of the many filmstrips which pertain to chemistry. Windows should be equipped with moderately lightproof curtains or shades to facilitate use of such visual aids.

For cost estimates on lecture demonstration room equipment see "Costs".

General Chemistry Laboratory

A suggested plan for the General Chemistry Laboratory is shown in figures 8, 9, 10, and 11 which diagram the arrangement of student work spaces and fume hoods. A representative list of apparatus for the general chemistry lockers, with a cost estimate of the contents of each locker, is shown in Appendix B. A list of

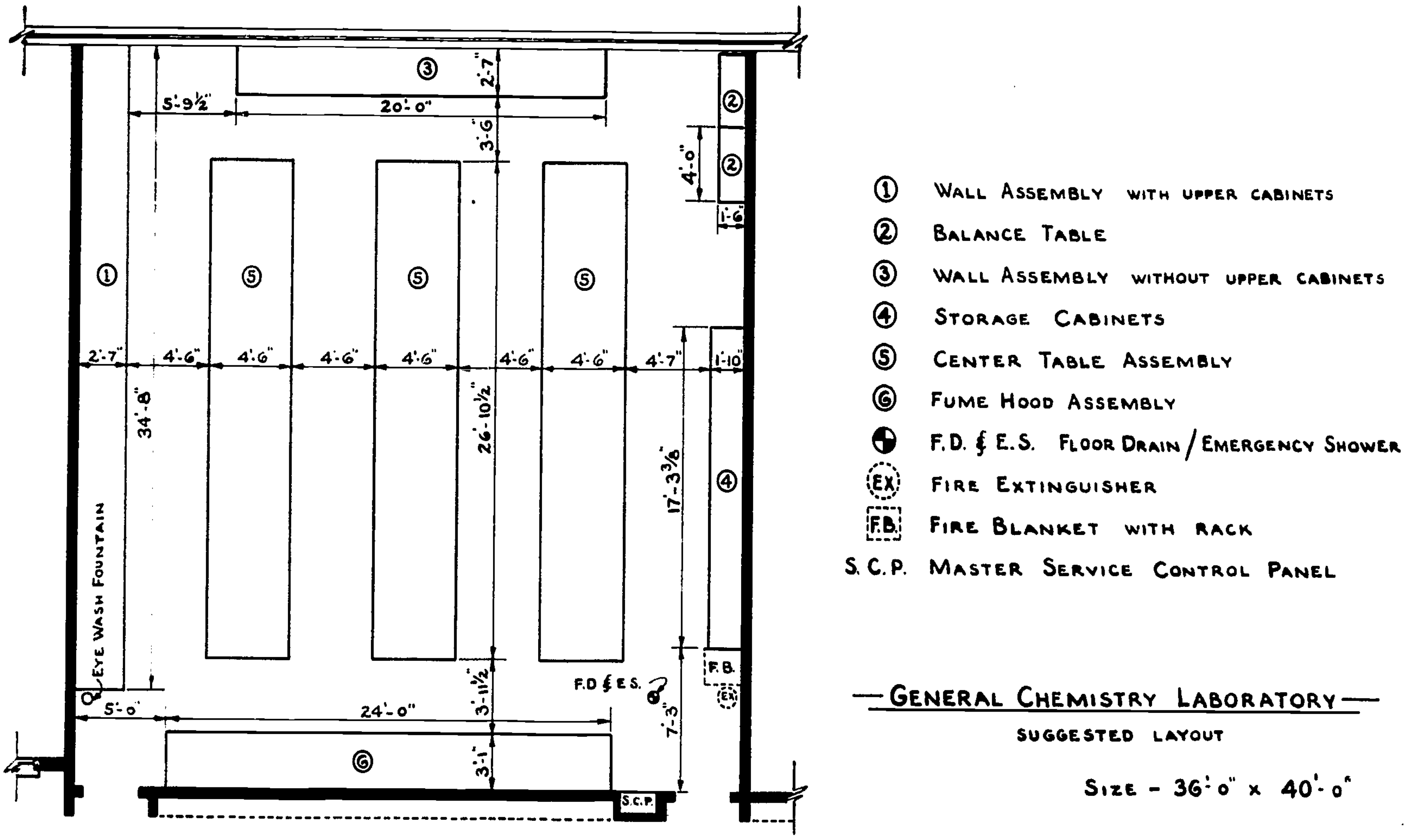


Figure 8

other major equipment items which are normally required in this laboratory room is shown under "costs."

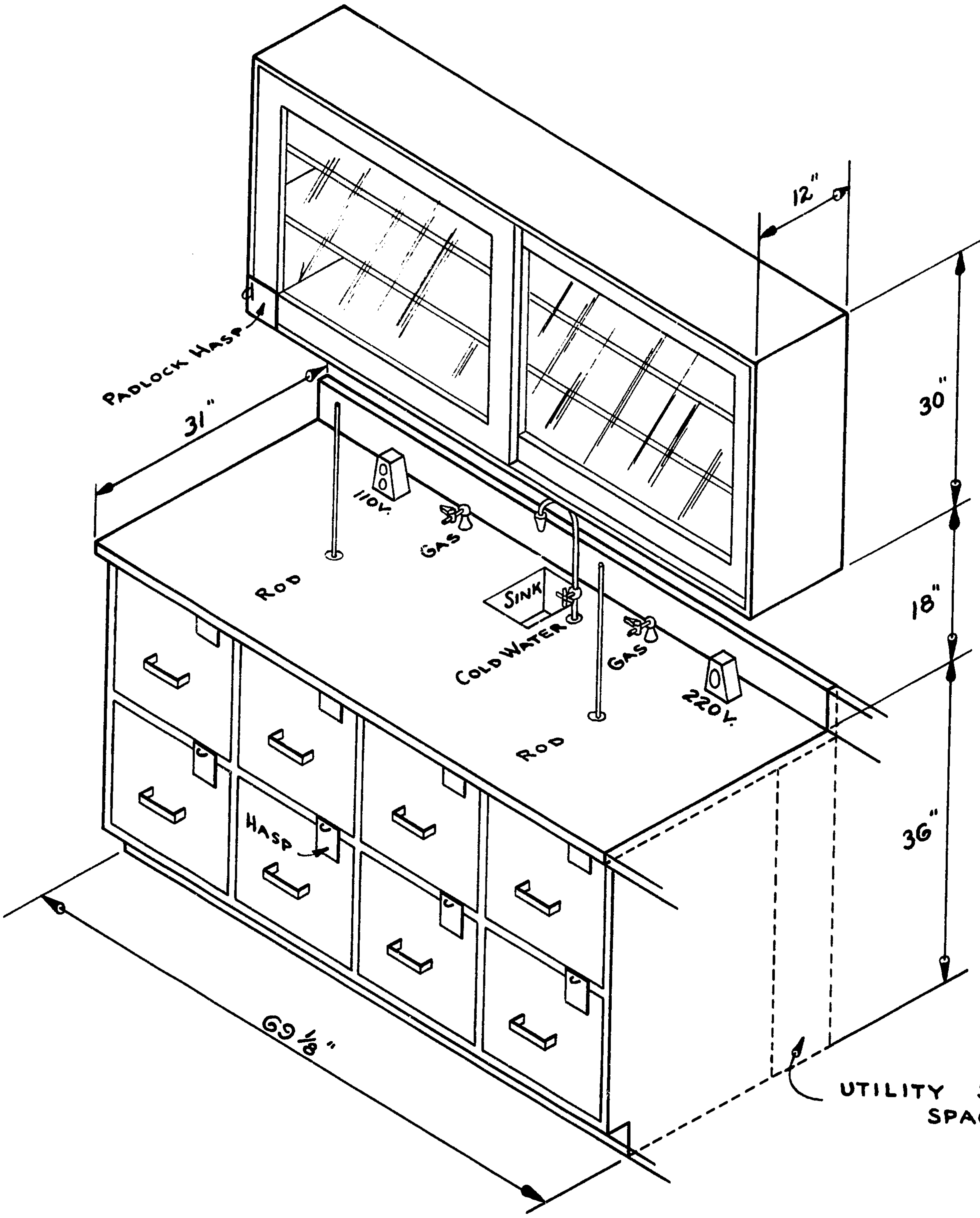
Students beginning a course in the general chemistry laboratory are assigned a locker which is stocked with most of the apparatus they will need. The commonly used chemicals and solutions required for most experiments are available from the side shelf which the instructor opens to the students.

Some items which students will need are not commonly stocked in student lockers. Such items as additional ring stands, meter sticks, and troughs, can be stored in the laboratory in wall cabinets above the work bench. They can be issued to the students by the instructor during the laboratory period as needed, and checked back in and returned to the cabinets at the end of the laboratory period. This eliminates excessive student traffic to the stockroom to obtain or return such items.

Items, such as glass tubing, glass rod, additional beakers, funnels, and similar apparatus, which have been broken or are needed in excess of the amount issued in the locker, must be obtained by students from the main stockroom by signing a requisition to withdraw them.

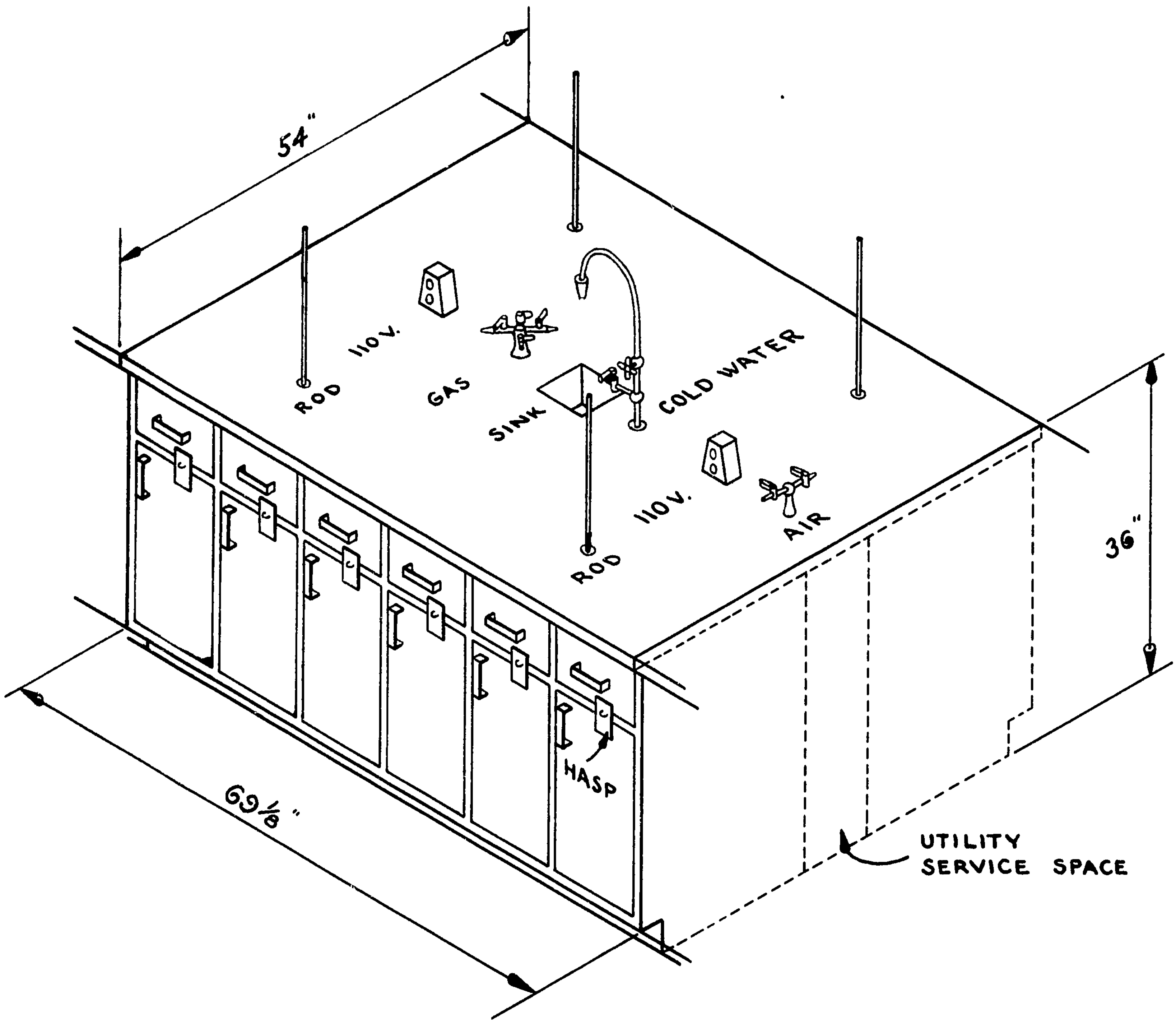
Several trip balances, triple-beam balances, and perhaps one or two torsion balances should be available in this laboratory. It is also desirable to provide three or four analytical balances of the cheaper and less sensitive variety. This makes it possible for students to perform experiments requiring second or third decimal point accuracy without having to go to the balance room to make weighings. The balances furnished for such purposes need not have an accuracy of four decimal places, and would not be suitable for use in the analytical laboratory.

Provision should be made for a muffle furnace and a drying oven in the general chemistry laboratory. They may be needed for chemistry service courses for other technologies, teaching a course in quantitative analysis, providing some specialized chemistry course during evening school, or to absorb overflow of students from other chemistry courses. If a muffle furnace and a drying oven are provided, they enhance the usefulness of the laboratory and reduce moving of large equipment to a minimum.



ONE UNIT OF
TYPICAL WALL ASSEMBLY
GENERAL CHEMISTRY LABORATORY
UNIT ①

Figure 9



ONE UNIT OF

CENTER TABLE ASSEMBLY

GENERAL CHEMISTRY LABORATORY

UNIT (5)

Figure 10

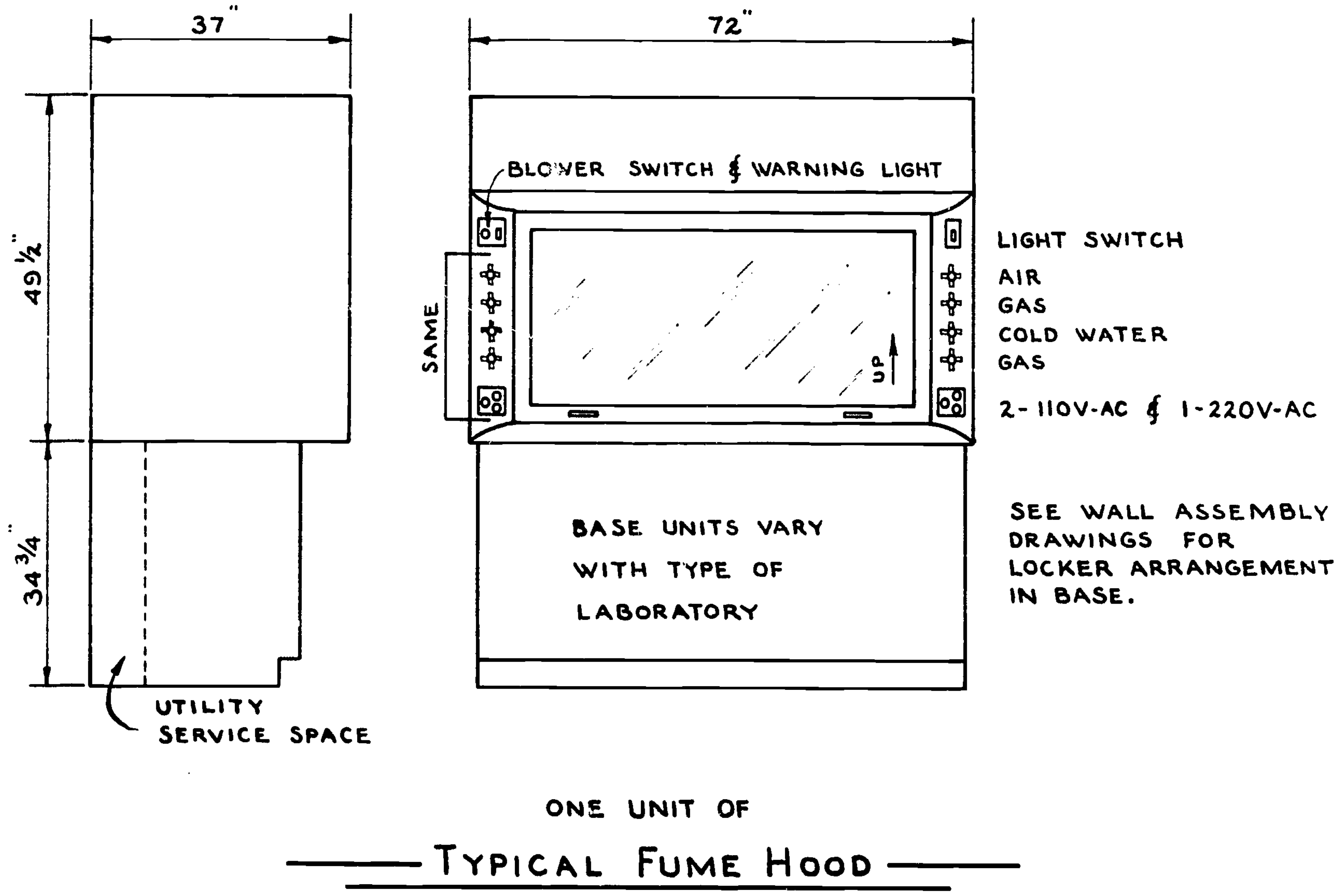


Figure 11

Analytical Chemistry Laboratory

The recommended location for the analytical laboratory is on the north side of the building, if possible, away from direct sunlight. It should accommodate at least 25 students, and preferably 30.

The balance room should be located immediately adjacent to the analytical laboratory so students do not have to go through the main corridor to use the balances. Since wet chemical processes must precede instrumental analyses, it is desirable that the room containing specialized equipment for instrumental analyses be immediately adjacent to the analytical laboratory.

Both the balance room and instrument room should be provided with constant temperature control to avoid inaccuracies in the use of gravimetric balances or instruments arising from changes in temperature. The instrument room should have controlled humidity in addition to constant temperature to avoid possible damage to instruments from moisture.

The arrangement within the analytical laboratory shown in figures 12, 13, and 14 differs from that of the general chemistry laboratory in that a larger number of muffle furnaces and drying ovens are required. Muffle furnaces should be located along a wall so that their automatic controllers can be mounted adjacent to them on the wall. The drying ovens may be arranged along the wall in front of the windows since they usually do not have separate automatic controllers.

One or more hotplates, approximately 18"x24", should be in each fume hood in the analytical laboratory. Small hotplates will be used periodically by students, but should be checked out of the storeroom for such temporary use.

It is recommended that muffle furnaces, hotplates, and drying ovens should not normally be turned off completely. There are several reasons for this. First, muffle furnaces are normally

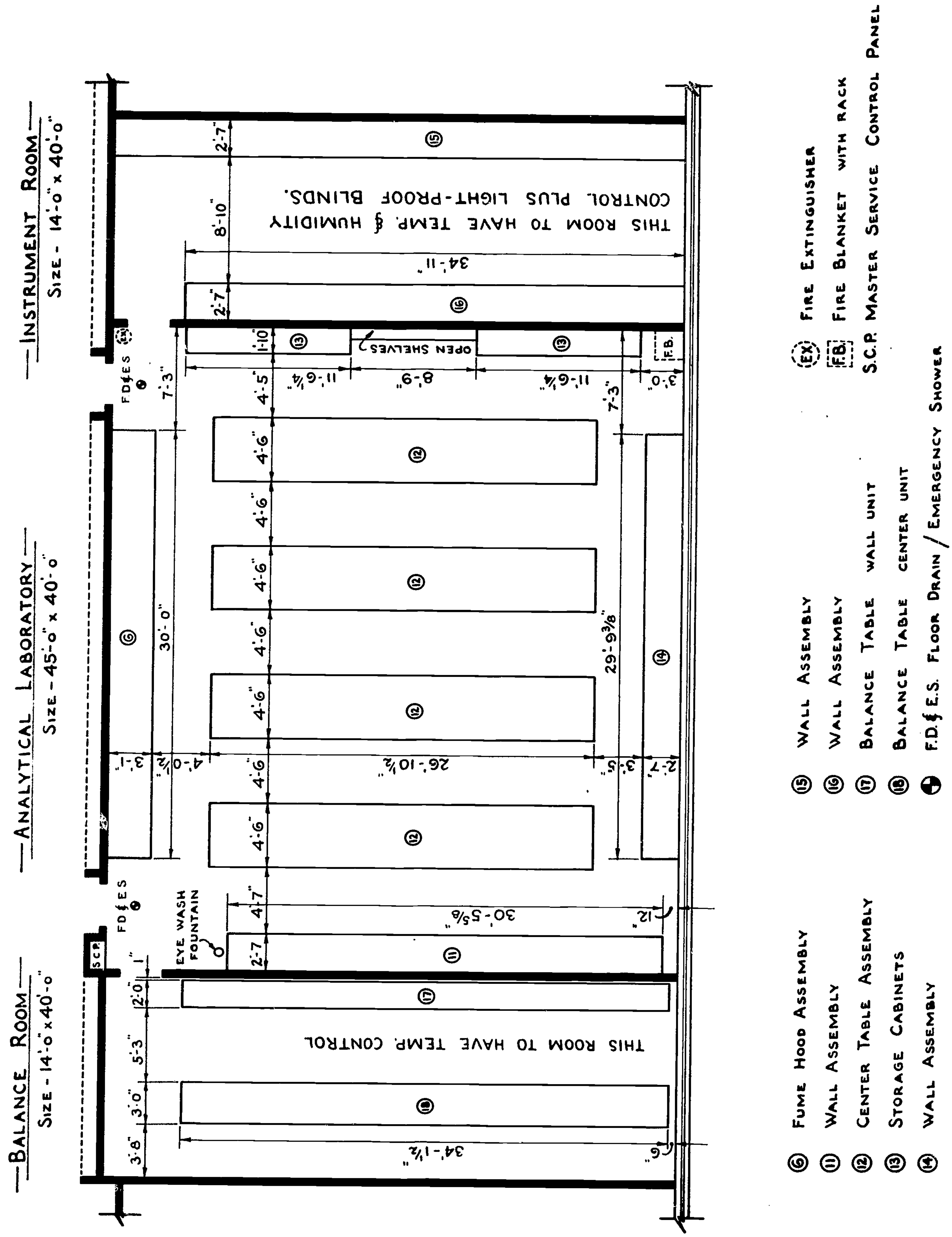

Balance Room
Size - 14'-0" x 40'-0"
Analytical Laboratory
Size - 45'-0" x 40'-0"
Instrument Room
Size - 14'-0" x 40'-0"
THIS ROOM TO HAVE TEMP. CONTROL
THIS ROOM TO HAVE TEMP. & HUMIDITY CONTROL PLUS LIGHT-PROOF BLINDS.
OPEN SHELVES
EYE WASH FOUNTAIN
FD & ES
S.C.P.
F.B.
EX
⑥ Fume Hood Assembly
⑪ Wall Assembly
⑫ Center Table Assembly
⑬ Storage Cabinets
⑭ Wall Assembly
⑮ Wall Assembly
⑯ Wall Assembly
⑰ Balance Table wall unit
⑱ Balance Table center unit
F.D. & E.S. Floor Drain / Emergency Shower
(EX) Fire Extinguisher
F.B. Fire Blanket with rack
S.C.P. Master Service Control Panel

Figure 12

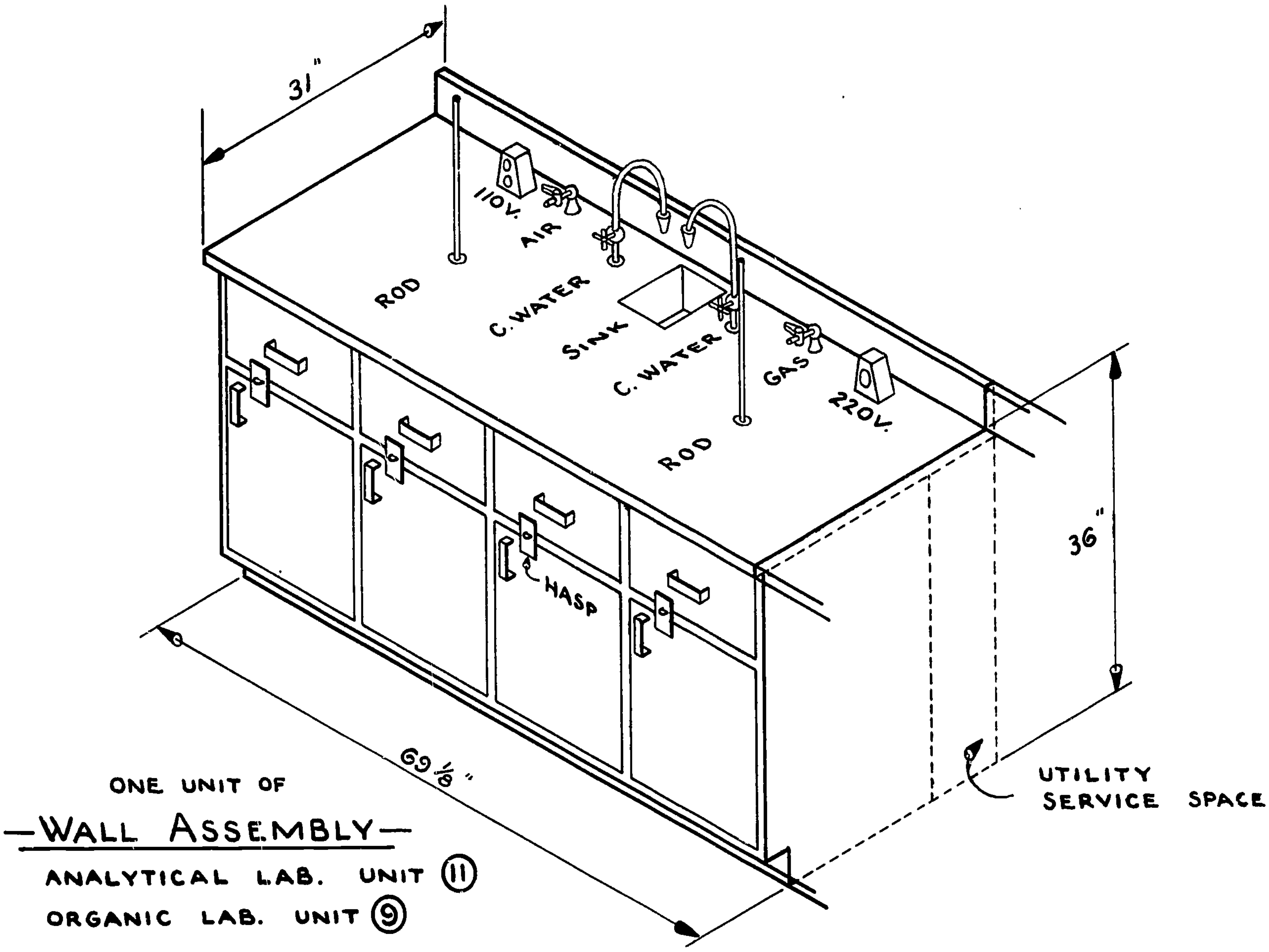
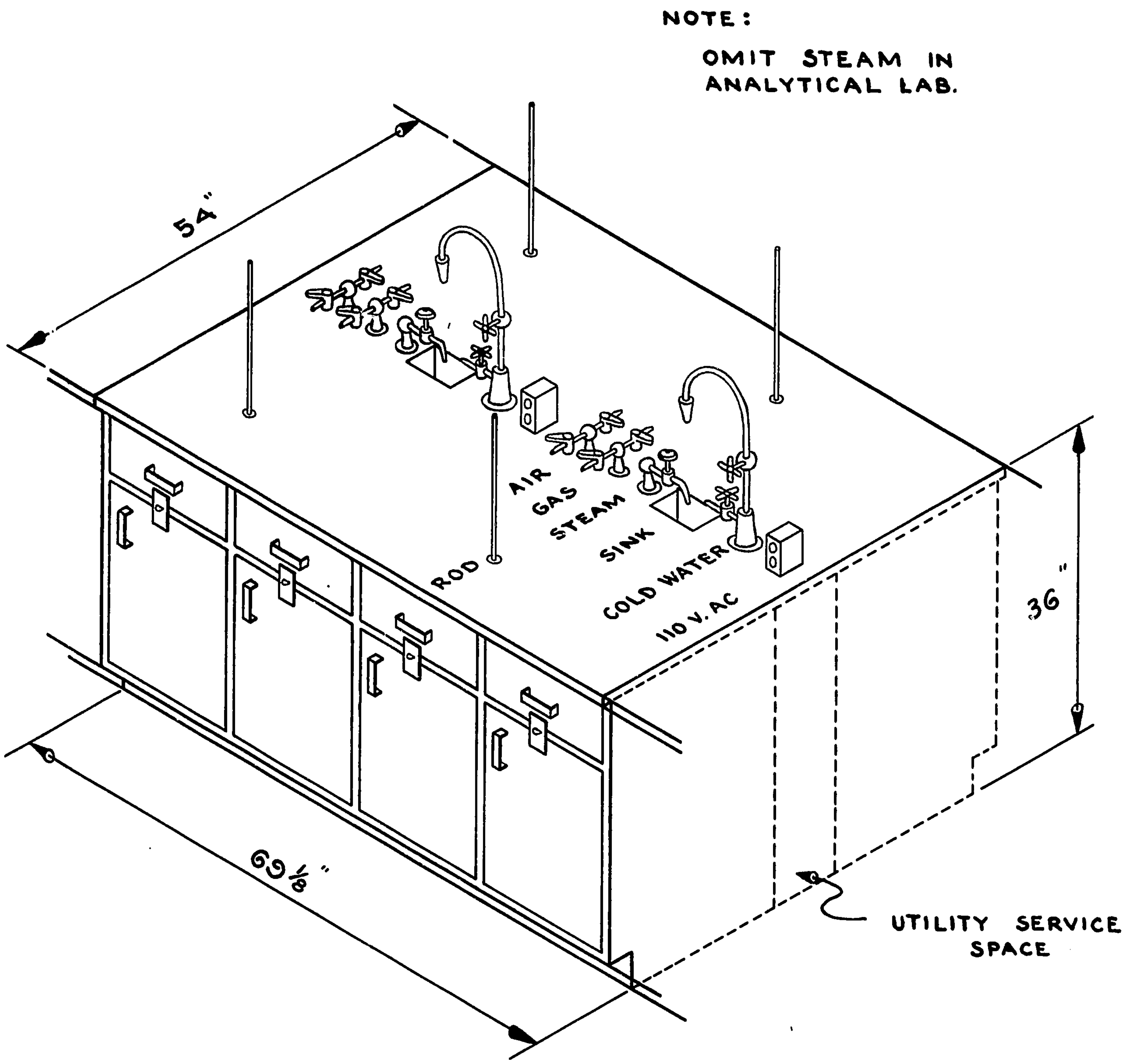


Figure 13

used at a temperature of approximately 2,000° Fahrenheit. If the furnaces are cold at the beginning of a laboratory period, most of the period is required for them to reach working temperature. A second reason is that frequent cooling and heating from room temperature to 2,000° causes the firebricks to spall and loosen, and eventually causes the furnace to fail, with the result that the furnace lining must be rebuilt. It is, therefore, recommended that the temperature controllers for such furnaces be set at a minimum of 400° Fahrenheit and the furnaces remain turned on constantly. The electric power thus required is negligible compared to cost of furnace repair. Similarly, drying oven controls should be set at some appropriate temperature for drying purposes, perhaps 105°, 110°, or 120° centigrade, and be left at that temperature so, when needed, they are ready for use. Hotplates in the fume hoods normally should be turned to the lowest possible heat and left on continuously. This makes it possible to heat the plates quickly to the temperature required for use, and minimizes failure of the heating elements from thermal shock due to frequent heating and cooling.

The lockers in the analytical laboratory are stocked with a larger assortment of apparatus and equipment than those in the general chemistry laboratory and, hence, must be larger. A representative list of student locker apparatus and its estimated cost is shown in Appendix B. The list of the major items of equipment required for this laboratory, including the balance room and the instrumentation room, and their estimated total cost are shown under "costs."



ONE UNIT OF

CENTER TABLE ASSEMBLY

ANALYTICAL LAB. UNIT (12)

ORGANIC LAB. UNIT (8)

Figure 14

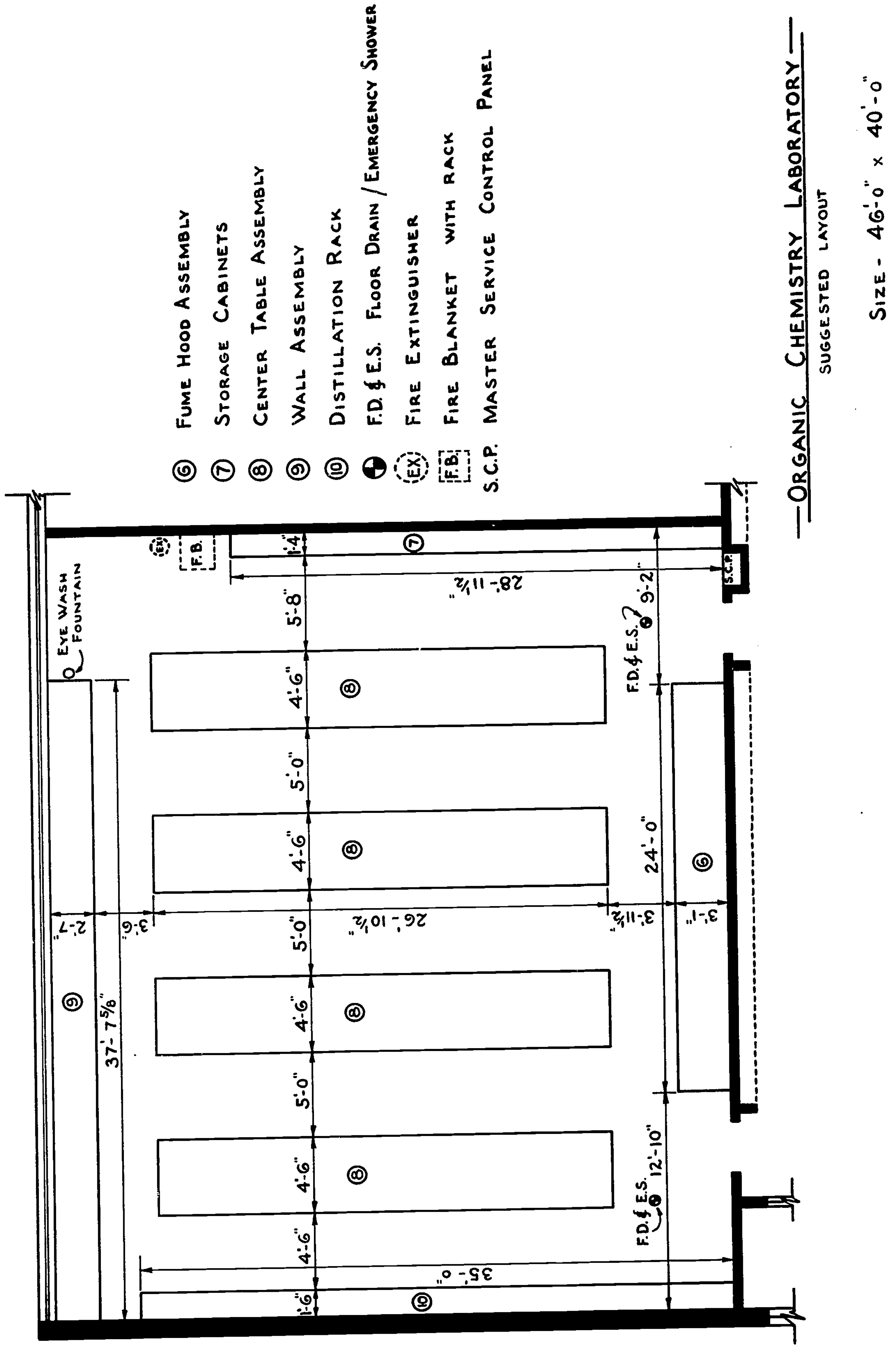

⑥ Fume Hood Assembly
⑦ Storage Cabinets
⑧ Center Table Assembly
⑨ Wall Assembly
⑩ Distillation Rack
F.D. & E.S. Floor Drain / Emergency Shower
EX Fire Extinguisher
F.B. Fire Blanket with Rack
S.C.P. Master Service Control Panel
Organic Chemistry Laboratory
Suggested Layout
Size - 46'-0" x 40'-0"
Eye Wash Fountain
F.B.
S.C.P.
F.D. & E.S.
28'-11½"
26'-10½"
37'-7⅝"
35'-0"
24'-0"
12'-10"
9'-2"
5'-8"
4'-6"
5'-0"
1'-4"
1'-6"
2'-7"
3'-6"
3'-11½"
3'-1"

Figure 15

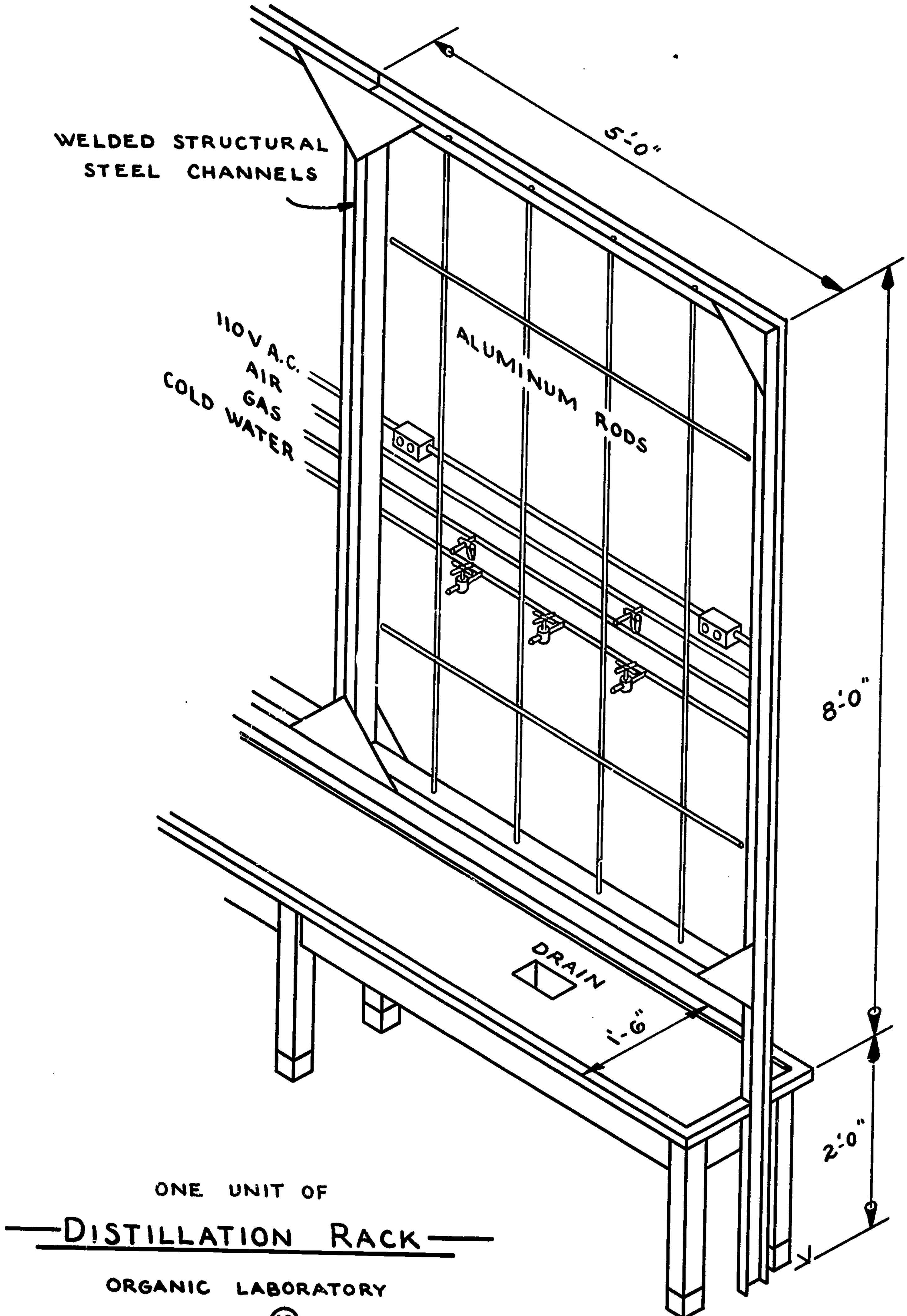

WELDED STRUCTURAL
STEEL CHANNELS
5'-0"
110 V A.C.
AIR
GAS
COLD WATER
ALUMINUM RODS
8'-0"
DRAIN
1'-6"
2'-0"
ONE UNIT OF
DISTILLATION RACK
ORGANIC LABORATORY
UNIT 10

Figure 16

Organic Chemistry Laboratory

The organic chemistry laboratory layout suggested in figure 15 is very similar to the layout in the main section of the analytical laboratory, including the lockers, work-station arrangements, and fume hoods. The most significant difference is that there is a distillation rack on one wall which can be used by students when an experiment requires that reaction or distillation apparatus be used for more than one laboratory period. The rack has sufficient space for all members of a class to mount their apparatus and leave it there until they have completed the experiment. The use of a wall rack, such as shown in figures 16 and 17, instead of the bench tops for experiments requiring assembled apparatus for more than one laboratory period makes it possible to use the laboratory for other classes between periods.

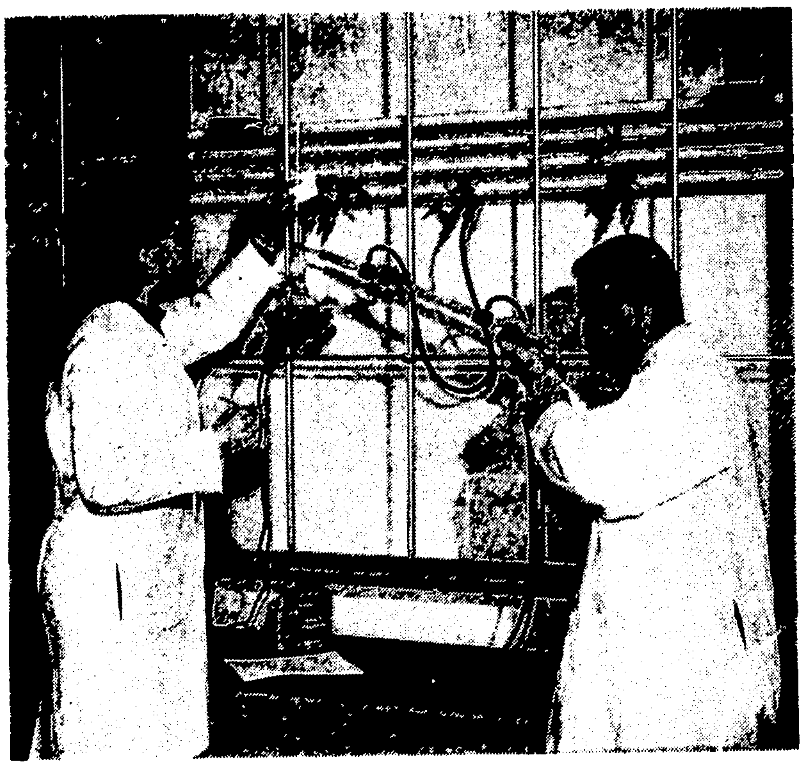


Figure 17. — Organic Chemistry Laboratory: Students assemble apparatus on distillation rack.

It is desirable but not mandatory that the organic chemistry laboratory be equipped with a muffle furnace, a drying oven, and one or two analytical balances. This permits the use of the laboratory for a physical chemistry group, a limited general chemistry course, or a biochemistry course in addition to organic chemistry.

A representative list of apparatus for each student locker is shown in Appendix B; and a list of major items of equipment for this laboratory, with their approximate total cost, is shown under "Costs."

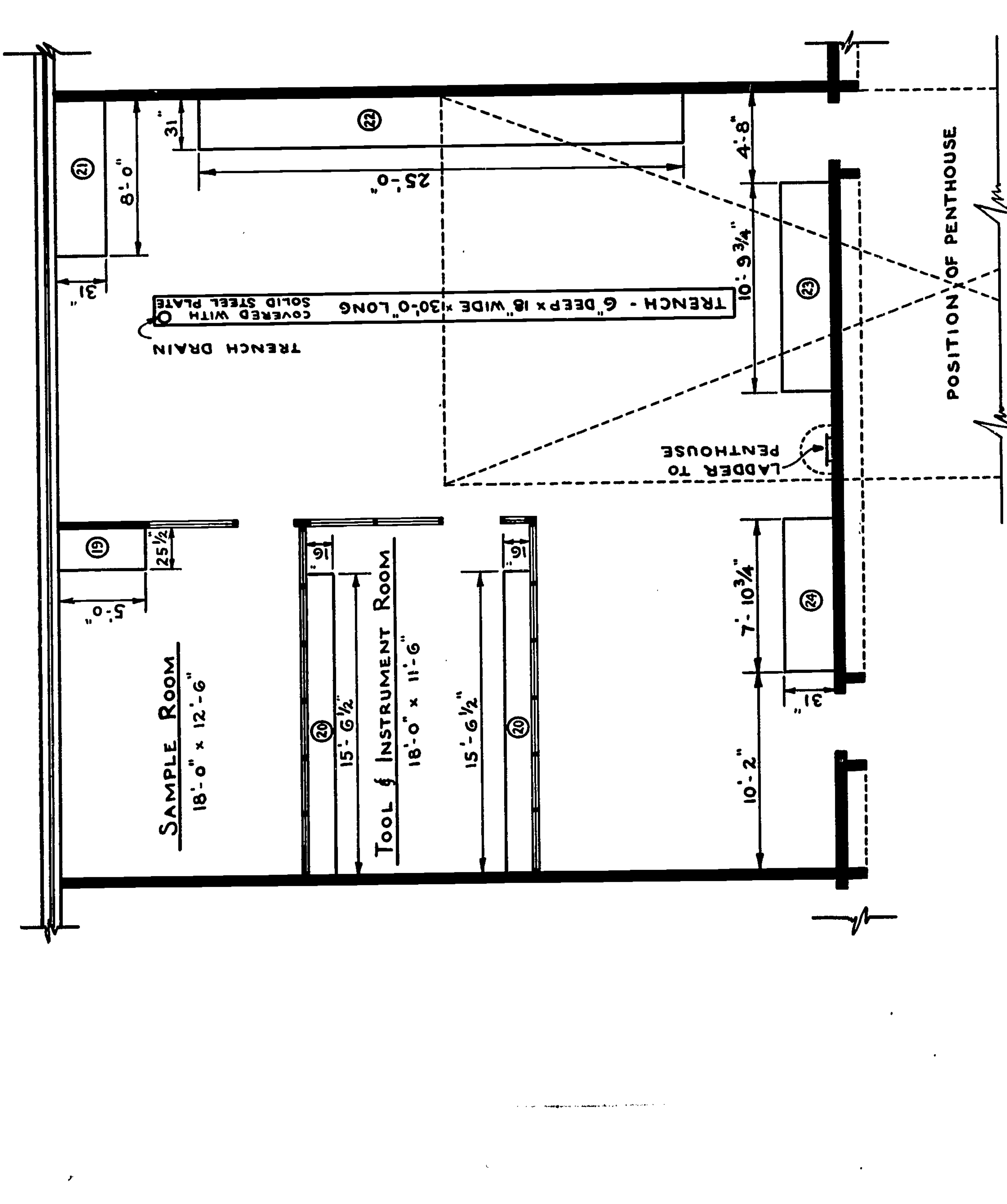
Unit Operations Laboratory

The suggested plan for the laboratory shown in figure 18 is different from the usual unit operations chemistry laboratory because it recommends that many of the instructional units be portable. In most unit operations or chemical engineering laboratories, equipment such as fluid-flow apparatus, heat exchangers, filter presses, and distilling units are complete assemblies, permanently installed, and connected to water, steam, and electrical services. Normally, each of these assemblies of equipment is used for a relatively short time during the course. As permanent installations, they occupy considerable laboratory space, and are seldom adaptable to other instructional use. It is therefore recommended for this laboratory that portable units be used which can be assembled, quickly connected to the plumbing or to the other services with snap-on connections, used, disassembled, and stored.

For example, the conventional equipment used to study filtration is comprised of a slurry tank with agitator, a variable speed pump to feed slurry through the filter press at the appropriate rate of flow, and a filter press. All are permanently assembled and connected to electric power, water, steam, and drain lines.

Using portable apparatus, two units are required to study filtration. One is a 40- to 60-gallon tank with agitator, and a metering pump piped to the tank, both mounted on a small platform which can be moved by a hand-operated fork-lift truck. The second unit is the filter press, mounted on a separate portable platform. Both are shown in figure 19.

The tank and pump unit can be moved with the forklift truck to a location in the laboratory where there is a suitable drain and set on the floor, with the filter press unit placed adjacent to it. The two units may then be connected together, to the drain, and to service outlets, such as water, steam, gas, and electric power with snap-on connections. The system is then ready



(19) Wall Sink
(20) Storage Cabinets
(21) Wall Assembly
(22) Wall Table Assembly
(23) Wall Assembly
(24) Wall Assembly

NOTE: Floor of penthouse over unit operations laboratory to be removable grating sections.

Unit Operations Laboratory

Suggested Layout

Size - 40'-0" x 40'-0"

Figure 18

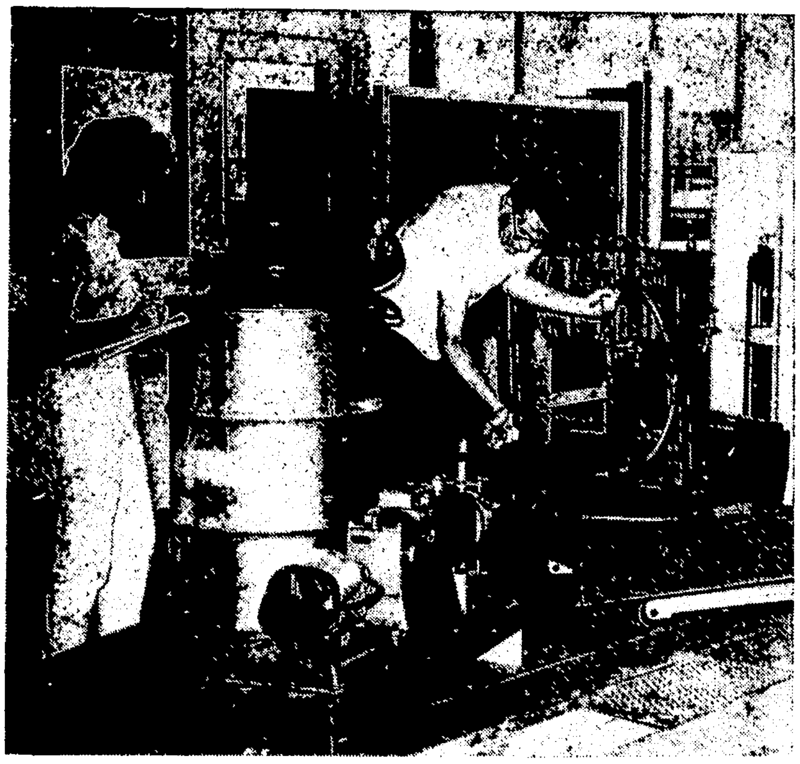


Figure 19.—Unit Operations Laboratory: Filtration Experiment — slurry tank unit with metering pump and filter press unit — using quick connections and floor drain.

to operate. The resulting unit is as efficient for the study of filtration as if it were permanently assembled.

The portable filtration study unit offers several advantages. First, it takes less space in the laboratory and can be dismantled into two sections and stored, thus releasing laboratory space for other phases of the course. Second, the students have the experience of assembling and connecting each piece of equipment, thus obtaining an understanding of the units and the interconnection and relationships in the final system. If the unit were permanently assembled and piped to the services, students might not really understand the elements of the system. When students assemble the portable system the exercise simulates industrial pilot-plant and small-batch production practice. Third, parts of portable units may be used for other types of experiments. The slurry tank and pump unit, for example, might be used in other experiments requiring a tank, agitator, and pump. Being portable and not permanently assembled to the filter press, it is available for use.

To study distillation it is suggested that a portable 4"- or 5"-diameter distillation unit with 5- or 6-bubble caps be made of glass pipe, mounted on a platform, and thus made portable,

Figure 20. — Unit Operations Laboratory: Student operating portable pyrex bubble cap fractionating equipment.

as shown in figure 20. It is further suggested that the still be electrically heated and supplied with a continuous feed. This eliminates the need for a large, jacketed steam kettle and for a batch operation, and more nearly simulates commercial distilling operations. The greatest advantage of using a glass still and bubble caps instead of the usual metal distillation column assembly is that the glass unit allows students to see what takes place inside of the column and on each bubble cap during the distillation process.

Some equipment required for a unit operation course is difficult to make portable. An example is the apparatus for the study of fluid flow suggested in figures 21 and 22. It requires so much piping and so many connections and measuring devices that it is more practical for the system to be permanently assembled on a wall or rack.

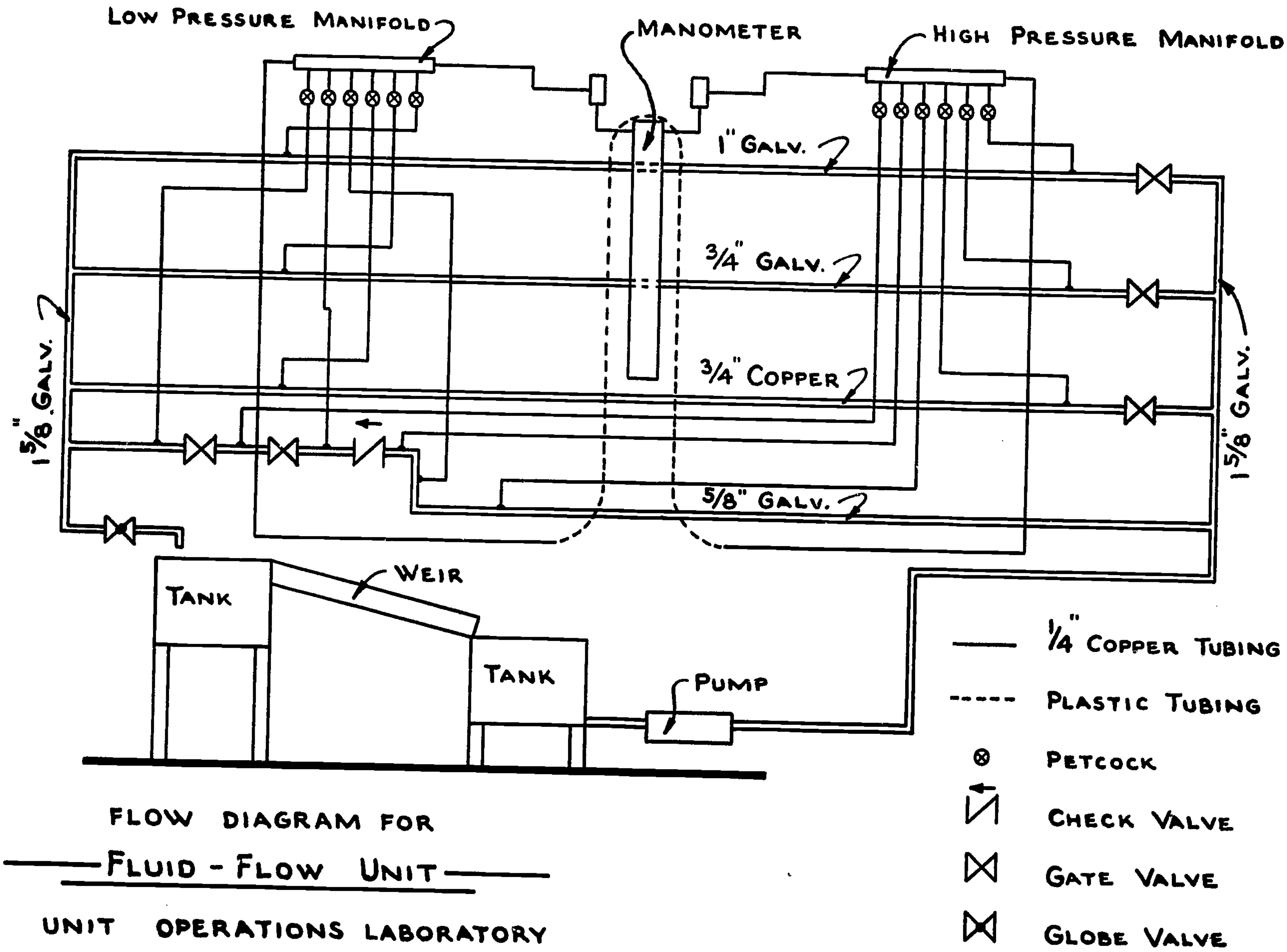


Figure 21

The equipment for studying heat exchange in liquids using heat exchangers connected to overhead tanks containing hot and cold water also probably should be mounted permanently on a laboratory wall where it occupies the least laboratory space, as shown in figure 23.

It is suggested that from 3 to 6 wooden tables mounted on large casters be part of the equipment in this laboratory. Various experiments involving small pieces of apparatus and equipment may be performed on them and the casters make them conveniently portable.

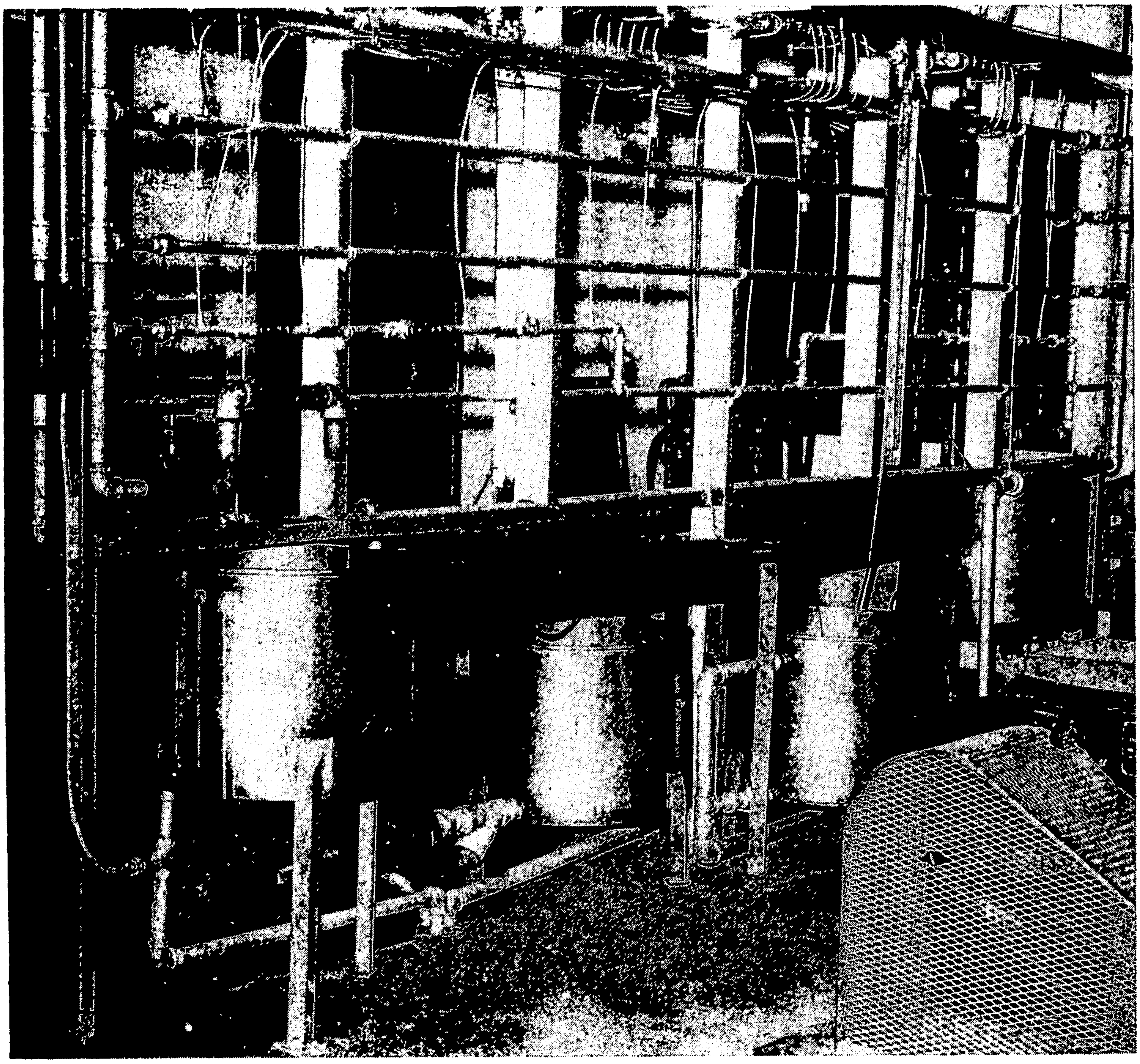


Figure 22. — Unit Operations Laboratory: Fluid Flow Apparatus, two units such as shown in Figure 21, set side-by-side provide experimental wash stations for 2 sets of students.

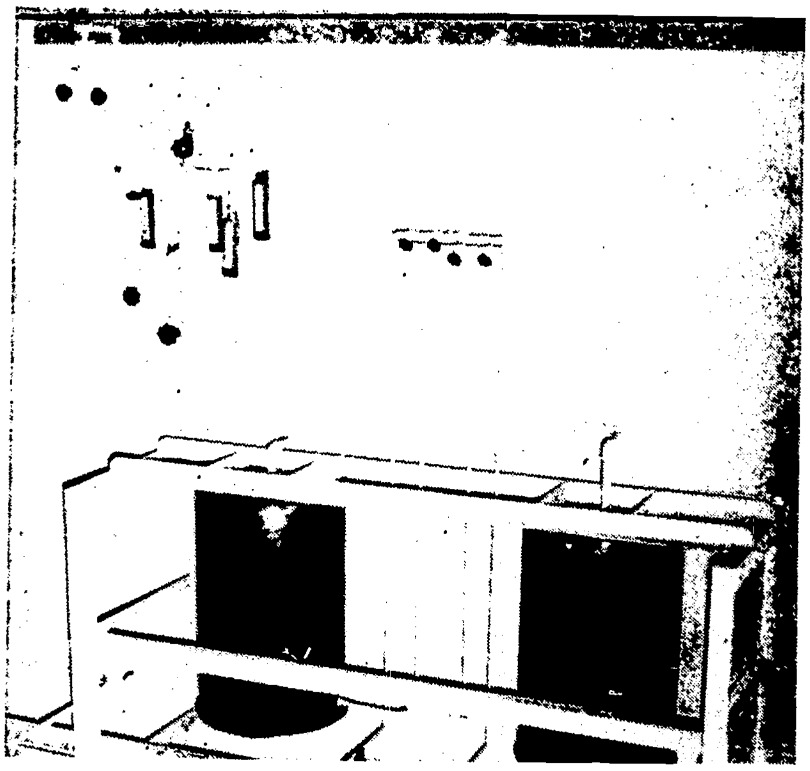


Figure 23. — Unit Operations Laboratory: Heat Exchange Experiment — Constant heat tanks and heat exchanger.

The part of the penthouse floor which overlaps the unit operations laboratory should be made of removable grating. If equipment must be assembled which requires more than ceiling height, the grating in the penthouse floor can be removed and the equipment assembled with the top extending into the penthouse.

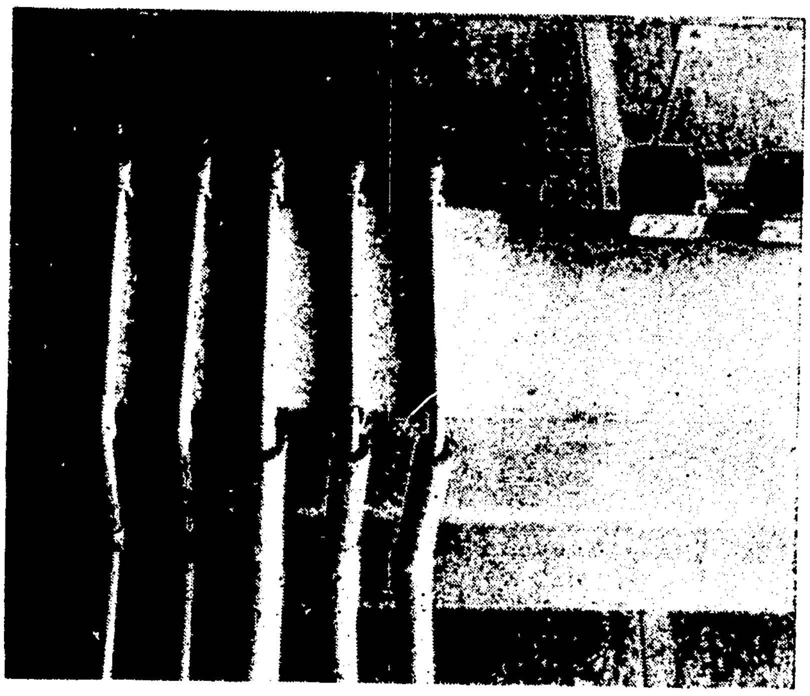


Figure 24. — Unit Operations Laboratory: Overhead quick connections for services, electricity, gas, water, steam, and air.

Provisions should be made for adequate dust collection and ventilation in the unit operations laboratory, with special attention to such dust-generating processes as grinding, crushing, and screening.

Careful planning to provide adequate service outlets for compressed air, gas, steam, hot water, and electric power in the unit operations laboratory equipped with portable instructional units is essential. Overhead outlets, such as are shown in figure 24, should be arranged so students can easily plug in or make the connections from a stepstool or short ladder. Numerous service outlets, well distributed on walls as well as overhead, provide maximum flexibility in the use of portable units.

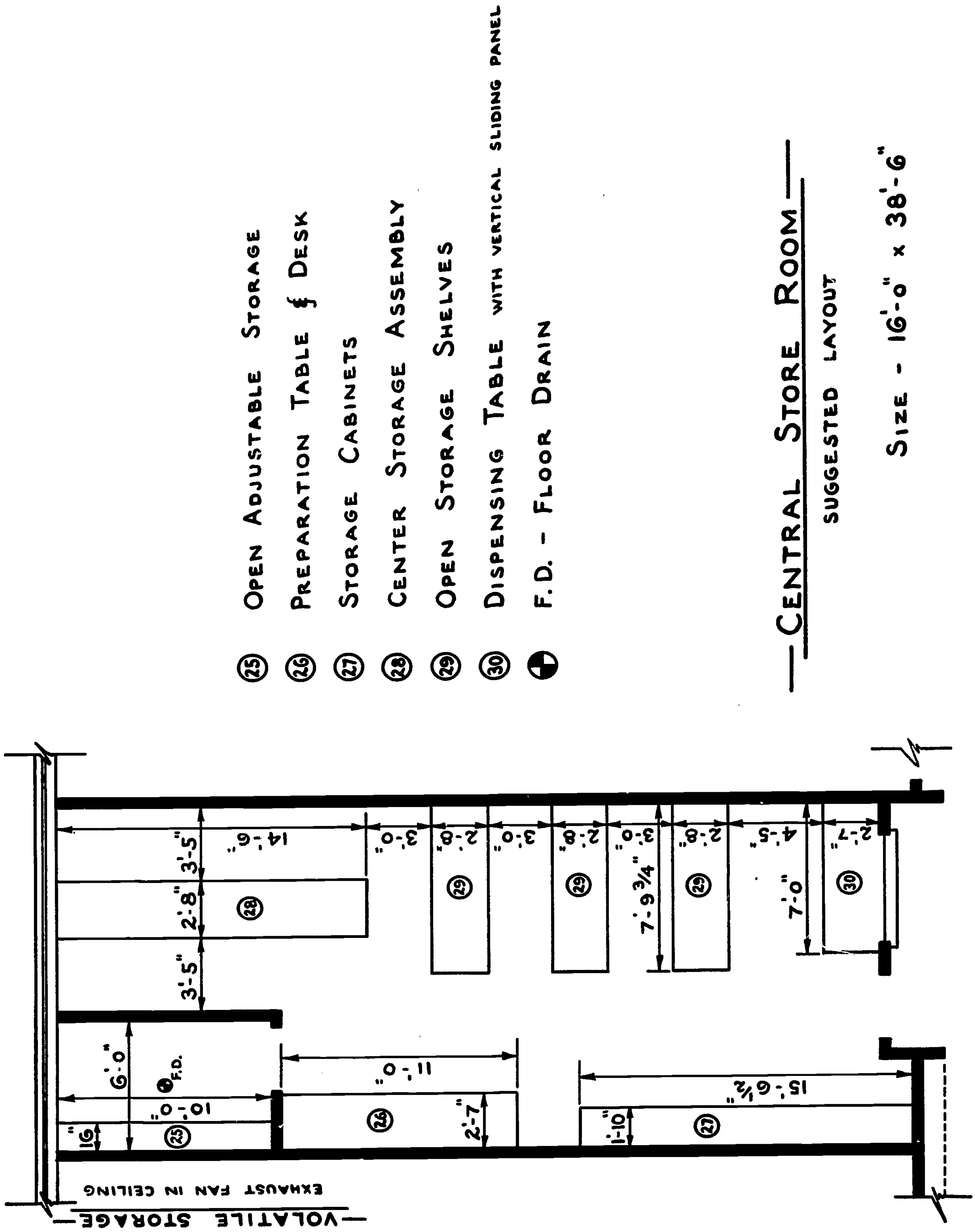
A list of suggested equipment for this laboratory, and an estimate of their total cost, is shown under "Costs."

Central and Reserve Storerooms

It is desirable to have the central storeroom located as near to all laboratories as possible to reduce to a practical minimum the distance and time required for students to go to the storeroom. In addition, a reserve storeroom is recommended in which to store case-lots of glassware, reagents, and similar items as they are delivered to the premises. This allows materials to be moved as needed to the central storeroom for distribution to various laboratories. The reserve storeroom should be located near the unloading ramp.

The central storeroom should be located away from exposure to direct sunlight if possible. Many chemicals tend to volatilize, and some decompose if exposed to direct sunlight; hence, windows should be few and shaded. The temperature of storerooms should be controlled to a uniform temperature and extremes of heat and cold should be avoided.

The central storeroom ideally should be managed by a full-time technical assistant. He should order materials, chemicals, and apparatus, and should also have enough technical training that he can supervise stocking and the general operation of the laboratories. He should see that safety equipment is operable and that



(25) Open Adjustable Storage
(26) Preparation Table & Desk
(27) Storage Cabinets
(28) Center Storage Assembly
(29) Open Storage Shelves
(30) Dispensing Table with vertical sliding panel
F.D. - Floor Drain
Central Store Room
Suggested Layout
Size - 16'-0" x 38'-6"
Volatile Storage
Exhaust fan in ceiling
14'-6"
3'-0"
2'-8"
3'-0"
2'-8"
3'-0"
2'-8"
4'-5"
2'-7"
3'-5"
2'-8"
3'-5"
7'-9 3/4"
7'-0"
6'-0"
F.D.
10'-0"
16"
11'-0"
2'-7"
15'-6 1/2"
1'-10"

Figure 25

hazardous chemicals are carefully controlled at all times. Poisonous, explosive, and other dangerous chemicals should be labeled with a special tag to indicate they are hazardous. Chemicals should be used in the order they are received, "first-in, first-out," to minimize deterioration with age. Unstable chemicals should be dated and a limit noted for the storage period permissible for each such chemical.

A "minimum-maximum" system of inventory control is recommended for the stockroom. It involves the setting of a minimum and maximum inventory for each item. A visual inspection of the supply of an item allows a quick count. When items have been reduced to the minimum, an order can be placed to replenish the quantity to the maximum.

The storeroom manager initially stocks student lockers, and students should provide him with an inventory slip at the end of each course to account for their breakage. Whenever students check materials out of the storeroom they should be required to sign checkout slips for accountability and inventory control.

The layout of the storeroom should be planned to facilitate easy issuance of stock from a dispensing window, see figures 25 and 26. When students are beginning laboratory exercises for which they need extra apparatus, the items most commonly used should be arranged near the window for quick issuance.

The storage units in which apparatus or supplies are stored should have adjustable shelves to fit various sizes and types of apparatus.

A section of the central stockroom should be a separate room for the storage of flammable and volatile materials. An explosion-proof exhaust fan should be installed in this room and operated continuously to prevent accumulation of volatilized fumes which may be explosive. A floor drain and a hose outlet should also be provided so that volatile chemicals, if accidentally spilled, can be flushed down the sewer without exposing other areas of the chemistry department to their hazards. The room should be provided with a wooden or metal panel door.

Volatile organic and other highly flammable materials should not be stored in quantity in chemical laboratories. They should be kept in the central storeroom and small amounts taken to laboratories as needed. Some, such as ether, may be stored in small safety cans in an explosion-proof refrigerator until needed in the laboratory.

Fire-extinguishing equipment should be located in the central storeroom. In case of fire in the storeroom or in any of the laboratories in the vicinity, extinguishers are thus available in or from the central storeroom.

The storeroom should contain extra supplies of from 20 percent to 50 percent of all items in the laboratory lockers. In addition, it must contain all materials necessary for all experiments in all courses and for all demonstrations. The content of any such storeroom is specific to the needs of each specific course; hence, cannot be predicted here. The instructors or head of the chemistry department must provide the list of items needed, based upon specific needs for the courses to be taught.

A portion of the central storeroom should be set aside to store apparatus and materials that are used in lectures and demonstrations. The storeroom manager may prepare such materials and store them for the lecturers to use as needed.

A suggested list of equipment required for the storeroom and its estimated cost is shown under "Costs."

Office Space for Staff

Suggested office space for staff is indicated on the schematic diagram, figure 2, for the chemistry department.

Office space should be provided for each instructor and it is recommended that no more than two staff members be located in any office. More than two staff members occupying an office tends to discourage students from approaching instructors for assistance.

It is desirable to have a waiting room adjacent to staff offices where students can study comfortably while waiting for the instructor's assistance. Usually the waiting room may house the departmental secretary who can arrange conference appointments for students if necessary.

No specialized equipment is needed for chemistry department staff offices.

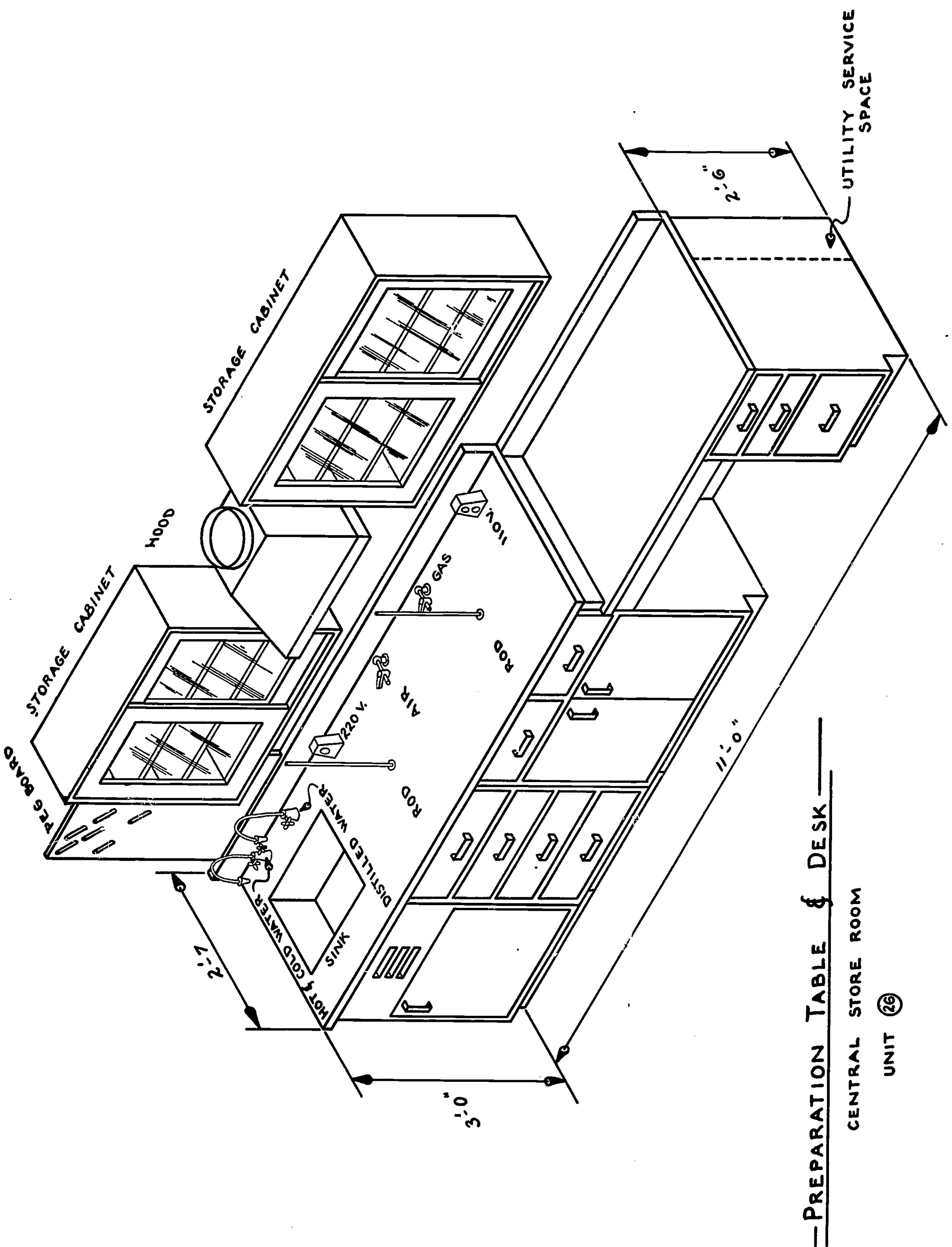

STORAGE CABINET
HOOD
STORAGE CABINET
PEG BOARD
HOT & COLD WATER
SINK
DISTILLED WATER
ROD
220 V.
AIR
ROD
GAS
110 V.
2'-7"
3'-0"
11'-0"
2'-6"
UTILITY SERVICE SPACE
PREPARATION TABLE & DESK
CENTRAL STORE ROOM
UNIT 26

Figure 26

Costs for Facilities and Equipment for Teaching Chemistry Technology

General Considerations

Building and equipping adequate chemistry laboratories for teaching chemistry is expensive. Institutions undertaking such programs may find it necessary or desirable to spread the initial building and acquisition expense of such laboratories over more than 1 year. Ideally, such laboratories will be built and completely equipped before the first class of students is enrolled. In practice, however, it is sometimes more feasible for the institution to build the laboratories and install the permanent work stations, lockers, fume hoods, and such equipment, and to provide only the *minimum of laboratory equipment*, such as analytical apparatus, balances, instruments, and such items as are required to begin the teaching program. This allows the program to be started with a minimum outlay of funds, and permits the cost of additional necessary or desirable equipment to be spread over a period of years while the laboratory equipment is being brought up to the level of a *well-equipped* facility for teaching chemistry.

If the entire group of laboratories and equipment cannot be purchased at the beginning of the program, it is strongly recommended that there should be no compromise in quality in the purchase of the permanently installed work stations, fume hoods, lockers, and chemical cabinets; and, that all of the laboratories be furnished with such equipment at one time. This plan provides good basic laboratories, usually at minimum cost, and allows them to be stocked with the necessary instruments, equipment, or apparatus as it is required or can be afforded.

The cost of establishing, equipping, and operating a department for teaching chemistry technicians will be found to vary somewhat depending upon whether it is near or far from major suppliers, the size of the department, the quality and the quantity of equipment or supplies purchased at a given time, and the method of purchasing. If the purchases can be made as a part of a large purchase of scientific equipment through a central purchasing agency, the total price of chemistry equipment and supplies may be somewhat less than if the items are purchased separately. Small purchases of chemical supplies or equipment usually are not subject to the supplier's discounts that are applied to purchases of larger quantities of the same supplies or equipment.

When plans to establish, enlarge, or re-equip a chemistry department progress to the point where a detailed and precise estimate of costs is required, it is suggested that the services of major suppliers be obtained so the cost estimates may be complete and sufficiently accurate for current budgetary purposes. Prior to a major purchase of equipment, a thorough examination should be made of the potential suppliers by the chemistry department head or instructors, because in chemistry, as in other technologies, major changes are constantly taking place in manufacturers and suppliers of special equipment. The purchase of up-to-date equipment of good quality is the best preparation for a successful teaching program for chemistry technicians.

Two types of suppliers probably will be involved in establishing or refurnishing a chemistry department. One type is the manufacturer and supplier of the major units of permanently installed equipment for chemistry laboratories, such as unitized chemistry worktables, fume hoods, sinks, and specialized storage cabinets. Generally these are supplied by the manufacturer and usually may best be purchased under a contract to both supply and install the equipment. Suppliers of such equipment provide engineering and consulting services free of charge, and will develop drawings, specifications, and plans that may be used for soliciting competitive bids.

The second type of supplier sells specialized equipment, such as gravimetric balances, glassware, chemicals, hotplates, muffle furnaces, and drying ovens.

Both types of suppliers may be found in *Thomas's Register*, or any other comprehensive listing of suppliers of chemical and scientific laboratory equipment.

Assumptions Made in the Following Estimated Costs

The following estimates of the cost of completely supplying and equipping an ideal chemistry department for teaching technicians are as of the time of this publication.

The estimates are based upon the acquisition of modern equipment and supplies of good quality, but not of the most expensive.

The estimates do not include equipment or facilities for teaching auxiliary chemistry courses for technologies other than chemistry, but the number of student lockers provided in the laboratories are sufficient to allow several classes of chemistry technicians to use the laboratories and have individual lockers. Some of these lockers could be equipped and used for auxiliary chemistry courses for other technologies.

The estimates assume the availability of a building of suitable construction, equipped with normal services, such as electricity, heat, and water, to and from the building, but otherwise unfurnished. The cost estimates include piping, wiring, plumbing, and other distribution of services within each facility described; and, include safety showers and eye-wash fountains.

No provision is made in this estimate for office furniture, conventional classroom blackboards, student seats, filing cabinets, and the conventional staff or instructor's office equipment.

Neither the conventional firefighting equipment commonly used in school buildings nor the special firefighting equipment required for a chemistry department is listed here because of the need for its being specifically indicated for each locality.

The estimated costs fall into two categories:

1. Permanently installed laboratory equipment, such as fume hoods, workbenches, sinks, and specialized cabinets. These are shown as estimates with a range of cost to allow for possible differences in quality, arrangement, or other differences arising and not predictable for a given situation. The cost estimates shown are for the equipment purchased and installed by a contractor. These are shown for each laboratory or major work space in the chemistry department. It is assumed and recommended that the basic work stations, fume hoods, chemical wall cabinets, and similar *permanently* installed equipment will be acquired for all laboratories at the same time and at the beginning of the program.
2. Specialized units of equipment, glassware, and similar supplies required for each laboratory or major working space, including the storeroom. These are shown as a gross figure with a range of estimated cost. Individual items are not priced for the reason that there may be substantial differences in the cost of comparable equipment and services available in various locations.

The estimates are for well-equipped laboratories having the furnishings and equipment described in the diagrams and listed hereunder for each facility. These facilities may be considered typical of those required for a good chemistry technician educating program. Facilities for any given institution may be expected to vary in detail, but should include most of the facilities and equipment here described to provide an adequately furnished and equipped department for teaching chemistry technicians.

The following list of laboratory equipment and apparatus is considered adequate. However, a *minimum* of laboratory equipment and apparatus required for starting the chemistry classes may be acquired at the beginning of the program and additional instruments, items of equipment, and apparatus added as necessary and feasible. *As a guide to the suggested minimum* required laboratory equipment and apparatus for chemistry teaching, *the items marked with an asterisk* (*) *are considered to be items* *which are not needed at the beginning of the teaching program but should be acquired as needed.* Where the number of items required is shown, as, Analytical balance 20 (10*), it means that 10 analytical balances should be acquired at the beginning of the teaching program and an additional 10 be added as needed or financially feasible.

The cost estimates include inventory for 30 student lockers for general chemistry and qualitative analysis taught in the first year of the curriculum. Stock for only 24 student lockers are included in the laboratory cost estimates for quantitative analysis and organic chemistry laboratories because experience shows that these second-year classes will be smaller due to student drop-outs. Classes of more than 24 students in quantitative analysis and organic chemistry are not recommended unless laboratories are larger than those suggested in this publication, and unless more than one instructor per class is available.

Estimates for Specific Facilities

Demonstration Lecture Room

Item	*Estimated cost*
Demonstration table	$ 750 to $ 1,000
Projection equipment for visual aids and periodic chart chemical elements	1,250 to 1,500
Total	2,000 to 2,500

General Chemistry Laboratory

Item	*Estimated cost*
Basic work stations, fume hoods, and chemical wall cabinets, installed	25,000 to 35,000
General analytical student locker inventory (30 lockers)	900 to 1,000
Qualitative analytical student locker inventory (30 lockers)	1,000 to 1,200

Laboratory Equipment

Item	*Number required*
Analytical balances, capacity 200 grams, sensitivity, 0.1 mg.	*4
Muffle furnace, 2000° F. with indicating Pyrometer controller	*1
Oven, drying, gravity convection, 40°-200° C. Range	*1
Shield, safety glass, approximately 30" x 30"	12
Balance, triple beam, capacity 311 grams, sensitivity, 0.01 gram	12
Estimated cost	$ 3,000 to $ 3,500
Estimated total cost of general chemistry laboratory and equipment cost	29,900 to 40,700

Analytical Laboratory (Including Balance and Instrument Rooms)

Item	*Estimated cost*
Basic work stations, fume hoods, and chemical wall cabinets, installed	$ 40,000 to $ 50,000
Student locker inventory (2)	3,200 to 3,600

Laboratory Equipment

Item	*Number required*
Hot plate, three-heat, 750° F., approximately 18" x 24"	6
Muffle furnace, 2,000° F. with indicating Pyrometer controller	6
Oven, drying, gravity convection 40°-200° C. Range	6
Desiccating cabinet, stainless steel, approximately 12" x 12" x 12"	4
Balance, torsion-type, dial and weight-loading device, 500 gm. capacity, 50 mg. accuracy	2
Balance, triple beam, capacity 311 grams, sensitivity, 0.01 grams	2
Estimated cost	$ 8,000 to $ 10,000

Balance Room Equipment

Item	*Number required*
Balance, analytical, direct reading constant load, 200 gm. capacity, sensitivity 0.1 mg.	*6
Balance, analytical, chainomatic, 200 gm. capacity, sensitivity 0.1 mg. with notched beam and damper	20 (*10)
Balance weights, tantalum, corrosion-resistant, 1 gm. to 50 grams, without fractionals, class S. tolerance	20 (*10)
Estimated cost	$ 12,000 to $ 15,000

Instrument Room Equipment

Item	Number required
Titrator, automatic	1
Polarograph, manual, nonrecording	2
Polarograph, recording	*1
Colorimeter, photoelectric	2
Spectrophotometer, for measurements in the 320- to 1000-millimicron range, with line-operated power supply	2
Spectrophotometer, recording, complete with accessories	*1
Balance, specific gravity, chainomatic type	1
Colorimeter, high resolution, grating type	2
Chromatograph, gas, with recorder, complete	1
Spectrophotometer, infra-red, recording, complete	*1
Microscope, polarizing	*1
Flame photometer, complete	1
pH meters, (line operated are recommended)	4
Potentiometric titrators	2

Plus quantities of assorted smaller items, such as magnetic stirrers, small hot plates, blender, various accessories, assorted electrodes, and spare parts.

Estimated cost	$ 35,800 to	$ 40,400
Total estimated cost of analytical laboratory and equipment	99,000 to	119,000

Organic Chemistry Laboratory

Item	Estimated cost	
Basic work stations, fume hoods, and chemical wall cabinets, installed	$ 35,000 to	$ 45,000
Student locker inventories (24)	2,800 to	3,200

Laboratory Equipment

Item	Number required
Desiccating cabinet, stainless steel, approximately 12 x 12 x 12 inches	4
Oven, drying, gravity convection, 40°-200° C. range	*1
Muffle furnace, 2,(( ))° F. with indicating pyrometer controller	*1
Air pump, vacuum, two-stage 33 liters/min. free air capacity 0.05 micron — vacuum ⅓ h.p. motor — mounted on dolly with casters	6 (* 4)
Shield, safety glass, approximately 30″ x 30″	12
Hot plate, three-heat, 750° F., approximately 18″ x 24″	4
Melting point apparatus, electric	2
Refractometer	

Plus quantities of assorted items, such as stirrers, small hot plates, and possibly an electric cork-boring machine. It is also assumed that the infra-red spectrophotometer and gas chromatograph located in the instrument room will be available for organic use.

Estimated cost	$ 7,200 to	$ 7,800
Total estimated cost of organic chemistry laboratory and equipment	45,000 to	56,000

Unit Operations Laboratory

Item	Estimated cost	
Basic work stations and special storage cabinets, installed	$ 4,000 to	$ 5,000

Laboratory Equipment

Item	Number required	
Heat-exchange assemblies	2	*1
Still assemblies, glass, bubble cap	2	*1
Fluid-flow assemblies (1 dual model), liquid	2	*1
Air-flow assemblies	2	*1
Slurry tank assemblies with agitators and metering pumps	2	*1
Filter press assemblies, 12″ x 12″ filter size	2	*1
Extraction apparatus, counter current	1	
Precision gas meter	1	
Pot-type electric furnace with controller	1	
Gas analyzers	2	*1
Tables on casters	6	
Platform scales, 500-lb. capacity	1	
Platform scales, 200-lb. capacity	1	
Solution scale, 20-kilo. capacity	1	
Pulverizer, Braun	1	
Chipmunk crusher, Braun	1	
Hammer mill, micropulverizer	1	
Ro-tap sieve shaker	1	
Sets of sieves for Ro-tap	2	*1
Recording thermometers	2	*1
Assorted voltmeters and ammeters		
Assorted thermometers		
Assorted manometers		
Potentiometers	6	*4
Assorted pipe flanges for orifices		
Assorted Rotameters		
Boiler, steam, approximately 25 lb. press — approximately 10 hp	*1	
Water still complete with tank controls, etc.	1	

Miscellaneous small tools, pipe fittings, power tools, etc.

Estimated cost	$28,000 to	$32,000
Total estimated cost laboratory and equipment	32,000 to	37,000

Storerooms

Item	*Estimated cost*
Work and desk assembly, exhaust fume, dispensing counter and window, storage racks, and cabinets, installed	$ 4,000 to $ 5,000
Glassware, equipment, and supplies	14,000 to 18,000
Total estimated cost storeroom	18,000 to 23,000

GRAND TOTAL ESTIMATED COST

(Recapitulation)

Demonstration lecture room	$ 2,000 to $ 2,500
General chemistry laboratory	29,900 to 40,700
Analytical laboratory	99,000 to 119,000
Organic chemistry laboratory	45,000 to 56,000
Unit operations laboratory	32,000 to 37,000
Storerooms	18,000 to 23,000
Grand total	$225,900 to $278,200

* The total estimated cost of the asterisked items in the foregoing list is from $35,000 to $40,200. This means that the initial financial outlay for minimum facilities for teaching chemistry technology should be from $190,000 to $238,000; and an additional expenditure of $35,000 to $40,000 for additional laboratory equipment and apparatus, either at the beginning of the program or as required and economically feasible.

The foregoing cost estimate does not include the building to house the laboratories and contained facilities. The schematic layout of these recommended facilities suggests 14,400 square feet of floor space. Bare building costs with electricity, plumbing, and such services to the building may be estimated to range from $10.50 to $12.00 per square foot. The building may, therefore, be estimated to cost from $151,000 to $173,000.

In summary, the estimated cost of providing buildings and facilities for teaching chemistry technology is from $377,000 to $451,000, of which from $35,000 to $40,000 may be spent for laboratory equipment as needed or as is financially feasible. Thus, the minimum estimated cost to start such a program by constructing buildings and equipping laboratories should be estimated to be between $342,000 to $410,000, with planned expenditure of an additional $35,000 to $40,000 for equipment and apparatus after the program is begun. In addition, when equipment becomes obsolete or new types of equipment or apparatus becomes standard for the industry, new laboratory equipment should be bought to keep the teaching facilities up to date.

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Appendixes

Appendix A

A Selected List of Professional and Technical Societies and Trade Organizations Concerned with Chemistry and its Application

THE LIST which follows[1] is not a complete listing of all such societies and organizations. Inclusion does not imply special approval, nor does omission imply disapproval. Details regarding local chapters or sections of these societies and organizations have been omitted.

Teachers and others desiring specific information from the societies and organizations listed here should address their inquiries to "the Executive Secretary" of the society or organization.

PROFESSIONAL OR TECHNICAL SOCIETIES

AMERICAN CHEMICAL SOCIETY, 1155 Sixteenth Street NW., Washington, D.C., 20036.

History: Organized April 20, 1876; incorporated 1877; reorganized 1891-92 to secure national participation; incorporated under Federal Charter, 1938.

Purpose: To encourage in the broadest and most liberal manner the advancement of chemistry in all its branches; to promote research in chemical science and industry; to improve the qualifications and usefulness of chemists through high standards of professional ethics, education, and attainments; to increase and diffuse chemical knowledge; and by its meetings, professional contacts, reports, papers, discussions, and publications, to promote scientific interests and inquiry, thereby fostering public welfare and education, aiding the development of the country's industries, and adding to the material prosperity and happiness of its people.

Membership: 95,623 (as of June 30, 1963)

ACS Local Sections: 164 local sections; boundaries determined geographically.

ACS Divisions

Agricultural and Food Chemistry
Analytical Chemistry
Biological Chemistry
Carbohydrate Chemistry
Cellulose, Wood, and Fiber Chemistry
Chemical Education
Chemical Literature
Chemical Marketing and Economics
Colloid and Surface Chemistry
Fertilizer and Soil Chemistry
Fuel Chemistry
History of Chemistry
Industrial and Engineering Chemistry
Inorganic Chemistry
Medicinal Chemistry
Microbial Chemistry and Technology
Organic Chemistry
Organic Coatings and Plastics Chemistry
Petroleum Chemistry
Physical Chemistry
Polymer Chemistry
Rubber Chemistry
Water and Waste Chemistry

Publications

Analytical Chemistry, monthly
Biochemistry, bimonthly
Chemical Abstracts, semimonthly
Chemical and Engineering News, weekly
Chemical Reviews, bimonthly
Chemistry, monthly
Industrial and Engineering Chemistry, monthly, plus any of the following three quarterly sections: Process Design and Development, Product Research and Development, Fundamentals

[1] Selected in part from *Scientific and Technical Societies of the United States and Canada*. 7th ed., National Academy of Sciences —National Research Council, Washington, D.C., 1961

Inorganic Chemistry, bimonthly
Journal of Agricultural and Food Chemistry, bimonthly
Journal of the American Chemical Society, semimonthly
Journal of Chemical and Engineering Data, quarterly
Journal of Chemical Documentation, quarterly
Journal of Chemical Education, monthly
Journal of Medicinal Chemistry, bimonthly
Journal of Organic Chemistry, monthly
Journal of Physical Chemistry, monthly
Rubber Chemistry and Technology, five times a year, free to members and affiliates of the ACS Division of Rubber Chemistry

AMERICAN ASSOCIATION OF CEREAL CHEMISTS, INC. 1955 University Avenue., St. Paul 4, Minn.

History: Founded May 8, 1915, at Kansas City, Mo.; merged with the American Society of Milling and Baking Technology, March 28, 1923.

Sections: Northwest; Pioneer; Kansas City; Nebraska; Central States; Niagara Frontier; Pacific Northwest; Midwest; New York; Lone Star; Toronto; Cincinnati; Canadian Prairie; Northern California; Southern California; Chesapeake.

Committees: 15 association committees, 35 technical committees.

Purpose: To encourage and advance scientific and technical research in cereals and their products, particularly milling and baking, but including other industries utilizing cereals and products; to study analytical methods used in cereal chemistry and develop and adopt uniform or standard methods of examination and analysis; to promote a spirit of scientific cooperation among workers in the field of cereal knowledge; and maintain high professional standards in Association as conditions of membership, to encourage more general recognition of the chemist and biologist as essential factors in the development of cereal industries.

Total Membership: 1,300.

Publications:
Cereal Chemistry, bimonthly.
Cereal Science Today, monthly, except June and August.

AMERICAN ASSOCIATION OF TEXTILE CHEMISTS AND COLORISTS, P.O. Box 28, Lowell, Mass.

History: Organized November 1921; incorporated (Mass.) 1929.

Sections: Northern New England; Rhode Island, Western New England; Metropolitan New York; Hudson-Mohawk; Western New York; Delaware Valley; Washington; Piedmont: South Central; Southeast; Midwest; Pacific Northwest; Pacific Southwest.

Student Chapters: Lowell Technological Institute; Philadelphia Textile Institute; North Carolina State College; New Bedford Institute of Textiles and Technology; Auburn University; Georgia Institute of Technology; Clemson College; Bradford Durfee Technical Institute.

Purpose: To promote the increase of knowledge of the application of dyes and chemicals in the textile industry; to encourage in any practical way research work on chemical processes and materials of importance to the textile industry; and to establish for the members channels by which interchange of professional knowledge among them may be increased.

Total Membership: 7,316.

Publications:
American Dyestuff Reporter, fortnightly.
Technical Manual.

AMERICAN CRYSTALLOGRAPHIC ASSOCIATION, P.O. Box X, Oak Ridge, Tenn.

History: Organized 1949 by consolidation of the American Society for X-ray and Electron Diffraction with the Crystallographic Society of America.

Committees: Apparatus and Standards, Crystallographic Computing, Crystallographic Data, Publications.

Purpose: To promote the study of the arrangement of atoms in matter, the causes of such arrangements and their consequences, and of the tools and methods used in such studies.

Total Membership: 1,080.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, United Engineering Center, 345 East 47th Street, New York, N. Y. 10017.

History: Organized in 1908; incorporated in 1910.

Purpose: The advancement of chemical engineering in theory and practice and the maintenance of a high professional standard among its members.

Total Membership: 18,940.

Publications:
Chemical Engineering Progress, monthly
Computer Program Manual, irregular
Monograph and Symposium Series, irregular

AMERICAN INSTITUTE OF CHEMISTS, 60 East 42d Street, New York 17, N. Y.

History: Organized January 22, 1923, as the American Institute of Chemistry; name changed to present title September 1923.

Chapters: Alabama; Baltimore; Beaver Falls, N. Y.; Chicago; Delaware; Florida; Louisiana; Middle West (Kansas-Missouri-Nebraska); New England; New Jersey; New York; Niagara; Ohio; Philadelphia; Piedmont (Ga.); Pittsburgh; Tennessee; Twin Cities (Minneapolis-St. Paul); Washington; Western.

Purpose: To advance the profession of chemistry in the United States.

Total Membership: 2,857.

Publications:
Chemists, monthly

AMERICAN LEATHER CHEMISTS ASSOCIATION, University of Cincinnati, Cincinnati 21, Ohio.

History: Organized 1903; incorporated August 1937 in New Jersey.

Purpose: To devise and perfect methods for analysis and testing of leathers and all materials used in connection with their manufacture; to promote the advancement of chemistry and other sciences, especially in regard to their application to problems of the leather industry; to publish results of investigations and research; and to advance the professional welfare of its members.

Total Membership: 932.

Publication:

Journal, monthly.

AMERICAN OIL CHEMISTS' SOCIETY, 35 East Wacker Drive, Chicago 1, Ill.

History: Organized 1909 as the Society of Cotton Products Analysts; name changed in 1920 to its present title.

Committees: Bleaching Methods, Cellulose Yield, Color; Fat Analysis; Glycerin Analysis; Refining; Seed and Meal Analysis; Soap and Synthetic Detergent Analysis; Spectroscopy; Statistical; Technical Safety; Uniform Methods.

Purpose: To encourage the advancement of the chemistry and technology of oils, fats, waxes, their constituents and compounds, and all allied and associated products; to promote research in these fields; to bring about standardization of analytical equipment, materials, and methods; to improve the qualifications and usefulness of oil chemists and technologists through high standards of professional ethics, education, and attainment; and by its meetings, discussions, analytical methods, and publications to increase and diffuse chemical and technical knowledge. The broad objects are to assist professionally and culturally the members of this Society to develop industry and technology in these fields and to add to the prosperity and welfare of the Nation.

Total Membership: 2,749.

Publication:

Journal, monthly.

AMERICAN PETROLEUM INSTITUTE, 1271 Avenue of the Americas, New York 20, N. Y.

History: Organized and incorporated March 20, 1919, in Washington, D.C.

Divisions: Production; Refining; Marketing; Transportation; Finance, and Accounting.

Departments: Technical Services, Statistics; Committee on Public Affairs.

Purpose: To afford a means of cooperation with the Federal Government in all matters of national concern; to foster foreign and domestic trade in American petroleum products; to promote, in general, the interests of the petroleum industry in all its branches; to promote the mutual improvement of its members and the study of the arts and sciences connected with the petroleum industry.

Total Membership: Approximately 11,000.

Publications:

Annual and Midyear Meeting Proceedings.
Statistical Bulletin, weekly.

AMERICAN SCIENTIFIC GLASSBLOWERS SOCIETY, 309 Georgetown Avenue, Gwinhurst, Wilmington, Del. 19809.

History: Organized March 14, 1952; incorporated in Delaware March 17, 1954.

Sections: Delaware Valley; Hudson-Mohawk; Metropolitan New York; Midwest; Niagara Frontier; Pittsburgh Tri-State; San Francisco Bay Area; Southeastern; Southern California; Washington-Baltimore.

Committees: Cooperative Testing, Methods and Materials, Safety and Hazards, Standards.

Purpose: To gather and disseminate knowledge concerning scientific glassblowing apparatus, equipment, and materials.

Total Membership: 536.

Publications:

Fusion, quarterly.
Symposium Proceedings, annual.

AMERICAN SOCIETY OF BREWING CHEMISTS, INC., 501 N. Walnut Street, Madison 5, Wis.

History: Organized as the Malt Analysis Standardization Committee; incorporated in Illinois, December 1935, under the present title.

Purpose: To study, develop, and adopt uniform or standard methods for the analysis of raw materials, supplies, and products of brewing, malting, and related industries; to secure uniformity in the statement of analytical results; to conduct, promote, and encourage scientific and technical research in brewing and related industries; to promote the spirit of scientific cooperation among all workers in the field of the industries concerned; to maintain high professional standards as requirements for membership in the Society; to encourage a more general recognition of the chemist and biologist as essential factors in the development of the brewing and related industries; and to communicate and cooperate with other organizations having similar or kindred purposes.

Total Membership: 890.

Publications:

Brewing Chemists Newsletter, quarterly.
Proceedings, annual.

AMERICAN SOCIETY FOR METALS, Metals Park, Novelty, Ohio

History: Founded 1920 as the American Society for Steel Treating, formed by an amalgamation of the Steel Treating Research Society and the American Steel Treating Society; name changed to present title in 1935. 114 chapters in United States and Canada.

Purpose: Service of members in the metal-producing and consuming industries through dissemination of technical information on the manufacture, treatment, and use of metals.

Total Membership: 31,500.

Publications:
- *Metal Progress,* monthly.
- *Transactions,* annual.
- *Review of Metal Literature,* monthly.
- Metals Handbook.

AMERICAN SOCIETY FOR QUALITY CONTROL, INC., 161 West Wisconsin Avenue, Milwaukee, Wis.

History: Organized and incorporated in New York City on February 16, 1946. There are 17 Districts.

Divisions: Administrative Applications, Aircraft and Missile, Automotive, Chemical, Electronics, Textile.

Committees: Metals Operations Research, Standards, Vendor-Vendee.

Purpose: To create, promote, and stimulate interest in the advancement and diffusion of knowledge of the science of quality control and of its application to industrial processes.

Total Membership: 12,000.

Publication:
- *Industrial Quality Control,* monthly.

AMERICAN SOCIETY FOR TESTING MATERIALS, 1916 Race Street, Philadelphia 3, Pa.

History: Organized June 16, 1898, as the American Section of the International Association for Testing Materials; incorporated under present title March 1902.

Purpose: The promotion of knowledge of the materials of engineering and the standardization of specifications and methods of testing.

Total Membership: 11,500.

Publications:
- *Book of ASTM Standards,* triennial.
- Supplements to above in intervening years, 10 parts.
- *Bulletin,* 8 issues per year.
- Proceedings, annual.
- *Year Book,* distributed to members only.
- Special Technical Publications, irregular.

ARMED FORCES CHEMICAL ASSOCIATION, 2025 I Street NW., Washington 6, D.C.

History: Organized February 6, 1946, as Chemical Warfare Association; name changed to Chemical Corps Association, June 1, 1947, and to present title May 1948; incorporated in the District of Columbia.

Purpose: Promotion of national defense through use of chemical and physical sciences.

Total Membership: 3,280.

Publication:
- *Armed Forces Chemical Journal,* bimonthly.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS OF NORTH AMERICA, INC., P.O. Box 540, Benjamin Franklin Station, Washington, D.C. 20044

History: Organized September 1884 at Philadelphia, Pa.

Purpose: To secure, devise, test, and adopt uniform and accurate methods for the analysis of fertilizers, foods, feeding stuffs, dairy products, economic poisons, and other materials relating to agricultural pursuits; also medicinal products; cosmetics; and caustic poisons; to secure uniformity in the statement of analytical results; to conduct, promote, and encourage research in chemistry in its relation to agriculture; and to afford opportunity for the discussion of matters of interest to agricultural chemists.

Total Membership: 1,100.

Publications:
- *Journal,* quarterly.
- *Official Methods of Analysis of the Association,* revised every 5 years.

ASSOCIATION OF VITAMIN CHEMISTS, 9232 S. Hamlin Ave., Evergreen Park, Ill., 60642

History: Incorporated as a nonprofit scientific organization in 1944.

Purpose: To provide a medium for the interchange of ideas and information pertinent to vitamin chemistry and technology; to stimulate the study of vitamin methodology; and to increase the fund of knowledge pertaining to vitamins.

Total Membership: 150.

Publication:
- *Vitamin Abstracts,* quarterly.

ELECTROCHEMICAL SOCIETY, INC., 20 East 42nd Street, New York, N.Y. 10017

History: Organized April 3, 1902.

Sections: Boston, Chicago, Cleveland, Columbus, Detroit, Indianapolis, Midland, Mohawk, Hudson, New York Metropolitan, Niagara Falls, Ontario-Quebec, Pacific Northwest, Philadelphia, Pittsburgh, San Francisco, Southern California-Nevada, Texas, Washington-Baltimore, India.

Divisions: Battery, Corrosion, Electric Insulation, Electro-deposition, Electronics, Electro-Organic, Electrothermics and Metallurgy, Industrial Electrolytic, Theoretical Electrochemistry.

Purpose: The advancement of the theory and practice of electrochemistry, electrometallurgy, electrothermics, and allied subjects. Among the means to this end shall be the holding of meetings for reading and discussion of professional and scientific papers on these subjects; the publication of such papers; discussions and communications as may seem expedient; and cooperation with chemical, electrical, and other scientific and technical societies.

Total Membership: 3,182.

Publication:
- *Journal,* monthly.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, 980 M. & M. Building, Houston, Tex. 77002

History: Organized October 11, 1943; incorporated in Texas, October 1945.

Divisions: Northeast; North Central; South Central; Southwest; Western; Canadian.

Committees: Six technical group committees, headed by a technical practices committee, under which function 55 units and task groups.

Purpose: To encourage and correlate special study and research to determine causes of corrosion; to promote standardization of terminology, technical equipment, and design in corrosion control; to contribute to industrial and public safety by promoting prevention of corrosion; to foster cooperation between companies and individuals in joint solution of corrosion problems.

Total Membership: 6,450.

Publication:
Corrosion, monthly.

RADIATION RESEARCH SOCIETY, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Ill.

History: Organized and incorporated in the District of Columbia in 1952.

Purpose: To promote original research in the natural sciences related to radiation; to facilitate the integration of different disciplines in the study of radiation effects; to promote the diffusion of knowledge in these fields.

Total Membership: 1047.

Publication:
Radiation Research, monthly.

SOCIETY FOR APPLIED SPECTROSCOPY, Executive Secretary: Rev. James J. Devlin, Boston College, Chestnut Hill, Mass.

History: Founded November 1958, in New York with 16 local sections formerly united in a federation.

Sections:
- Baltimore-Washington Spectroscopy Society
- American Association of Spectroscopy, Chicago
- Cincinnati Society for Applied Spectroscopy
- Cleveland Society of Spectroscopy
- Society for Applied Spectroscopy, Delaware Valley
- Rocky Mountain Spectroscopy Society, Denver
- Optical Society of America, Detroit
- Indiana Spectrographers Society
- Intermountain Society for Applied Spectroscopy, Idaho Falls
- Southern California Society of Applied Spectroscopy, Los Angeles
- Milwaukee Society for Applied Spectroscopy
- New England Spectroscopic Society
- Society for Applied Spectroscopy of New York
- Optical Society of America, Niagara Frontier Section
- Society for Applied Spectroscopy, Ohio Valley Section
- Spectroscopy Society of Pittsburgh
- San Diego Society for Spectroscopy
- Southeastern Association of Spectrographers
- St. Louis Society for Applied Spectroscopy
- North Texas Society for Applied Spectroscopy
- Northern California Spectroscopy Society, San Francisco

Purpose: To advance and disseminate knowledge of spectroscopy in its widest sense; to advance the professional standing of its members; and to coordinate the efforts of its members individually and in sections.

Total Membership: 1,600.

Publication:
Applied Spectroscopy, six times yearly.

SOCIETY OF CHEMICAL INDUSTRY, AMERICAN SECTION, 30-30 Thomson Ave., Long Island City, N.Y.

History: Organized 1894; parent society, originally English, with sections in all parts of the English-speaking world, organized 1881.

Purpose: The promotion of industrial chemistry.

Total Membership: 874.

SOCIETY OF COSMETIC CHEMISTS, 2 East 63d Street, New York 21, N.Y.

History: Founded 1945.

Chapters: Chicago, California, New York, New England.

Scientific Committees: Laboratory Methods, Literature Review.

Purpose: To establish a medium for the dissemination of scientific knowledge of the toilet goods industry, and to improve the professional standing of scientists in the fields of cosmetics and perfumery.

Total Membership: 950.

Publication:
Journal, bimonthly.

SOCIETY OF PETROLEUM ENGINEERS (AIME), 6300 North Central Expressway, Dallas 6, Tex.

History: Organized in 1913 as a Committee on Oil and Gas of the AIME; expanded to become the Petroleum Division of AIME in 1922; became the Petroleum Branch of AIME in 1949; and, with the reorganization of AIME in 1957, became the present society, a largely autonomous organization operating within the framework of AIME.

Sections: Thirty-six sections in the United States, 2 in Canada, 3 in Venezuela, 1 in Saudi Arabia, and 1 in Sumatra; with 6 subsections in the United States and 27 student chapters.

Technical Committees: Education, General Editorial Production Review, Program, Symbols, Transactions Editorial.

Purpose: To furnish a medium of cooperation among those interested in the petroleum-natural gas industry, and to promote the advancement of this branch of mineral technology through meetings to stimulate the preparation, reading, discussions, and circulation of papers.

Total Membership: 14,453.

Publications:

Journal of Petroleum Technology, monthly.

Petroleum Transactions, AIME, annual.

SOCIETY OF PLASTICS ENGINEERS, INC., 65 Prospect Street, Stamford, Conn.

History: Organized December 1941, incorporated August 1942.

Committees: Education, Technical Advisory, Inter-Society Relations, Meetings, Publications, Administrative, Sections, Membership.

Professional Activities Groups: Plastics in Buildings; Plastics in Electrical Insulation; Extrusion; Reinforced Plastics; Injection Molding; Metal Mold Design and Construction: Castings and Plastics Toolings; Forming; Finishing; Thermosetting Molding; Vinyl Plastics, Polymer Structure and Properties; Fabricating; Standards for Reporting Properties; Plastics in the Automotive industry.

Purpose: To promote in all lawful ways the scientific and engineering knowledge relating to plastics.

Total Membership: 7,679.

Publication:

Journal, monthly.

SOCIETY OF THE PLASTICS INDUSTRY, INC., 250 Park Avenue, New York 17, N.Y.

History: Organized 1927; chartered in the State of New York 1937.

Sections and Chapters: Midwest: Chicago, Detroit, Ohio; New England; Philadelphia; Western: Northern California, Southern California; Canadian: Montreal, Toronto.

Divisions in the United States: Button, Cellular Plastics, Epoxy Resin Formulators, Fluorocarbons, Garden Hose, Housewares Manufacturers, Industrial Container, Machinery, Melamine Dinnerware, Mold Makers, Molders Management, Plastics for Tooling Polyethylene Film, Polystyrene Wall Tile, Reinforced Plastics, Sheet Forming, Shoe, Thermoplastics Pipe, Thermoplastics Structures, Vinyl Dispersions, Vinyl Film Manufacturers, Profile Extruders, Plastic Bottle and Tube Manufacturers Institute, Vinyl-Metal Laminators Institute.

Committees in the United States: Accounting and Financial, Code Advisory, Plastics Education, Fire Prevention, Domestic Refrigeration, Engineering and Technical, Food Packaging Materials, Injection Machine Molding Standards, International, National Plastics Exposition, Plastics for Lighting Joint SPI-IES-NEMA, Public Relations, Radio Frequency, Heating, Safety, Tariff, Traffic, Polyethylene Committee on Construction, Industrial and Agricultural Applications, SPI National Conference.

Purpose: To assemble and disseminate scientific, engineering, and general informative data on plastics; to cooperate with the military and allied departments of the United States and Canadian Governments in the furtherance of their plastics projects; to act as an authoritative central forum for member companies; and to promote actively and to advance the application and use of plastics through greater public acceptance and favorable recognition of plastics products.

Total Membership: 3,550.

Publications:

Library: 1,000 volumes.

Appendix B

Representative Examples of Student Locker Equipment Lists

THE STUDENT LOCKER equipment lists shown here are those from a technical institute with a well-established chemical technician educating program. The lists are shown *only as examples*. Each institution teaching chemical technology must make its own individual list of student locker equipment to serve the needs of the courses it intends to teach.

GENERAL CHEMISTRY

Locker Inventory

1 Beaker, 100 ml	______	1 Ring, 4″	______
1 Beaker, 250 ml	______	4 Rubber stoppers	______
1 Beaker, 400 ml	______	1 Scoopula	______
1 Beaker, 600 ml	______	1 Spoon, deflagrating	______
4 Bottles, gas	______	1 Support, test tubes	______
1 Bottle, wash, plastic	______	10 Test tubes, soft, 6″	______
1 Brush, test tube	______	2 Test tubes, pyrex, 6″	______
1 Burette-student	______	1 Thermometer, 110″	______
1 Burner, Bunsen	______	1 Thistle tube	______
1 Clamp, pinchcock	______	1 Tongs, crucible	______
1 Clamp, test tube	______	1 Triangle, wire	______
1 Clamp, utility	______	1 Tubing, rubber, 2′	______
1 Crucible, porcelain	______	1 Watch glass	______
1 Crucible, cover, porcelain	______	______	______
1 Cylinder, graduated, 50 ml	______	______	______
1 Dish, evaporating	______	______	______
1 File, triangular	______	______	______
1 Flask, Erlermeyer, 125 ml	______	______	______
1 Flask, Florence	______	______	______
1 Funnel, filtering	______	______	______
1 Gauze, wire	______	______	______
2 Glass plates	______	______	______
1 Litmus paper	______	______	______

Date______________________ Section No.______________________

Name______________________ Locker No.______________________

A representative checklist showing equipment locker inventory for General Chemistry laboratory experiments.

NOTE: 1964 cost, bought in case lots or bulk purchase, $30.

QUALITATIVE ANALYSIS

Locker Inventory

2 Beakers, 100 ml	______	2 Scoopulas	______
2 Beakers, 250 ml	______	2 Spot plates	______
2 Beakers, 400 ml	______	2 Supports, test tube, semimicro	______
30 Bottles, dropping, 15 ml	______	20 Test Tubes, 3″ pyrex	______
2 Bottles, wash	______	1 Tray, bottle	______
2 Brushes, test tube, semimicro	______	2 Test Tubes, 6″ pyrex	______
2 Burners, Bunsen	______	2 Tubings, rubber, 2′	______
2 Clamps, test tube	______	______	______
2 Crucibles	______	______	______
2 Cylinders, graduated, 10 ml	______	______	______
20 Droppers, medicine	______	______	______
2 Flasks, Erlermeyer, 250 ml	______	______	______
2 Funnels, 65 mm	______	______	______
2 Gauges, wire	______	______	______
2 Glass plates, cobalt	______	______	______
2 Litmus papers	______	______	______
2 Rings, 4″	______	______	______

Date______________________ Section No.______________________

Name______________________ Locker No.______________________

A representative checklist showing equipment locker inventory for Qualitative Analysis laboratory experiments.

NOTE: 1964 cost, bought in case lots or bulk purchase, $40.

QUANTITATIVE ANALYSIS

Locker Inventory

3 Beakers, 100 ml	______	3 Funnels, 65 mm	______
3 Beakers, 250 ml	______	1 Gauze, wire	______
4 Beakers, 400 ml	______	1 Pipette, Mohr, 5 ml	______
3 Beakers, 600 ml	______	1 Pipette, 10 ml	______
2 Beakers, 100 ml	______	1 Pipette, 25 ml	______
4 Bottles, sample 4 oz.	______	1 Pipette, 50 ml	______
2 Bottles, storage, 21	______	3 Rings, 4″	______
2 Bottles, tincture, 500 ml	______	1 Scoopula	______
1 Bottle, wash	______	3 Speedy-vaps	______
4 Bottles, weighing	______	1 Thermometer, 110°	______
1 Burette, 10 ml	______	4 Test tubes 3″	______
2 Burettes, 50 ml	______	6 Test tubes 6″	______
2 Burette Caps	______	1 Test tube support	______
2 Burette Funnels	______	1 Tongs, crucible	______
1 Burette Holder	______	3 Triangles, wire	______
1 Burner, Fisher	______	2 Tubings, rubber, 2′	______
9 Crucibles	______	3 Watch glasses 5″	______
3 Crucible covers	______	1 Watch glass 6″	______
1 Cylinder, graduated 100	______	6 Crucibles, Gooch	______
2 Droppers, medicine	______	1 Desiccator	______
3 Flasks, Erlermeyer, 250 ml	______	1 Filtering flask	______
3 Flasks, Erlermeyer, 500 ml	______	1 Flask, volumetric, 100 ml	______
1 Flask, volumetric, 25 ml	______	1 Funnel, ground top	______
9 Flasks, volumetric, 100 ml	______	1 Holder, Gooch	______
2 Flasks, volumetric, 500 ml	______	3 Policemen	______
2 Flasks, volumetric, 250 ml	______	1 Funnel support	______
1 Tubing, rubber, vacuum	______	1 Test tube brush	______

Date______________________ Section No.______________________

Name______________________ Locker No.______________________

A representative checklist showing equipment locker inventory for Quantitative Analysis laboratory experiments.

NOTE: 1964 cost, bought in case lots or bulk purchase, $145.

ORGANIC CHEMISTRY

Locker Inventory

2 Adapters, bent ____
3 Beakers, 100 ml ____
3 Beakers, 250 ml ____
3 Beakers, 400 ml ____
3 Beakers, 600 ml ____
2 Beakers, 1000 ml ____
1 Beaker, 2000 ml ____
3 Bottles, gas ____
3 Bottles, reagent, 68 ml ____
6 Bottle, sample ____
1 Bottle, wash ____
1 Brush, test tube ____
1 Burner, Fisher ____
4 Clamps, condenser ____
4 Clamps, extension ____
1 Clamp, pinchcock ____
1 Clamp, screw ____
2 Clamps, test tube ____
1 Clamp, thermometer ____
8 Clamps, holder ____
3 Condensers ____
1 Cylinder, graduated ____
1 Dish, evaporating ____
1 Distilling column ____
2 Droppers, medicine ____
1 File, round ____
1 File triangular ____
2 Flasks, distilling, 50 ml ____
2 Flasks, distilling, 125 or 250 ml ____
2 Flasks, distilling, 500 or 1000 ml ____
4 Flasks, Erlenmeyer, 250 ml ____
1 Flask, filtering, 500 ml ____
1 Flask, Florence 500 or 1000 ml ____
1 Flask, round bottom, 200 or 300 ml ____
1 Flask, round bottom, 500 ml ____
1 Funnel, 65 mm ____
1 Funnel, Buchner, No. 0 ____
1 Funnel, separatory, 60 ml ____
1 Funnell, separatory, 125 or 250 ml ____
1 Funnel, separatory, 500 or 1000 ml ____
2 Gauzes, wire ____
2 Glass plates ____
1 Litmus paper ____
4 Rings, extension ____
2 Rings, flask ____
2 Scoopulas ____
1 Support, test tube ____
10 Test tubes, soft, 6″ ____
4 Test tubes, pyrex, 6″ ____
1 Test tube, pyrex, 8″ ____
2 Thermometers, 100° C. ____
2 Thermometers, 360° C. ____
1 Tongs, crucible ____
1 Tube, drying ____
1 Tube, "T" ____
8 Tubings, rubber 3′ ____
2 Tubings, vacuum ____
____ ____
____ ____
____ ____
____ ____

Date____ Section No.____

Name____ Locker No.____

A representative checklist showing equipment locker inventory for Organic Chemistry laboratory experiments.

NOTE: 1964 cost, bought in case lots or bulk purchase, $120.

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