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The design and organization of a junior college general chemistry laboratory

Malcolm Cornelius Holmberg
University of the Pacific

THE DESIGN AND ORGANIZATION OF A JUNIOR COLLEGE GENERAL CHEMISTRY LABORATORY

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by

Malcolm Cornelius Holmberg

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CHAPTER I

STATEMENT OF THE PROBLEM

Statement of the problem. How can a chemistry laboratory in the junior college be designed and organized so that there may be achieved a maximum of efficiency and minimum of time lost to the student in implementing the "scientific method"?

At Modesto Junior College the building which houses the chemistry laboratory at the present time was an aircraft shop during World War II. In 1946, as a result of increased enrollment, this building was converted into a chemistry laboratory. This was intended to be a temporary arrangement. With the expansion of program and further increases in enrollment, it became apparent that this building would not be adequate for this purpose.

There are certain aspects of this building that strike one with compelling force even on casual observation: (1) the laboratory cannot be readily adaptable to changes in curricula, (2) the instructor cannot discuss procedures with a single class because of physical limitations or poor organizational practices, (3) the student must spend much time collecting supplies and equipment in order to perform his task, and (4) it is difficult to read the etched

lines of burettes, volumetric flasks, and other calibrated equipment because of poor lighting.

There will follow in the ensuing chapters a brief list and definition of terms and the history, growth, purpose, and philosophy of the chemistry laboratory will be explained. How the laboratory achieves its purpose through the scientific method will be examined; also, the laboratory manual now being used will be evaluated. Another chapter will analyze the inadequacies of the physical plant, item by item. Pictures, diagrams, and tables will substantiate the statements regarding present conditions. A chapter will be devoted to a comparative study of design and organization of ten northern California junior colleges. The characteristics and a plan of a desirable laboratory will be followed by a summary, conclusions, and recommendations.

The sources of data and information used in this report are the literature, visitations by the investigator, a meeting of chemistry teachers, and an interview. The sources of literature were the libraries of the College of the Pacific, Modesto Junior College, and the University of California. Ten northern California junior college general chemistry laboratories were visited. In each case a member of the chemistry staff of the college visited served

as guide. A meeting of the Pacific Southwest Association of Chemistry Teachers was held January 8 and 9, 1954, at California State Polytechnic College in San Luis Obispo, California. On January 8, G. Ross Robertson, of University of California at Los Angeles, addressed the group on fundamental problems in chemistry building design. On January 9, a six-man panel discussed the usual problems faced in the construction of new science buildings. An interview was conducted by the investigator with Karl M. Roth, heating and ventilating expert.

The method of procedure employed is what Whitney refers to as the research survey method. "The survey, according to recent social science terminology, is an organized attempt to analyze, interpret, and report the present status of a social institution, group, or area."[1]

As a result of the findings in this report, structural and organizational changes were made in the present laboratory at the Modesto Junior College, and ideas acquired will be used in the new laboratory which is now in the planning stage.

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[1]Frederick Lamson Whitney, The Elements of Research (New York: Prentice-Hall, Inc., 1950), p. 161.

CHAPTER II

THE DEVELOPMENT OF THE CHEMISTRY LABORATORY

The laboratory, including the chemistry laboratory, enjoys a prominent place in all institutions of learning today. Its dual purpose of training students to observe and to think has been unimpeachably established. How this came about is a matter of great interest to teachers of science.

The first chemistry laboratory of which there is any record was established by Johannes Hartman at the University of Marburg in 1609.[1] Laboratory work consisted of practical exercises in pharmaceutical preparations. The first modern laboratory was established by Friedrich S. Stromeyer in the year 1806 at Gottingen University in Germany.[2] Students, the majority of whom were training for medicine, performed experiments in qualitative and quantitative analysis. Each student gave a written and oral report about his analysis.

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[1] George Lockemann and Ralph E. Oesper, "Friedrich Stromeyer and the History of Chemical Laboratory Instruction," Journal of Chemical Education, 30:203, April, 1953.

[2] Ibid., p. 202.

The first professor of chemistry in this country was appointed in 1786 at the College of the Province of New York.[3] Chairs of chemistry were established at Princeton in 1795, at Columbia in 1800, at Yale in 1802, at Bowdoin in 1805, at South Carolina and Dickinson in 1811, at Williams in 1812, and thereafter at most recognized universities.[4] Instruction was almost entirely by lecture demonstration with very few laboratories, and these were for the instructor and his assistants. President Eliot of Harvard wrote in 1904:

> When I was a student in the Harvard College there was not a single laboratory open to the students in any subject, either chemistry, physics, or biology. The only trace of such instruction open to students was in the department of botany and that was only for a few weeks with a single teacher, the admirable botanist, Asa Gray, and he had neither apparatus nor assistants, and it was a hopeless job which he undertook for a few weeks in May and June. I was the first student who ever had the chance to work in the laboratory in Harvard College and that was entirely due to the personal friendship of Professor J. P. Cook, who fitted up a laboratory in the basement of University Hall,

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[3] Frank Pierrepont Graves, <u>A History of Education in Modern Times</u> (New York: The Macmillan Company, 1925), p. 347.

[4] David J. Blick, "The Purpose and Character of Laboratory Instruction," <u>Journal of Chemical Education</u>, 32:264, May, 1955.

> entirely at his own expense. That was the situation of the colleges in the country--for Harvard was by no means peculiar in this respect--only sixty years ago.[5]

Another early chemistry laboratory established in this country was at Rensselaer Polytechnic Institute in 1825.[6] Students were required to lecture and perform experiments before the class. It was not until the beginning of the twentieth century that individual laboratory work became common.

Then, as now, the objectives of the laboratory were to teach students the art of accurate observation and how to think. In 1906 Eliot wrote,

> There are then two quite distinct functions which school and college laboratories perform. They tend to raise the observational powers of the average, and they give chance to men of remarkable capacities to develop these capacities.[7]

In 1935 Schlesinger wrote, "Every teacher of elementary science knows that the average human being must learn how to see correctly and observe objectively."[8] And in 1952

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[5]C. W. Eliot, "Laboratory Teaching," School Science and Mathematics, 6:703, November, 1906.

[6]Blick, op. cit., p. 264.

[7]Eliot, op. cit., p. 704.

[8]H. I. Schlesinger, "The Contribution of Laboratory Work to General Education," Journal of Chemical Education, 12:525, November, 1935.

Nechamkin wrote, "A primary function of the chemistry laboratory is to encourage impartial observation and recording of facts."[9]

As content increased and classes became larger, teachers began to lose sight of the purpose of the laboratory. Too many teachers began to feel that the main purpose of the laboratory was to support classroom work by illustration and example. The objectives of observation, planning, application of scientific method, and drawing sound conclusions were ignored. These difficulties of teaching laboratory technique encountered by Eliot in his day are still present, namely, using the laboratory for illustration and to verify statements.[10]

There is meager literature concerning the development of the physical plant of the chemistry laboratory. The following description tells about the type of laboratory that was common around the turn of the century. They were very much like the buildings in use today.

Floors were sometimes made of wood, despite the current opinion of the time that asphalt or lithoplast,

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[9]Howard Nechamkin, "Laboratory Meetings Should Teach Too," Journal of Chemical Education, 29:92, February, 1952.

[10]Eliot, op. cit., p. 705.

a mixture of parafined sawdust, sand, and magnesia cement was more suitable. Since asphalt gives way under pressure, desks and other heavy pieces were supported on wood framing.

Waste lines were made of high carbon cast iron, lead, and glazed earthenware. Water pipe of galvanized iron or lead-lined black iron was considered to be most desirable. Sinks were generally alberene stone which was considered to be the best material for that purpose. Stoneware was used by some, however. Whitewash and a mixture of lithopone (zinc sulfide and zinc oxide) were the surface coverings used for protection of walls and other surfaces. Asphalt, chrysolite, and pitchy coatings were used on pipe.

Walls were constructed of red brick, yellow brick, or brick with white glazed facing. Plaster was rejected because it cracked, peeled, and broke away leaving patches of exposed lath. Matched wood varnished in its natural state was acknowledged to be the ideal ceiling.

Hoods were designed, for aesthetic effect, with backing of glass tile. The square or rectangular hood ducts were made of wood, iron lined with glazed tile set in tar, asbestos composition, or other specially designed material. Baskerville[11] designed a duct which consisted

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[11]Charles Baskerville, "Some Principles in Laboratory Construction," Science N. S., 28:668, November 13, 1908.

of a frame of galvanized iron lined with a lattice work of expanded metal bands. This lattice lining was riveted to the frame, thereafter being covered with approximately five eighths inch layer of cement containing some plaster and sodium silicate.

Desks and desk tops were made of wood. Concerning desk tops Gill wrote,

> Speaking from wide observation and the experience of others, the writer is convinced there is no better (and in the long run cheaper) material for the tops of ordinary laboratory desks than wood.[12]

The different types of wood advocated were northern pine, whitewood, cedar, and California redwood. An aniline black formula mixed with an equal part of linseed oil was used to finish and protect the table tops. This formula consisted of two solutions. The first solution composed of one hundred grams aniline hydrochloride, and forty grams of sal ammoniac dissolved in 650 cubic centimeters of water was applied to the table top. When this coating was thoroughly dry, the second solution containing one hundred grams of copper sulfate, and fifty grams of potassium

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[12]Augustus H. Gill, "Suggestions for the Construction of Chemical Laboratories," <u>Science N. S.</u>, 30:550, October 22, 1909.

chlorate dissolved in 650 cubic centimeters of water was applied.[13] This type of protective coating applied in the same manner is used today.

Laboratories were heated by steam radiator. Ventilation was affected by an exhaust fan. Baskerville[14] describes the "push-pull" system of ventilation. By this he means air was filtered and then drawn over tempering coils by a larger motor-driven fan. It was then carried by the ducts and driven into the upper portion of the room. A fan in the attic pulled the air from the bottom of the room through another set of ducts.

The safety measures provided in the early laboratories were pails of sand with scoops, small fire hose, portable fire extinguishers, and showers.

Lighting was given a good deal of thought. Baskerville says,

> The width of the building, in my opinion, should at no point be more than sixty feet except where the lecture theater is located. This will provide an ample corridor of about ten feet and laboratories not too deep for good light throughout, from without. To secure the latter, ceilings should be at least fifteen feet in the clear from the floor.[15]

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[13] *Ibid.*

[14] Baskerville, *op. cit.*, p. 667.

[15] *Ibid.*, p. 666.

Pertaining to plumbing, the thinking then as now was that it should be exposed where it is easily accessible. Pipes were hung from the ceiling or conducted through vertical raceways where they could be easily repaired, or taken down, or where new lines could be installed.

Some materials used in the construction of laboratories today, such as alberene stone desk tops, or oakwood furniture, or plaster walls, were utterly repudiated in the pioneer laboratories. For instance, Gill wrote, "Quartered-oak desks and alberene stone tops seem almost as much out of place amid the fumes and acids of a chemical laboratory as dress suits for the students."[16] Gill had this to say about plaster, ". . . plaster of any kind is inadmissible in a ceiling on account of its disintegration by acid fumes."[17] Today the composition of plaster is such that it no longer disintegrates in the manner described by Gill. Also, alberene stone is found to hold up better than any other desk top material on the market today.

Summary. This history indicates that the purpose of conducting a laboratory even from the time of its crude beginning has changed appreciably little through the years.

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[16] Gill, loc. cit.

[17] Ibid., p. 549.

The validity of the scientific method, the concept upon which the laboratory was developed, has not changed. Only the physical plant has undergone some changes. Development of new materials and changes in design and organization are the only ideas that have changed with respect to the chemistry laboratory.

CHAPTER III

DEFINITION OF TERMS USED, AND THE PURPOSE AND CONTENT OF THE GENERAL CHEMISTRY LABORATORY

The search for truth in the field of science has been going on for centuries. The methods used in pursuit of this search has very often determined the validity of results. Because this is so, scientists have for centuries attempted to define "the scientific method." The following definitions tell about some of the most commonly used methods.

I. DEFINITION OF TERMS

Scientific method. It is difficult to pin the scientific method down to a step-by-step series of thought processes as many authorities do. Blick says:

> It should be borne in mind that much that has been written about the scientific method is sheer verbalism, and that the scientific method does not follow a series of steps but consists of the use of innumerable and almost unclassified techniques.[1]

However, it is helpful to an individual to have a stepwise outline of the scientific method for a pattern,

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[1]David J. Blick, "The Purpose and Character of Laboratory Instruction," Journal of Chemical Education, 32:265, May, 1955.

realizing that it is flexible and adaptable to different situations. One such step-by-step definition of the scientific method is by Garrett, Haskins, and Sisler: (1) observing a phenomenon, (2) collecting and organizing facts regarding the phenomenon, (3) devising an hypothesis, (4) testing the hypothesis experimentally, and (5) altering or rejecting the hypothesis or accepting it as theory.[2]

Deductive method. Bossing defines the deductive method of problem solving as, (1) clear recognition of the problem, (2) the search for a tentative hypothesis, (3) the formulation of a tentative hypothesis that appears to have promise as a possible solution, and (4) verification of the hypothesis.[3] Blick gives a simplified definition which is more applicable to problem solving in chemistry as, "In the deductive approach the student starts with a principle and makes observations or performs experiments to verify what is already known."[4] An example of a chemistry

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[2]Alfred Benjamin Garrett, Joseph Fredric Haskins, and Harry Hall Sisler, Essentials of Chemistry (Boston: Ginn and Company, 1951), p. 4.

[3]Nelson L. Bossing, Progressive Methods of Teaching in Secondary Schools (Boston: Houghton Mifflin Company, 1935), pp. 467-70.

[4]Blick, loc. cit.

experiment performed using the deductive method would be the usual laboratory preparation of oxygen after it has been discussed in class. Here the student knows in advance what to look for, and performs the experiment to merely verify what he has read or heard discussed.

Inductive method. Bossing's definition is (1) clear recognition of the problem, (2) the search for data, (3) the careful sifting, comparing, and abstracting of the significant data collected, and (4) generalization.[5] A simplified definition would be the formulation of concepts and principles based upon carefully sifted data and facts. Using the above experiment as an example, if the student performed the experiment, preparation and properties of oxygen, before it is discussed or assigned, and detailed instructions omitted, the student probably will not know what to look for in advance, and must observe carefully in order to advance sound conclusions.

II. AIMS, OBJECTIVES, AND SHORTCOMINGS OF THE LABORATORY TODAY

The objectives of the laboratory, to which most chemistry teachers agree, are:

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[5]Bossing, op. cit., pp. 470-72.

1. To develop interest. Carmody[6] rates this objective first in relative importance because without it other objectives cannot be attained.

2. To train students in the recognition and solution of problems by means of the scientific method.

3. To illustrate and clarify principles discussed in the classroom. The laboratory is a means by which the student comes in actual contact with chemicals and equipment. It gives real meaning and clarification to concepts.

4. To develop habits of accuracy, honesty, self-reliance, ingenuity, cleanliness, and keen observation. Chemistry is an exact science which requires accurate measurements, calculations, and precise definitions of principles and laws. Schlesinger states, "teaching students how and what to see is just as much a part of well-rounded curriculum as is teaching them how to think."[7]

5. To develop laboratory technique and skill in the use of equipment. Such skills as bending of glass, use of the burette, analytical balance, pipette, volumetric flask, and barometer.

6. To develop the ability to write a satisfactory report; that is, to organize and express clearly what took place in the experiment.

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[6] W. R. Carmody, "Elementary Laboratory Instruction," Journal of Chemical Education, 12:233, May, 1935.

[7] H. I. Schlesinger, "The Contribution of Laboratory Work to General Education," Journal of Chemical Education, 12:524, November, 1935.

The shortcomings of the laboratory are:

1. Experiments are sometimes performed in cook-book fashion where the student follows printed directions, fills in blanks, and answers questions with information taken from the text. It is not uncommon for a student to have his experiment written up before coming to laboratory by copying the work of a previous student or by using information derived from the text.

2. Too much emphasis is placed on the deductive method where the student knows what to look for before going into the laboratory, and not enough on the inductive method. In other words, the scientific method of solution to problems is ignored, resulting in very little experience in formulating and developing plans, observation, and conclusions from observations. Thus, interest in laboratory work lags, and very little learning takes place.

III. HOW THE LABORATORY ACHIEVES ITS AIMS AND HOW THE SHORTCOMINGS ARE ELIMINATED

To resolve the shortcomings enumerated above, some chemistry teachers recommend that the lecture-demonstration method be used. Arenson[8] recommends that this method be

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[8]Saul B. Arenson, "Demonstrations vs. Chemistry Laboratory for Freshman Engineers," *Journal of Chemical Education*, 18:241-42, May, 1941.

used for students in the field of engineering (except chemical engineering). Hunt[9] describes a method of lecture demonstration which is used for freshmen chemistry students. The demonstrations are given at regularly scheduled two-hour periods, and do not consist of the spectacular demonstrations used with the formal lecture. The student is graded on written tests which follow the demonstration. The advantage of this method is that it saves time and money to the student and the school. As a general practice, for all work in chemistry, the lecture-demonstration method is not considered to be the best nor does it produce the best results in carrying out the objectives of the laboratory. There are times, however, when the lecture-demonstration method is more practicable: experiments where there is an element of danger, where accurate results are difficult to attain, or where elaborate equipment is needed.

Most of the shortcomings of the laboratory may be resolved by the individual laboratory method. According to Thomas,[10] most shortcomings can be resolved if the experiment provides for an unknown, if detailed

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[9]Herschel Hunt, Demonstrations as a Substitute for Laboratory Practice in General Chemistry," Journal of Chemical Education, 12:73-75, February, 1935.

[10]W. B. Thomas, "Laboratory Work and the Scientific Method," Journal of Chemical Education, 20:379, August, 1943.

instructions are avoided, if results are not given in advance, and if results are needed to plan further work. The use of unknowns makes it impossible for a student to copy from his neighbor, or to write up the experiment from the text. By leaving the details of the experiment up to the student he must plan, develop, and make keen, accurate, impartial observations in order to gain good results.

IV. EVALUATION OF THE LABORATORY MANUAL USED AT MODESTO JUNIOR COLLEGE

The topics covered in the laboratory manual presently being used at the Modesto Junior College are: weight relations in chemical formulae and equations, gaseous states of matter, concentration, acids, bases, salts, electrolytes, ionization, and chemical equilibrium. This is essentially the same material that is covered at the University of California.

The good features of the manual are: (1) the content, illustrations, and safety precautions are very good; (2) the questions are of the type that require considerable thought and instructions preceding each experiment are clarifying; and (3) the write-up contains a section which requires the application of principles to problems or to new situations.

The unsatisfactory features of this manual are: (1) only eleven of the first thirty experiments provide for an unknown or the taking of measurements to make calculations. This is not enough. With few exceptions every experiment should be of this type. Also, since this manual is the interlinear type (by interlinear is meant the fill-in type), the student gets very little training in organizing his experiment and describing the results of his observations and his conclusions in a clear, concise form. He is, in effect, scientifically inarticulate. A survey conducted by Hart[11] reflects this. A personal letter was addressed to the directors of technical personnel procurement of fifty-three nationally known companies, research institutions, and government agencies that employ scientists. These men were asked to comment upon specific omissions in the science training backgrounds of recent college graduates. From this group thirty-three replies were received. They were practically unanimous in their criticism that recent graduates can neither read nor write, nor can they think in logical fashion or present ideas verbally; (2) the term formality is used instead of

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[11]William F. Hart, "Evaluation of an Undergraduate Chemistry Curriculum," Journal of Chemical Education, 31:363, July, 1954.

molarity to express concentration. This can cause confusion in the minds of students because molarity is more commonly used by most authors; (3) experiments are sometimes presented in improper order. For instance, oxidation-reduction is placed too early in the manual; before students have had an opportunity to build up a sufficient background. This can be discouraging to students, and so, they may lose interest.

V. SUMMARY

Although the laboratory may undergo periods of deterioration under the individual laboratory method, it is still the best method of instruction if used properly. Interest is maintained because most students have a natural curiosity and desire to know about things going on about them. The students also take pride in individual accomplishment. Also, concepts are more clearly pin-pointed by the individual laboratory method, and thus they are better understood. If the instructor fully understands the purposes of the laboratory and what the scientific method attempts to achieve, the individual laboratory method does accomplish its purpose most effectively.

CHAPTER IV

THE PHYSICAL PLANT OF THE CHEMISTRY LABORATORY AT MODESTO JUNIOR COLLEGE

Structure of building. The frame building housing the chemistry laboratory is 110 feet long, 47 feet wide topped by an arched roof with a maximum and minimum height of nineteen and twelve and one-half feet, respectively. The arched roof, which is constructed with one-inch by six-inch pine boards covered with roofing paper has a surface area of 5,790 square feet. The wall surface covers an area of 3,587 square feet, 986 square feet of this is single glass window, and the remaining area is stucco on the outside and plaster board on the inside. There are 5,264 square feet of concrete floor divided as follows: 704 square feet for lecture room, 992 square feet for storeroom, 768 square feet for advanced laboratory work, 132 square feet for two offices reserved for three instructors. Figure 1 shows the division of floor space as described above.

Heating system. There are two Fraser gas fired forced air furnaces each having an output of 67,500 British

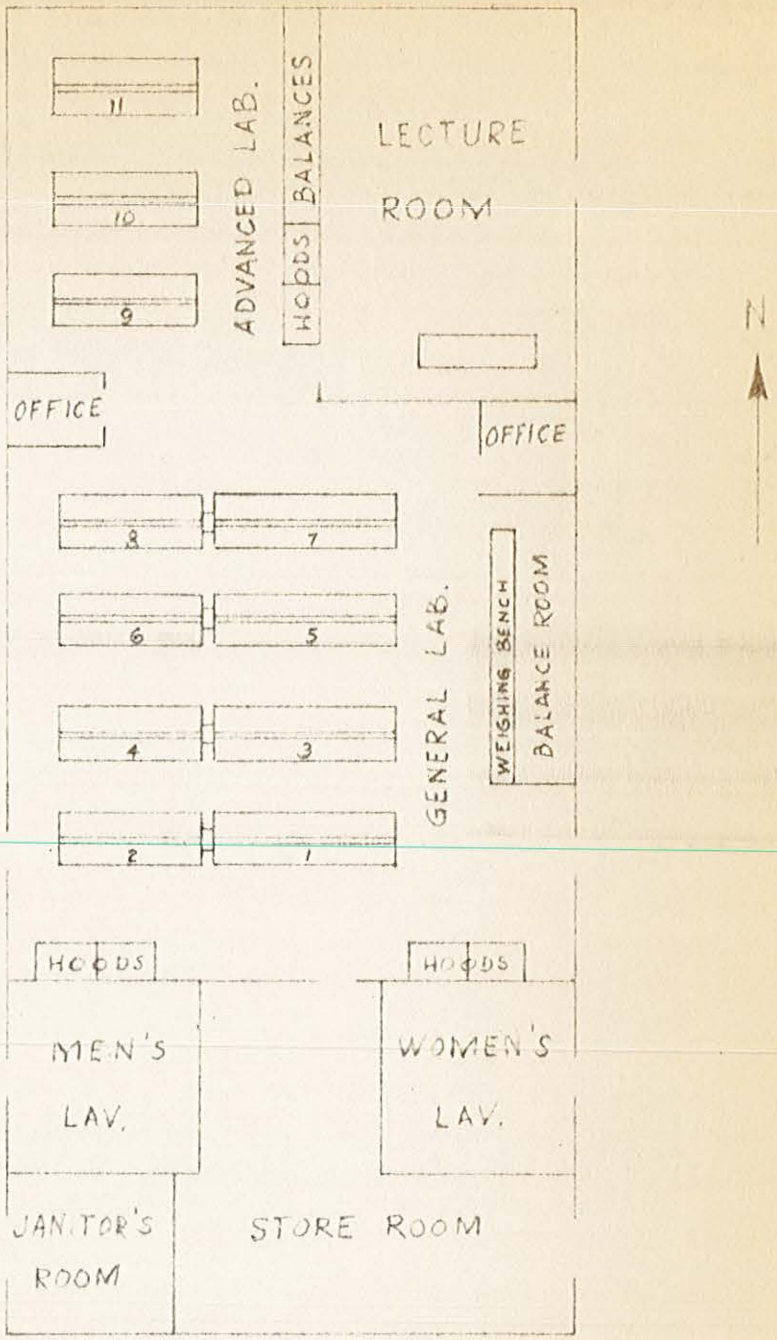

FIGURE 1

FLOOR PLAN OF THE CHEMISTRY BUILDING AT MODESTO JUNIOR COLLEGE

SCALE 1/16"=1.0'

thermal units[1] per hour. This means that actually 135,000 British thermal units of heat flow through a room of approximately 69,000 cubic feet of space per hour.

Temperatures were recorded at various times between the hours of 9:00 A.M. and 5:00 P.M. during the five-day period from December 15 to December 19, 1952. Three Fahrenheit thermometers were placed along the west wall near the door, in the center of the room, and along the north wall of the laboratory. The lowest temperature recorded was sixty degrees and the highest temperature recorded was sixty-eight degrees.

Table I shows the record of temperatures taken. It is to be noted that only the thermometer placed in the center of the room recorded temperatures of sixty-eight which is considered to be the desirable temperature by health authorities. The first reading was taken at 4:30 P.M. on the twelfth of December and then again at 3:30 P.M. on the fourteenth of December and most of the afternoon of the following day. It is to be noted that the laboratory closes at 5:00 P.M. At no time during that week did the other two thermometers reach sixty-eight degrees.

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[1]The British thermal unit is the quantity of heat required to raise the temperature of one pound of water through one Fahrenheit degree.

TABLE I

TEMPERATURES, IN DEGREES FAHRENHEIT, OF THE CHEMISTRY LABORATORY FROM DECEMBER 15 TO DECEMBER 20, 1952

Date	Time	Thermometer Number No. 1	No. 2	No. 3
Dec. 15	2:00 P.M.	63	63	62
	3:00 P.M.	66	67	65
	4:30 P.M.	67	68	66
Dec. 16	9:00 A.M.	61	62	62
	10:30 A.M.	64	64	63
	12:30 P.M.	65	66	64
	3:00 P.M.	63*	66	64
Dec. 17	8:30 A.M.	61	62	61
	11:00 A.M.	61	62	61
	1:00 P.M.	63	64	63
	3:30 P.M.	67	68	66
Dec. 18	9:00 A.M.	64	65	64
	11:30 A.M.	67	68	66
	2:30 P.M.	66	68	66
	4:30 P.M.	65	68	66
Dec. 19	9:00 A.M.	60	61	60
	11:00 A.M.	61	63	62

*Window open.

Calculations were made to determine the heating requirements for a building of this size. Two different forms were used: (1) the Coleman Company, Incorporated, condensed method which is based on the fundamental code of the National Warm Air Heating Association, and (2) the Servel Incorporated method based on the American Society of Heating and Ventilating Engineers. According to the Coleman method calculations, a minimum of 234,678 British thermal units per hour are required to heat this room adequately. Based on the Servel method calculations a minimum of 316,742 British thermal units per hour are required to heat this room comfortably. These calculations do not take into consideration the discharge of conditioned air by two exhaust fans located in the roof, and three hood fans. These fans withdraw vast quantities of heat. When any or all of these fans are in operation the heat requirements are considerably larger. The deficiency of heat is felt most in the storeroom where one small duct must supply heat for a room of approximately 140,000 cubic feet (992 square feet of floor space).

The gaseous conditions that exist at various times cause the thermostatic controls of the heater to corrode. This renders the furnaces inoperative necessitating the bother and delay of getting a repairman to get the furnaces

back in working order. Meanwhile the students suffer from extreme cold.

<u>Lighting</u>. The chemistry laboratory is 47 feet long by 47 feet wide making the floor area a total of 2,209 square feet. There are 142 square feet of window area on each of the east and west walls of the laboratory, making a total of 284 square feet of window. The windows, which are not shaded in any manner, start at 4 feet above the floor and rise to a height of 11 feet. (See Figures 2 and 3.)

The balance room runs parallel with the windows along the east wall. (See Figure 1, page 23.) At a distance of five and one-half feet west of the east wall of the building is located the west wall of the balance room. (See Figure 1, page 23, and Figure 4, page 30.) This further obscures the admission of light. The chemistry laboratory building is surrounded entirely on all sides by other buildings, light from the west being somewhat cut off by a shop building approximately twenty feet to the west.

According to J. L. Tugman, "the glass area should utilize as much of the outside wall as practicable,

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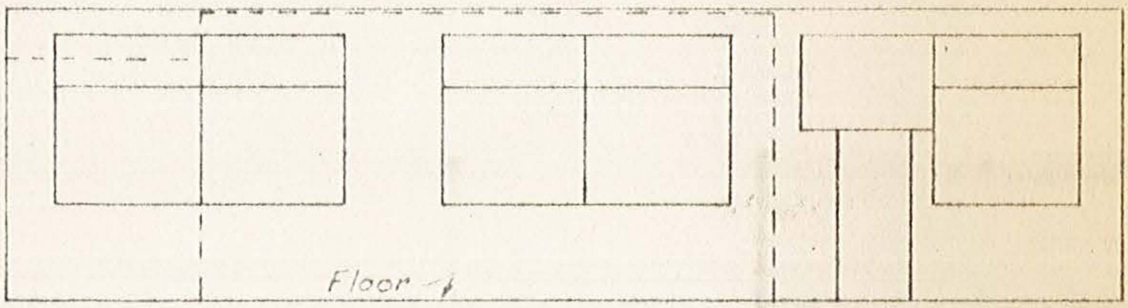

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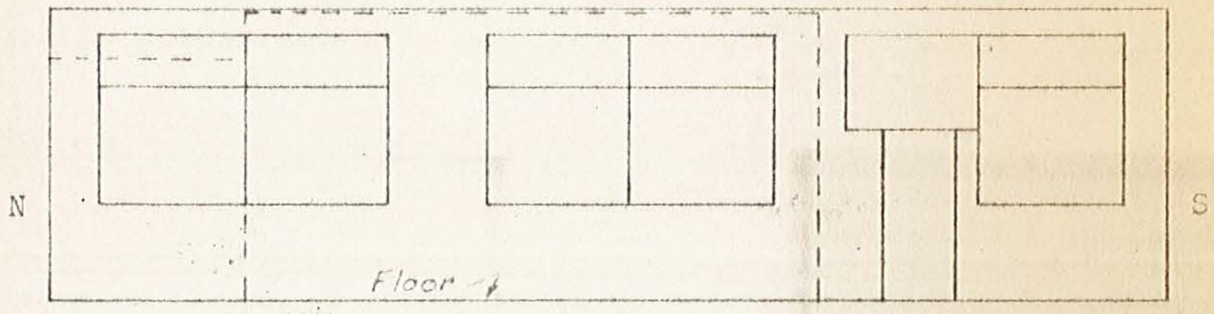
FIGURE 2

EAST WALL OF GENERAL CHEMISTRAY LABORATORY
AS VIEWED FROM INSIDE

(Dotted line in lower left hand corner indicates office.)
(Dotted line to right of office indicates balance room.)

SCALE 1/8"=1.0'



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(Dotted line in lower left hand corner indicates office.)
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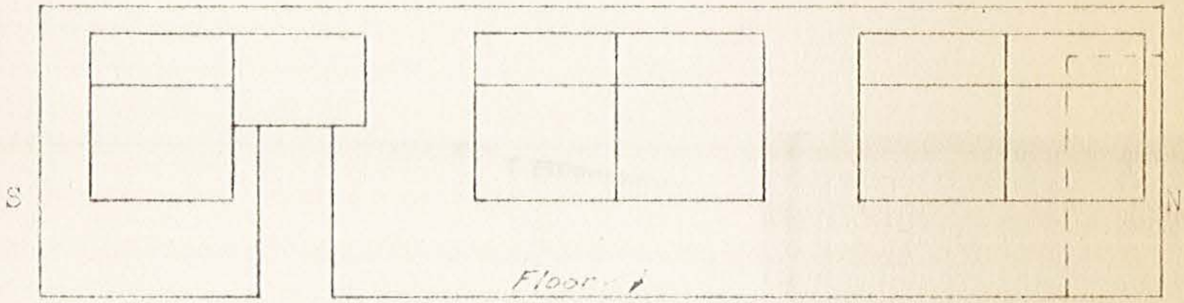

FIGURE 3

WEST WALL OF GENERAL CHEMISTRY LABORATORY
AS VIEWED FROM INSIDE

(Dotted line in lower right hand corner indicates office.)

SCALE 1/8"=1.0'

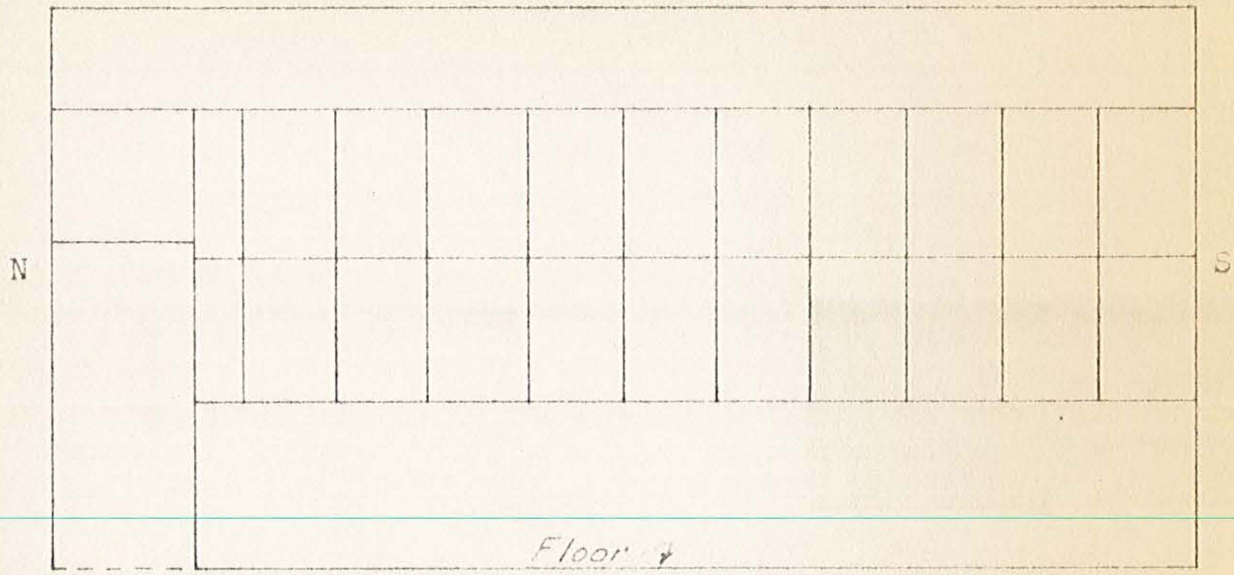

FIGURE 4

WEST WALL OF BALANCE ROOM AS VIEWED FROM INSIDE THE LABORATORY

SCALE 1/4"=1.0'

favorable ratios of glass area to floor area ranging from .15 to .25."[2] The ratio of window area to floor area of this laboratory is .12. Discounting the great limitation placed upon this ratio .12, by the presence of obstruction of balance room, it is still below the recommended minimum set by Tugman.

There are nine direct lighting fixtures utilizing 500 watt incandescent bulbs. Baked enamel reflectors, white on the inside and green on the outside, shield these lights. These fixtures are placed eleven feet eight inches from the east and west walls, and there is an equal distance between fixtures which are suspended twelve feet above the floor. (See Figure 5.)

Light meter readings were taken under four typical conditions on all chemistry laboratory tables, the work surface where students conduct experiments. A General Electric pocket type light meter, Model Number 8DW40Y16, with window up, was placed on student tables. Tables II, III, IV and V, pages 33 through 36, show the results obtained from this search.

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[2]H. S. Coleman (ed.), Laboratory Design (New York: Reinhold Publishing Corporation, 1951), p. 50.

FIGURE 5

CHEMISTRY LABORATORY

TABLE II

LIGHT METER READINGS IN FOOT-CANDLES ON JULY 16, 1952, 11:00 TO 12:00 NOON. BRIGHT SUNNY DAY. LABORATORY LIGHTS WERE NOT TURNED ON

Table Number	East End	Middle	West End
1	--	25	25
2	--	--	55
3	30	27	--
4	--	--	100
5	--	27	--
6	--	--	--
7	25	--	--
8	--	--	--

TABLE III

LIGHT METER READINGS IN FOOT-CANDLES JULY 25, 1952,
1:30 TO 2:00 P.M. A BRIGHT CLOUDY DAY.
LABORATORY LIGHTS WERE TURNED ON.

Table Number	East End	Middle	West End
1	40	38	41
2	45	52	52
3	40	37	35
4	37	50	100
5	37	32	32
6	36	59	100
7	36	37	35
8	40	--	100

TABLE IV

LIGHT METER READINGS IN FOOT-CANDLES DECEMBER 24, 1952, 11:00 TO 12:00 NOON. CLOUDY RAINY DAY. LABORATORY LIGHTS WERE TURNED ON

Table Number	East End	Middle	West End
1	22	28	30
2	34	37	60
3	26	28	27
4	27	36	53
5	22	13	20
6	26	27	37
7	22	24	25
8	30	35	44

TABLE V

LIGHT METER READINGS IN FOOT-CANDLES ON THE NIGHT OF JULY 16, 1952, 9:30 TO 10:30 P.M.

Table Number	East End	Middle	West End
1	20	35	26
2	--	--	13
3	23	27	20
4	--	16	9
5	22	--	20
6	17	14	9
7	21	27	20
8	--	20	10

On July 16, 1952, a bright sunny day, light measurements were taken at eight different desk top locations between the hours of 11:00 A.M. and 12:00 Noon. The amount of light recorded varied from twenty-five to one hundred foot-candles.[3] (See Table II, page 33.) On a bright, but cloudy day (Table III, page 34), with the aid of artificial lights, light measurements ranged from thirty-two to one hundred foot-candles on the various tables. Next, on December 24, 1952, a cloudy rainy day (Table IV, page 35), light measurements were taken between the hours of 11:00 A.M. and 12:00 Noon with the artificial lights turned on. At twenty-four different desk top locations, the light intensity varied from thirteen to sixty foot-candles. Table IV, page 35, shows fourteen of the twenty-four desk tops registered a light intensity of below thirty foot-candles. Light readings were taken at night between the hours of 9:30 and 10:30 P.M. (See Table V, page 36.) The intensity of light recorded varied from nine to thirty-five foot-candles.

The presence of the reagent shelves on the work tables (Figure 6) casts a shadow over a portion of the work table. On the night of July 16, 1952 (Table VI, page 39)

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[3] One foot-candle is the illumination of a surface one foot away from a uniform one candle power source. A new primary standard of luminous intensity has been adopted in 1948 by the International Committee on Weights and Measures. It consists of a glowing enclosure operated at the temperature of solidifying platinum.

FIGURE 6

STUDENT LABORATORY TABLES

TABLE VI

LIGHT METER READINGS TAKEN IN SHADOWS CAST ON LABORATORY TABLES ON THE NIGHT OF JULY 16, 1952, 9:30 TO 10:30 P.M. READINGS ARE IN FOOT-CANDLES

Table Number	East End	Middle	West End
1	7	--	6
2	--	--	--
3	9	--	10
4	--	--	--
5	8	--	--
6	--	8	--
7	7	--	5
8	--	--	--

light measurements taken in the shadow ranged from five to ten foot-candles. On a bright cloudy day (see Table VII) light measurements taken in the shadow varied from twelve to thirty foot-candles.

J. L. Tugman says, "no surface in the laboratory is more important visually than the desk or table top. For a person working at a desk, the top occupies most of the visual field."[4] The amount of light recommended for general laboratory work is thirty foot-candles, according to J. L. Tugman.[5] Even on the brightest of days there are places in the laboratory where the amount of light does not meet the recommended requirement of thirty foot-candles (see Table II, page 33), and on a cloudy day there are tables that show recordings of as little as thirteen foot-candles (see Table IV, page 35), which is far below the minimum standard.

Waste sinks and troughs. In the laboratory there are four rows of student tables. Each row consists of a double set of tables placed back to back with a twelve foot and a fifteen foot table placed end to end. Each row of four tables is adjoined by a single sink. (See Figure 1,

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[4]Coleman, op. cit., p. 48.

[5]Ibid., p. 47.

TABLE VII

LIGHT METER READINGS TAKEN IN SHADOWS CAST ON LABORATORY TABLES ON JULY 25, 1952, 1:30 TO 2:00 P.M. READINGS ARE IN FOOT-CANDLES. A BRIGHT CLOUDY DAY. LIGHTS WERE TURNED ON

Table Number	East End	Middle	West End
1	17	--	15
2	--	30	--
3	--	--	--
4	--	--	--
5	21	17	18
6	24	--	--
7	19	12	16
8	20	--	--

page 23.) The stone sink is sixteen inches by eight inches by six inches deep. (See Figure 7.) A brass chrome plated asphalt-lined gooseneck trap empties into a covered concrete trough in the floor which is connected with the sewer line. The tables placed back to back are serviced by a single trough six inches wide running the length of the tables and emptying into the sink described in the paragraph above. Some troughs are constructed of wood, and others are lined with lead. The lead lining has disintegrated due to the corrosive action of acids and other potent chemicals. During vacations when the troughs are not in use they dry out leaving large cracks. Waste water then runs into student lockers and on to the floor. Frequent repairs with tar or asphalt must be made. If lead sheeting is used for such repairs it becomes very expensive to maintain these old tables.

<u>Tables</u>. The tops for five of the eight tables in the laboratory were made by gluing the two-inch edge of two pine boards two inches by twelve together, making a table two feet wide. Some of these tables have large cracks where the edges come together. The remaining three table tops have wood base covered with quarter-inch layer of composition material.

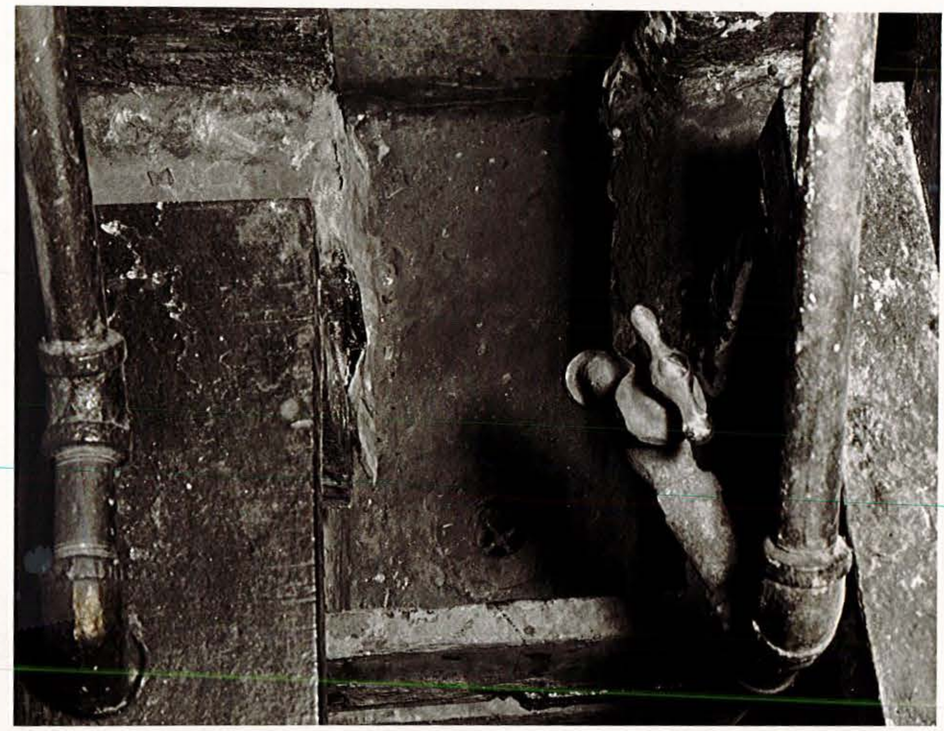

FIGURE 7

SINK BETWEEN LABORATORY TABLES

Water spilled on the tables seeps through the cracks into the lockers beneath damaging metal equipment. Paper linings become saturated; locker drawers stick. In some cases the locker drawers have become so swollen it was impossible to open without pulling off the drawer handle.

In the laboratory there are forty lockers possessing a volume of 1,216 cubic inches (table number eight in Figure 1, page 23), 109 lockers with a volume of 1,155 cubic inches (tables number two, four, and six in Figure 1, page 23), and 150 lockers with a volume of 936 cubic inches (tables number one, three, and seven in Figure 1, page 23). There is one table (table number five in Figure 1, page 23) that has no lockers at all. (See also Figure 6, page 38.)

These lockers were outfitted with equipment without regard to size of the locker. There are fifty-seven lockers stocked with small semi-micro equipment for chemistry 1B, qualitative analysis. The remaining lockers contain large equipment for chemistry 1A, chemistry three, and chemistry four.

The most crowded conditions exist in the drawers fitted out with large equipment (see Figure 8). Overcrowding of this kind makes it difficult to find small pieces of equipment, such as small test tubes, pinch clamps, and rubber stoppers without the student losing time. Also,

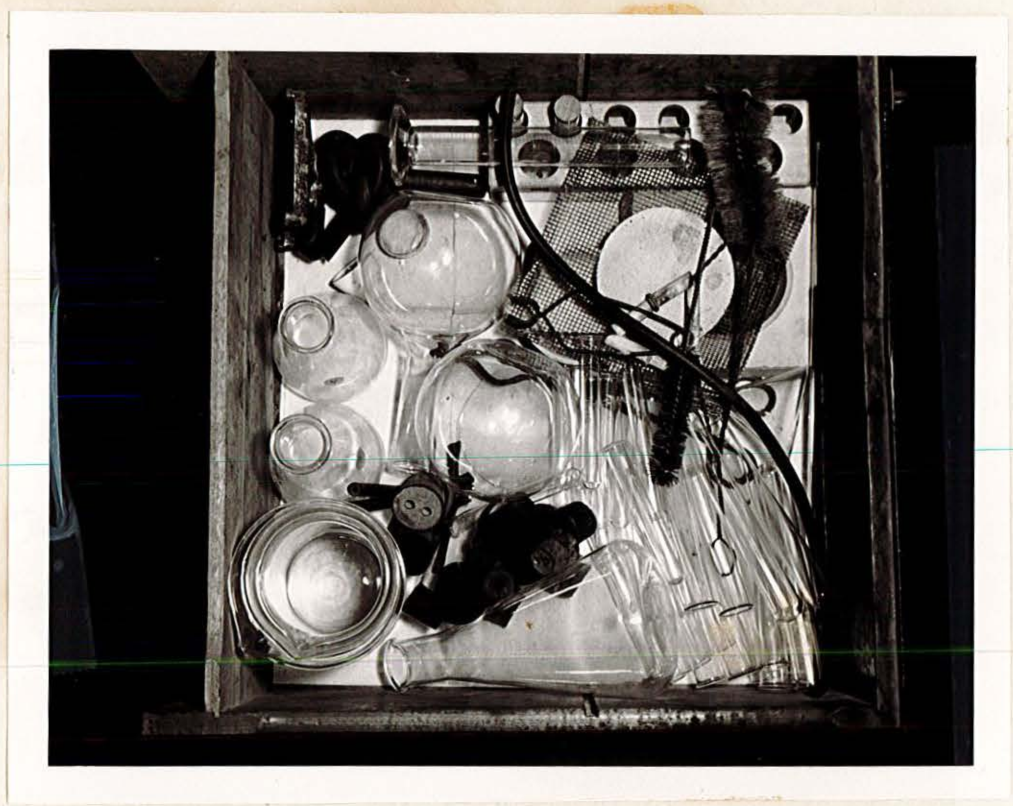

FIGURE 8

STUDENT LOCKER BEFORE REMOVAL OF SOME EQUIPMENT
(After removal of equipment see Figure 10)

there is excessive breakage in these lockers, which increases the danger of cuts (sometimes severe) to fingers and hands. And, finally, it is almost impossible to keep a neat, clean, orderly locker when there is too much equipment for even the largest locker to hold.

A superstructure elevated eighteen inches above the desk tops supports the reagent shelves. (See Figure 9.) This is a large room with many students working at one time. Such a superstructure obscures supervision. Then, too, it becomes a catch-all for things that should be tossed in the waste basket, discarded notes, and so forth. And, lastly, it is unsightly. With these archaic tables, however, this superstructure is a necessary adjunct, for it holds in place the gas and water lines, as can be seen in Figure 9.

The aisle space between the four rows of tables is sixty, forty-nine, and forty-six inches. Students working back to back in a space forty-six and forty-nine inches wide are working under hazardous conditions. There is of necessity a certain amount of moving about when performing experiments, and in such a small area a certain amount of crowding and bumping occurs. Dangerous chemicals such as concentrated acids and bases have been spilled on students and many experiments have been ruined because of this condition.

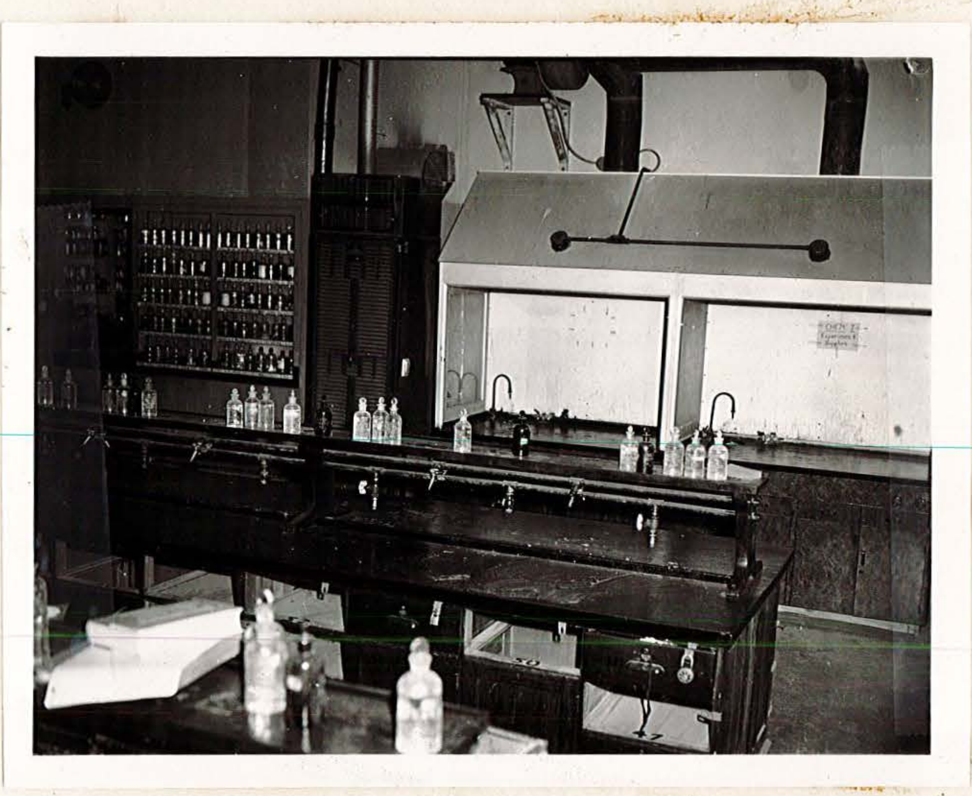

FIGURE 9

SOUTH END OF LABORATORY. STUDENT TABLES IN FOREGROUND

Service lines. All gas, water, and waste lines are laid in the concrete floor. This means that whenever repairs or alterations are required it is necessary to break up the concrete floor in order to get at these service lines. For example, should it be decided to move the tables in order to widen the aisles labor costs would be high.

The matter of aspirators or provision for vacuum is another cause of concern in this laboratory. There are certain experiments of slow filtration that require a vacuum. Modesto Junior College has a vacuum pump in storage. Although a vacuum pump creates a better vacuum, it is costly to install, operate, and maintain. So nothing has been done about this matter to date. As things now stand, students use the aspirators at tables nine, ten, and eleven as shown in Figure 1, page 23, a matter of some distance from their own work tables. Their equipment must be gathered up and carried to the aspirators, inconveniencing not only themselves, but also the students working in the laboratory for advanced chemistry students as well.

On tables number three and five (see Figure 1, page 23) are placed the electrical outlets.

Organization of the laboratory and storeroom. There are three areas of laboratory and storeroom organization to be discussed. The relationship of the size of room and the

number of students occupying it at one time, the method of issuing and checking in locker equipment, and of least importance, although a matter of convenience to the students, the placement and distribution of reagent shelves.

There have been as many as four different chemistry classes at work in the laboratory at the same time. The average number of classes occupying the laboratory during the same hour is two. The maximum number of students working on experiments in the laboratory at one time has been eighty-three. With respect to classes the students are distributed at random throughout the laboratory.

The laboratory room is too large, and there are too many classes in session at the same time. A large room, where the students are spread out in this way, is very difficult to supervise. There is too much area to be surveyed by the instructor. There tends to be more confusion, noise, and distraction in a laboratory where there is more than one class in session. This situation makes it impossible for the instructor to conduct a discussion without taking the class into a separate room. When a laboratory is designed to handle sixty-four students, and as many as eighty-three students are scheduled to work in it at a given time, the aisles become overcrowded, individual work area is greatly reduced, danger of accident becomes

more acute, and an excessive load is placed upon the storeroom clerk.

Table VIII shows the laboratory schedule. It reveals in numbers the situation described above.

At the beginning of the semester the student comes to the storeroom to pick up his locker which is completely furnished with the necessary equipment for the chemistry course he is taking. The student then finds the proper location of his locker by number, checks his equipment, and locks it with his own padlock. At the end of the semester the student replaces all broken and missing equipment, and takes his locker back to the storeroom clerk for checking. The storeroom clerk then must carry it up a narrow steep stairwell for storage on the upper level of the storeroom.

There are several disadvantages to this method of checking out and checking in equipment. First of all, a great deal of storage space is required for only a short period of time. The rest of the time this space is wasted. Secondly, carrying all those drawers up and down that narrow stairwell (see Figure 10) is not only dangerous to the person of the storeroom clerk, but may also cause unnecessary breakage, and certainly is time consuming. The storeroom clerk's time should be spent in more worth-while pursuits.

TABLE VIII

TIME AND BY WHOM LABORATORY IS OCCUPIED

			Number of Students	
Year	Courses	Hours	Beginning of Semester	End of Semester
Fall 1948	Chem. 42, 21	9-12 T	75	66
	Chem. 42, 21	9-12 Th	50	41
	Chem. 22, 21	2-5 W	60	46
	Chem. 21	2-5 T	30	23
	Chem. 42, 21	2-5 Th	52	43
	Chem. 22, 21	2-5 F	60	46
Spring 1949	Chem. 21, 22, 42	9-12 T	38	28
	Chem. 21, 22	9-12 Th	30	21
	Chem. 21, 22	2-5 M	62	52
	Chem. 21, 22	2-5 W	62	52
	Chem. 42	2-5 Th	23	18
Fall 1949	Chem. 1, 21, 22	9:55-11:40 M, W, F	80	69
	Chem. 1	3:15-5 M, W, F	39	37
	Chem. 21, 22	2-5 T, Th	41	33

TABLE VIII (continued)

Year	Courses	Hours	Number of Students: Beginning of Semester	Number of Students: End of Semester
Spring 1950	Chem. 21, 22, 1, 2	2-5 M, W	83	72
	Chem. 21, 22	2-5 T, Th	46	38
Fall 1950	Chem. 3, 1A	2-5 M, W	61	38
	Chem. 1A, 1B	2-5 T, Th	40	27
	Chem. 3, 1A	9-12 T, Th	61	43
Spring 1951	Chem. 3, 1B	2-5 M, W	36	32
	Chem. 1A	2-5 T, Th	24	23
	Chem. 1B	9-12 T, Th	5	4
Fall 1951	Chem. 1A, 3	2-5 M, W	64	53
	Chem. 1A, 1B	2-5 T, Th	33	26
	Chem. 3	9-12 T, Th	35	28
Spring 1952	Chem. 1B, 3	2-5 M, W	44	36
	Chem. 1B, 1A	2-5 T, Th	41	37
	Chem. 4	9-12 T, Th	6	4

FIGURE 10

STOREROOM WITH NARROW STAIRWELL TO LEFT
LEADING TO MEZZANINE

Lastly, at opening and closing of each session there is much congestion, confusion, and loss of time around the storeroom window waiting for the lockers to be brought down and assigned, or checked in.

The last and possibly the least objectionable of the laboratory organizational features is the placement of reagent shelves. At the present time there is one reagent shelf located in the middle of the south wall. (See Figure 11.) Dilute hydrochloric acid, nitric acid, sulfuric acid, ammonium hydroxide, and silver nitrate are placed on the shelves above the work tables.

I. RECOMMENDATIONS

Heating. The output of 135,000 British thermal units per hour produced by the heating system in use at the present time falls far short of meeting the heat requirements of this building. To alleviate this situation more heat must be supplied by a centralized heating--steam or warm air--with operating controls located away from the chemistry laboratory. The addition of a plastered or plaster board ceiling would cut down heating requirements by about 15 per cent. The addition of an insulated plastered ceiling would reduce the heating requirements by about 30 per cent.

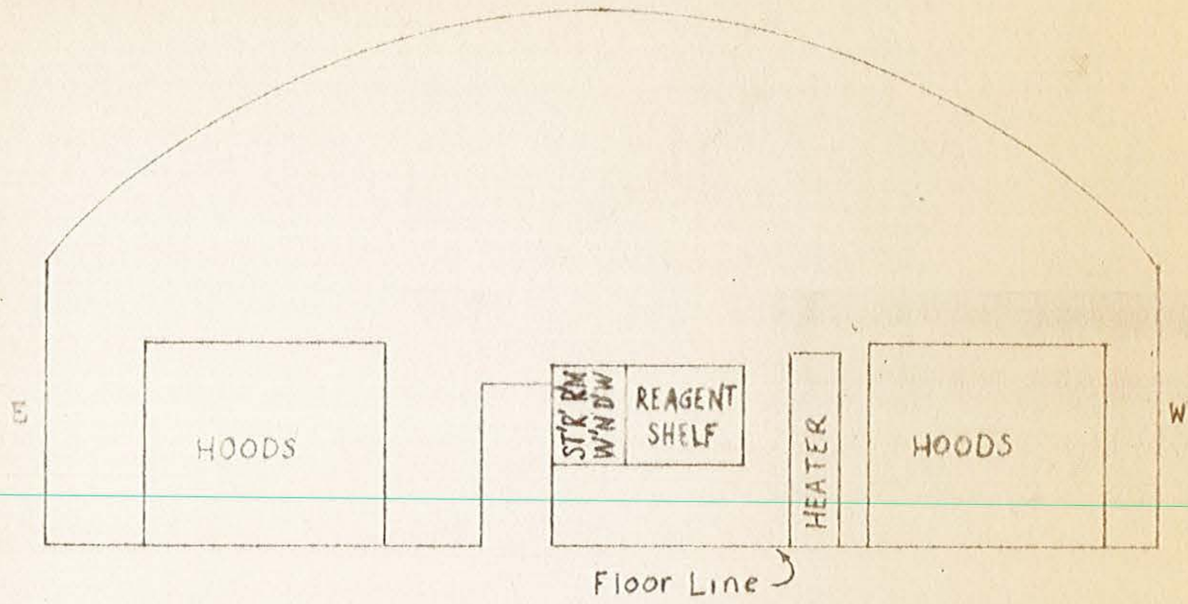

FIGURE 11

SOUTH WALL OF GENERAL CHEMISTRY LABORATORY
AS VIEWED FROM INSIDE

SCALE 1/8"=1.0'

Lighting. Insufficient light, the presence of shadows (caused by lack of diffused light), and glare from unshaded windows, indicates that the lighting conditions are grossly inadequate. There are two ways of increasing the amount of light in the laboratory. One is to increase the window area, and the other is to increase the number of artificial lights. To increase the window area would be too costly considering the amount of light that would be gained. The addition of four fluorescent light fixtures would be more practicable. The light unit should consist of four five foot 40 Watt tubes which would produce the minimum standard of light required for this laboratory. Windows on both east and west walls should be equipped with Venetian blinds to eliminate the hot intense sun's rays.

Waste sinks and troughs. A student cannot do accurate qualitative analysis unless the equipment used is absolutely clean. Neither the sinks nor the troughs provide a place convenient to carry on the task of washing glassware. The trough is too narrow, the sink too small, and the distance between tables is too narrow to make the sink accessible.

In a survey of ten junior college laboratories, the sinks of the Modesto Junior College laboratory were the smallest, having a capacity of 736 cubic inches; the largest

had a capacity of 2,970 cubic inches. The average size sink had a capacity of 2,243 cubic inches. A stone sink twenty inches by twelve inches by twelve inches deep would meet the specified requirements.

Waste chemicals that go down the drain eat through the sink traps about every five months. This means that on the average four sinks will require repairs about two times each school year. The removal of brass, and the installation of lead or Duriron traps will relieve this situation.

It is possible to move the tables and install larger sinks. Even this would not eliminate the high cost of maintaining these old tables. But the other gross inadequacies of the tables now being used predetermines the recommendation that new tables be installed.

<u>Tables</u>. The five cracked table tops could be removed, and replaced with either stone, synthetic, or laminated wood tops. Inasmuch as these tables have other objectionable features, such as leaky troughs, and lockers that are too small, it would be more practical to replace these tables with new ones with stone or laminated wood tops.

A possible solution to relieve the crowded locker situation is to reduce the amount of equipment issued to students as standard equipment. The bunsen burner may be removed from the drawer and wired to the gas jets on top of

student tables as standard procedure. Other equipment which is not absolutely necessary, such as one 500 milliliter flat-bottom boiling flask, ring support, and burette clamp may be removed and thereby relieve the situation. (See Figure 12.) It is to be noted that the removal of some equipment still leaves the locker somewhat crowded, and the basic problem still remains. John C. Bailar, Jr. says, ". . . give each student a single drawer, which may be 16" by 20" by 9" deep."[6]

Since there is enough floor space, it is recommended that tables be moved to allow for five foot aisles between tables. Says John C. Bailar, Jr., "the space between tables should not be less than five feet, and preferably six feet."[7] The average distance between laboratory tables for nine northern California junior colleges was 58.7 inches --the maximum 76 inches, and the minimum 46 inches found only at Modesto.

<u>Service lines</u>. Not much can be done about the high cost of relocating service lines embedded in concrete after a building is completed and laboratory furniture installed.

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[6] <u>Ibid</u>., p. 95.

[7] <u>Ibid</u>., p. 99.

FIGURE 12

LOCKER AND EQUIPMENT FOR GENERAL CHEMISTRY

In a new science building recently built at Reed College where the floor is concrete, a trench dug around the perifery of the building houses the service lines. This is a satisfactory solution to the high cost of repairs and alterations.

Water aspirators, which make a vacuum suitable for most purposes, should be installed at each table. This would not be a costly undertaking.

Organization of the laboratory and storeroom. To eliminate the unnecessary handling and transporting of lockers, each locker should be placed in its proper laboratory table place all fitted out for a specific course. Combination padlocks resistant to corrosion should be assigned to each locker, the storeroom clerk to hold in his possession a master key. Combinations can be changed as necessary. At the end of each semester a schedule could be set up for the storeroom clerk to check the student's locker at the assigned table. After the student has replaced all broken or missing equipment the lockers are ready to be issued at the beginning of the next semester.

Reagent shelves can be placed on the west wall and one resting on the floor between tables eight and nine. (See Figure 1, page 23.) These more centrally located areas would eliminate a great deal of the unnecessary walking and

with it confusion and accidents, which sometimes occur.

II. SUMMARY

The structural changes referred to in Chapter I, page 2, were the result of a fire which broke out in the chemistry building in August of 1953. The roof of the building was almost completely destroyed before the fire was extinguished, causing extensive water and smoke damage to supplies and equipment. In the process of rebuilding, some of the recommendations made in this chapter were used, namely, fluorescent lights were installed, and an asbestos board ceiling was added.

Prior to the fire in the spring of 1953, the Modesto Board of Education was presented the facts concerning the condition of the laboratory tables in use, and it was decided to purchase eight new ones over a period of two years. After the fire the Board decided to purchase the eight at once, even though the tables that went through the fire were still usable. These new tables were designed to the specifications listed in Chapter VI; for example, hardwood tops and cabinets, stone sinks, service lines (cold water, gas, electricity, and water aspirators), and method of locking were provided according to those specifications.

CHAPTER V

COMPARATIVE STUDY OF LABORATORY DESIGN AND CONSTRUCTION OF TEN NORTHERN CALIFORNIA JUNIOR COLLEGES

I. INTRODUCTION

This chapter will deal with a survey which was made during the period from March 2, 1951 to May 12, 1951 in ten northern California junior colleges. The names of the junior colleges visited are being withheld for reasons of public relations; alphabetical letters are substituted for the junior college names. Table IX shows that the survey is incomplete on junior college F because of the host's lack of time. Each general chemistry laboratory was observed by the investigator with written notes made on each item that appears on the checklist. (A copy of the checklist appears in Appendix, page 117.)

The materials, facilities, services, and equipment necessary for a general chemistry laboratory determined what items went into the checklist.

In January, 1955, four members of the science department at Modesto Junior College visited five junior colleges in southern California. Some of the more noteworthy observations, which were not tabulated in Table IX, will be presented in the following paragraphs; see pages 77 through 81.

TABLE IX

COMPARATIVE DESIGN AND CONSTRUCTION OF TEN NORTHERN CALIFORNIA
JUNIOR COLLEGE LABORATORIES

School	A	B	C	D	E
Laboratory Dimensions					
Length	60 ft.	50 ft.	36 ft.	30 ft.	40 ft.
Width	26 ft.	40 ft.	20 ft.	24 ft.	30 ft.
Floor Area	1560 sq.ft.	2000 sq.ft.	720 sq.ft.	720 sq.ft.	1200 sq.ft.
Area per student	21.8 sq.ft.	36.8 sq.ft.	15.7 sq.ft.	21.0 sq.ft.	26.2 sq.ft.
Construction Materials					
Walls	Plaster	Plaster	Plaster	Plaster	Plaster
Ceiling	Cello-tex	Plaster	Cello-tex	Plaster	Concrete
Floor	Hardwood	Hardwood	Hardwood	Hardwood	Concrete dovered with asphalt tile
Lighting					
Artificial Lights	Incandescent	Incandescent	Incandescent	Flourescent	Icandescent
Window Area	273.3 sq.ft.	231.3 sq.ft.	168 sq.ft.	81.3 sq.ft.	289.5 sq.ft.
Window Area per sq. ft. of floor	.17	.12	.24	.11	.24
Ventilation					
Doors	One	One	One	One	One
Hoods	Wall	Individual and wall	Wall	None (Porch)	Wall

TABLE IX (continued)

School	A	B	C	D	E
Exhaust Vents	Three; no fans	One	Four	Two	Four
Heating System	Steam Radiator	Forced Warm Air	Steam Radiator	Steam Readiator	Steam Radiator
Desks					
Cabinets	Hardwood	Hardwood	Hardwood	Hardwood	Hardwood
Tops	Synthetic	Hardwood	Hardwood	Hardwood	Hardwood
Minimum Length of Desk top per student	3.2 ft.	3.6 ft.	3.0 ft.	3.9 ft.	4.0 ft.
Width of Aisles	6 ft.	6 ft.4in.	4 ft.6in.	5 ft.	4 ft.8 in.
Height	36 in.	36 in.	36 in.	36 in.	37 in.
Lockers					
Number	Two	Two	Two	Two	Two
Method of Locking	Lock and key	Combination Padlock	Lock and Key	Lock and Key	Lock and Key
Equipment Accessible to all	Ring Stand Rings Clamps Troughs Bunsen Burners	Ring Stand Rings Clamps Burette Holders	Ring Stand Troughs	None	Ring Stand Rings Bunsen Burners

TABLE IX (continued)

School	A	B	C	D	E
Stools Used	Yes	Yes	Yes	Yes	Yes
Sinks					
Material	Stone	Stone	Stone	Duriorn	Stone
Size (in inches)	17 x 9.5 x 10.5 deep	20 x 12 x 12 deep	17.5 x 10 x 10.5 deep	22 x 15 x 9 deep	20 x 12 x 11.5 deep
Service Lines					
Water	Cold (One hot tap in lab.)	Cold	Cold	Cold	Cold
Gas	Natural	Natural	Bottled	Natural	Natural
Electricity	A.C. & D.C.	A.C.	A.C.	A.C. & D.C.	None
Steam	None	None	None	None	None
Vacuum	Aspirators	None	Aspirators	Motor Driven Pump	Aspirators
Air	None	None	None	Yes	None
Waste Line Material	Lead	Lead	Ceramic Tile	Duriron	Duriron
Hoods					
Service Lines	Gas	Gas & Hydrogen Sulfide	Gas, Water & A.C.	No Hoods	Gas, Water & Air
Number & Size	5-29" x 47"	2-30" x 72"	3-30" x 56"	None	2-32" x 87"
Length of Hood per student	.39 ft.	.32 ft.	.44 ft.	None	.45 ft.

TABLE IX (continued)

Schools	A	B	C	D	E
Hoods (continued)					
Super-structure Material	Transite	Wood	Wood (Stone top)	None	Transite (top stone)
Open or Closed type	Closed	Open	Closed	None	Closed
Safety Features					
Fire Extinguishers	Five	Two	Two	None	One
Fire Blanket	None	None	None	None	None
Shower	None	None	None	None	None
First Aid Kit	Two	None	None	One	None
Maximum Number of Students	50	38	32	24	32
Storeroom	Off Lab.	Off Lab.	Off Lab.	Central	Central
Balance Room					
Students Assigned Bal.	Yes	No	Yes	Yes	Use Triple Beam
Students Sit or Stand	Sit	Sit	Sit	Sit	Use Triple Beam
Ventilation	None	Windows	None	Windows	Use Triple Beam

TABLE IX (continued)

School	F	G	H	I	J
Laboratory Dimensions					
Length		28 ft.	40 ft.	40 ft.	47 ft.
Width		25 ft.	30 ft.	35 ft.	47 ft.
Floor Area		700 sq.ft.	1200 sq.ft.	1400 sq.ft.	2209 sq.ft.
Floor Area per Student		20 sq.ft.	26.2 sq.ft.	41 sq.ft.	24.2 sq.ft.
Construction Materials					
Walls	Plaster	Plaster	Plaster	Stucco	PlasterBoard
Ceiling	Plaster	Plaster	Plaster	Plaster	Wood
Floor	Concrete	Wood (Soft)	Wood (Hard)	Linoleum on concrete	Painted Concrete
Lighting					
Artificial Lights	Incandescent	Incandescent	Incandescent	Incandescent	Incandescent
Window Area		131.3 sq.ft.	192 sq.ft.	155.8 sq.ft.	285.2 sq.ft.
Window Area per Sq.Ft. of floor		.19 sq.ft.	.16 sq.ft.	.11 sq.ft.	.12 sq.ft.
Ventilation					
Doors	One	One	One	Two	Two
Hoods	Wall	Wall	Wall	Wall	Wall
Exhaust Fans or Vents	None	One	None	None	Two
Heating System	Steam Radiator	Steam Radiator	Steam Radiator	Steam Radiator	Gas Furnace
Desks					
Cabinets	Hardwood	Hardwood	Hardwood	Hardwood	Hardwood
Tops	Shellstone	Hardwood	Soft wood	Chem-rock	Synthetic & soft wood

TABLE IX (continued)

School	F	G	H	I	J
Desks (continued)					
Minimum Length of desk top per student	4.0 ft.	3.0 ft.	3.2 ft.	3.7 ft.	3.4 ft.
Width of Aisles		4 ft.9 in.	4 ft.6 in.	4 ft.	4 ft.3 in.
Height	37 in.	36.5 in.	36 in.	36 in.	36 in.
Lockers					
Number		Two	Three	One	One
Method of Locking	Combination Padlock	Lock & Key	Lock & Key	Combination Padlock	Lock & Key
Equipment Accessible to All		Bunsen Burners Burette Holders Troughs Rings Ring Stands	Ring Stand	Ring Stand	Ring Stand Rings Troughs Clamps
Stools Used	Yes	No	Yes	No	Yes
Sinks					
Material	Stone	Stone	Stone	Stone	Stone
Size (in inches)	12 x 21 x 10 deep	20 x 12 x 12 deep	10 x 17 x 7.5 deep	12 x 20 x 12 deep	16 x 8 x 6 deep
Service Lines					
Water	Cold	Cold	Cold	Hot & Cold	Cold
Gas	Natural	Natural	Natural	Natural	Natural
Electricity	A.C.	A.C.	None	A.C. & D.C.	A.C.

TABLE IX (continued)

School	F	G	H	I	J
Service Lines (con'd)					
Steam	None	None	None	None	None
Vacuum		Aspirators	None	Aspirators	None
Air	None	None	None	None	None
Waste Line Material	Duriron	Duriron	Standard Piping	Duriron	Standard Piping
Hoods					
Service Lines	Gas & A.C.	Gas, Water & Hydrogen Sulfide	Gas & Water	Gas, Water & Hydrogen Sulfide	Gas, Water & Hydrogen Sulfide
Number & Size		2-72" x 40"	2-60" x 30"	3-44" x 27"	4-57" x 32"
Length of Hood per Student		.5 ft.	.31 ft.	.46 ft.	.30 ft.
Super-structure Material	Transite	Transite	Wood	Transite	Transite
Open or closed type	Closed	Closed	Closed	Closed	Open
Safety Features					
Fire Extin.		One	None	One	Two
Fire Blanket	None	None	None	One	One
Shower	None	None	None	None	None
First Aid Kit	None	None	None	None	None
Maximum Number of Students	24	24	32	24	64
Storeroom	Central	Off Lab.	Central	Off Lab.	Off Lab.
Balance Room					
Students Assigned Bal.	Use Triple Beam	Yes	Use Triple Beam	Yes	Yes
Students Sit or Stand		Sit		Sit	Stand
Ventilation		Windows		None	Windows

The results of the survey as tabulated in Table IX, pages 63 through 69, will be analyzed here.

Laboratory dimensions. The average number of square feet of floor space per student is an important value from the standpoint of economy in construction and crowding of students. Using the University of California at Los Angeles--which is efficiently designed--as a model, approximately 70 per cent of the laboratory floor area is usable by the students. The other 30 per cent of floor area is consigned to student desks, weighing benches, and hoods. Robertson[1] points out that if 75 per cent of the floor is usable area, one has very nearly achieved the maximum of efficiency. In calculating the floor area, in square feet per student as seen in Table IX, pages 63 through 69, the formula used was:

$$\frac{\text{Length (feet)} \times \text{Width (feet)} \times 0.70}{\text{Student capacity of Laboratory}}$$

Using this formula, the usable floor area at the University of California at Los Angeles general chemistry laboratory is approximately twenty square feet per student. If one compares the area per student at junior college C, which is

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[1]G. Ross Robertson, "Chemistry at UCLA," *Journal of Chemical Education*, 30:527, October, 1953.

15.7 square feet, with 20 square feet one can readily see that school C is overcrowding its laboratory. On the other hand, it is seen that colleges I and B with 41 and 36.8 square feet, respectively, are too liberal with floor space.

It was noted that junior college A, with a length of 60 feet and a capacity of 50 students, has too many students and is too long for one instructor to do an effective job of supervision.

Construction materials. The majority of laboratories had plaster walls and ceilings because plaster is resistant to corrosive fumes, economical, and can be textured and painted to give a pleasing appearance. It can be repainted to change color schemes or brighten up dirty surfaces.

Floors were generally made of hard wood because it looks good, wears well, and offers resiliency, which is desirable. The two most recently built laboratories, E and F, had concrete covered with asphalt tile floors. Concrete is considerably more economical, and for that reason is used in more recent construction.

Lighting. Only one junior college of ten is using fluorescent light, yet this one laboratory, without doubt, had the best lighting. Junior college D not only had installed fluorescent lights to improve lighting conditions,

but had also coated desk tops a pale gray. This color vastly improves the amount of reflected light making it easier to read hair lines or etched markings on instruments. The probable reason for the use of incandescent light in the other nine laboratories is that at the time of construction fluorescent lighting was not on the market or had not proved itself.

Daylight is admitted into the laboratory via windows. The ratio of window area to floor area is a more accurate measurement of the amount of light entering a room than is just window area. As can be seen school J with next to the largest amount of window area had a very low ratio of window area to floor area. Junior college C with a medium amount of window area had one of the highest ratios of window area to floor area. Using Tugman's[2] ratio of 0.15 as a standard, about one-half of the laboratories visited are substandard with respect to admission of daylight.

Ventilation. Every laboratory called upon had some means of ventilation. This indicates the importance of this problem. Wall hoods were part of the ventilating system at

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[2]H. S. Coleman (ed.), Laboratory Design (New York: Reinhold Publishing Corporation, 1951), p. 50.

every school except one which used an open air porch. School B had individual hoods at the students' desks in addition to the wall hoods mentioned. This furnished a very efficient, but most costly means of ventilation. Wall hoods are far less expensive because less desk space, ducts, exhaust fans, and room space are required. This accounts for the preference of wall hoods over individual hoods.

Heating. The use of steam radiators to supply heat is the most popular as revealed in Table IX, pages 63 through 69. Steam has proved to be an efficient and comfortable way of heating a room.

Furniture. With respect to student desks, it was interesting to note that, in every institution viewed, the cabinets below desk tops were made of hardwood, denoting that chemistry instructors prefer the non-corrosive, noiseless, warm appearance of wood over metal. Investigation revealed that a variety of materials were used for desk tops. Such materials as, synthetic, Chem-rock (manufactured by Kewaunee Manufacturing Company), Shelstone (manufactured by E. H. Sheldon Equipment Company), and soft or hard wood. Laminated hardwood was used as desk top material by more schools than any other material. The cost of Alberene stone on the west coast is the limiting factor in its use.

The maximum and minimum length of desk top per student observed was four and three feet, respectively. The instructors, whose students were allowed only three feet of desk top complained of crowded conditions. Students at the University of California at Los Angeles have three and one-half feet of desk top length, which seems to be satisfactory. Accordingly it would appear that each student should have at least three and one-half feet of desk top and preferably more. Bailar[3] thinks that each student should have five feet.

It was noticed that at one school, other than Modesto Junior College, the aisles between desks were only four feet wide. At another they were six feet, four inches. Aisles six feet, four inches seem to be a waste of floor space even with the use of stools; aisles of four feet are too close resulting in crowding. Robertson[4] favors aisles five feet in width.

There has been talk of eliminating stools in the laboratory, but survey results clearly showed that stools are preferred and used by a majority of students. At junior

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[3] Ibid., p. 96.

[4] "Proceedings of the Pacific Southwest Association of Chemistry Teachers," Journal of Chemical Education, 31:269, May, 1954.

college C the aisles were too narrow to permit the use of stools.

It was found that the larger pieces of metal equipment were stored in the laboratory, for example, under hoods, where it is accessible to all. This system decreases the amount of bulky student locker equipment making it possible to add greatly needed smaller items. Ring stands, rings, clamps, troughs, burette clamps, and bunsen burners are examples of community equipment. A unique way of wiring bunsen burners to the gas jets was observed at institution E. Another junior college had screwed the ring stand bases to desk tops, thereby decreasing the work area.

The majority of junior colleges provide their students with two lockers, usually a large one for stowage of large articles, and a small one for stowage of small pieces. The trend is toward one medium-sized locker per student, and thus nearly double the number of students handled per laboratory.

Seven of the ten schools called upon were using the lock and key system to lock student drawers. Students were issued a locker key to carry for the ensuing semester at four of the seven schools, the other three schools required students to place their key on a keyboard before leaving the laboratory.

Service lines. Cold water and gas were found to be indispensable because every laboratory had these services piped to student desks near each working area. One hot water tap in the laboratory was observed on two occasions, junior colleges A and I. Receptacles for alternating current were observed in eight laboratories, while three had both alternating and direct current. Two schools did not have electricity in the laboratory at all. Since the cost of installation and upkeep is a fraction of motor driven vacuum pumps, water aspirators were commonly used. Results of the survey revealed that compressed air and steam are considered unessential for only on one occasion was either provided, that being compressed air. Materials used for waste pipes were Duriron, the most popular, followed by lead, next in popularity, and finally galvanized steel. A great deal of breakdown and repair occurred in laboratories where galvanized steel was used.

Sinks. The preference of materials for sinks turned out to be Alberene stone in every laboratory except one, which was Duriron, iron of high silicon content. This was the only laboratory that did not have the central trough running the length of student tables, and, therefore, twice as many sinks were required. The difference in cost between Alberene stone and Duriron could have been the reason for

the latter.

<u>Hoods</u>. Every hood, as seen in Table IX, pages 63 through 69, had gas, the majority had water, some hydrogen sulfide and a few electricity or air. The hood superstructures were made of wood, or more often asbestos composition board, known as transite. Stone tops were observed on very few hoods, a place where corrosion is the most severe. The length of wall hood per student is a worthy method of determining hood requirements. The calculation was made by dividing the student capacity of the laboratory into total length of hood. School B, which had individual hoods, and school D, which used the open porch were not included. The determinations revealed that schools H and J, with ratios of 0.31 and 0.30, respectively, were noticeably short on length of hoods. A more desirable ratio would be somewhere between 0.40 and 0.50 feet per student.

<u>Safety measures</u>. The safety protection equipment noted were fire extinguishers, fire blankets, and first aid kits. It was surprising to find that showers were not included. The investigator visited some laboratories in the southern half of California, and found that safety showers were installed. The purpose of a safety shower is

to offer a fast means of washing off dangerous chemicals from one's clothing or body.

Storerooms. Storerooms that opened directly off the laboratory were more common than central storerooms. The feeling among some instructors is that they would rather have several small storerooms than one large central one.

Two science departments employed student assistants and a full-time person in charge of the central storeroom. In the storeroom of junior college E the full-time employee was a certified instructor. One great advantage of the central storeroom is that it makes possible the employment of such a full-time person. Another science department had done away with having their students sign for equipment drawn from the storeroom. Instead each student contributed the same amount, approximately $1.00, toward a breakage fund. This is a way of freeing the storeroom clerk from record keeping.

Balance rooms. It was discovered that not all chemistry departments were using analytical balances. Two departments were using the less accurate triple beam balances. If larger samples are taken, the use of triple beam balances proves quite satisfactory, but it does not give the student training in the use of the analytical

balance. Most chemistry instructors were using analytical balances, and, therefore, feel development of skill in the use of this balance is important.

A special room near the laboratory was set aside to house the analytical balances. Such a room protects these delicate instruments from fumes thereby, preserving their accuracy and extending their life. It was noted that students sit down rather than stand to make their weighings. In a majority of schools students were assigned a definite balance on which to perform their weighings. There did not appear to be any accepted way of handling balance weights. At a number of institutions the weights were locked in the balance drawer or one built into the bench. The key to the drawer was kept in the storeroom. In other chemistry departments the weights were left unlocked in the drawers mentioned above. School D left the rider on the balance beam at the zero mark, which seemed to be a good way to handle the rider.

<u>Handling of distilled water</u>. A majority of schools carried distilled water in five gallon carboys from the still to the laboratory. One of the best systems for distributing distilled water seen was at school E where the water was piped to a centrally located drinking fountain in the hall. Of the ten schools visited none were using

recently developed demineralized water, a substitute for distilled water. The trip to southern California referred to above disclosed that at least one junior college visited was using demineralized water, and with satisfactory results.

Student capacity. The maximum number of students in the laboratory at a given time was sixty-four and the minimum twenty-four. The capacity of sixty-four was composed of students from more than one chemistry course. Table IX, pages 63 through 69, reveals that a capacity of twenty-four appears the greatest number of times, namely, four. This is in keeping with the trend toward smaller laboratories. At one institution in southern California, the laboratory capacity was sixteen.

Other features. Junior college C had a centrally located chalkboard that was double sliding, one section behind the other.

The chemistry instructor of this school had placed on a book shelf in the laboratory a number of chemistry textbooks for student use which he had received from book companies.

II. SUMMARY

The more desirable laboratory features observed were: (1) fluorescent lighting, (2) hardwood tables (student), (3) forced ventilation, (4) safety showers, (5) bunsen burners with tubing secured to gas cocks, (6) central storeroom, (7) distilled water piped to the laboratory, (8) central chalkboard, and (9) capacity of twenty-four students.

CHAPTER VI

CHARACTERISTICS OF A DESIRABLE GENERAL CHEMISTRY LABORATORY

The ideas presented in this chapter grew out of the investigator's experience, the literature read, junior colleges visited, and attendance at a meeting of chemistry teachers. (See page 3.)

This chapter will be divided into two parts. Part I will be a general description of chemistry laboratories. It will cover the topics of construction materials, plumbing, ventilation, lighting, furniture, and safety. In Part II, specific ideas believed to be the best for the situation at Modesto Junior College will be selected for presentation. Layout drawings will explain further the textual material.

I. GENERAL ACCOUNT OF CHEMISTRY LABORATORIES

A chemistry laboratory will have to be a suitable room in a building which houses all the sciences, any combination of sciences, or straight chemistry. The building can be of single story or multiple story type. A campus where the amount of land is limited and the number of students large will of necessity require the multiple story

type of building. Here at Modesto Junior College where there is ample land and the number of students small, the single story type of building is more desirable. In a single story building it is desirable to have the lecture rooms, recitation rooms, library, and offices located at the front of the building and student laboratories in the rear.

In order that this laboratory may function properly, it must be a room with walls, floor, ceiling, windows, furniture, service lines, sinks, lighting, ventilation, and provision for safety.

Walls. There are two types of walls: (1) structural, which give support to the building, and (2) non-structural, which are movable or semi-movable and serve to divide building space.

The various materials used for structural walls are concrete, concrete block, terra-cotta tile, concrete brick, clay brick, and glass block. These masonry walls are resistant to the passage of fire and sound. Their hard surface is much easier to keep clean by washing, but there is a tendency for sound to be reflected.

In a semi-movable wall a certain amount of material is salvaged and reused. An example of this type of wall would be panels screwed to wooden studs. These panels are

made of plywood, hardboard, or plastic. Movable walls are usually steel strips to which asbestos cement is applied. This surface can be painted any desired color or left to its original color.

Floors. The material used for floors must be resistant to acids, bases, and solvents, and at the same time make it comfortable upon which to walk. Some materials which are used are asphalt tile, painted concrete, linoleum, asphalt mastic, quarry tile, terrazzo, wood, and plastic tile. Floors of concrete, quarry tile, and terrazzo, which are very hard to walk on, required rubber or linoleum mats in aisles and along benches. Hardwood floors, if coated properly are quite resistant to acids, bases, and solvents, and at the same time they wear well, and are easy to walk on. The upkeep of wood floors is a little more costly. The floor should be set high enough off the ground to make repairs and alterations to service lines easy.

Ceiling. Lighter materials can be used for ceilings because they do not take the wear of floors or contribute to building support like walls do. The main function of a ceiling is to reflect light. Therefore, the material or coating should be light in color and free from light glare. A mat-type material, such as acoustic tile or acoustic

plaster is good because reflection of sound is eliminated. In the ceiling there generally is electrical conduit, pipe, heating, and ventilating ducts to conceal. The hung ceiling, which affords a means of improving appearance, is designed with removable units which make service lines accessible. (See Figure 13.)

Windows. The function of windows is to admit daylight which replaces or supplements artifical light. Windows also ventilate and permit one to view the outside which is comforting to the eyes. Daylight is essential; so large window area must be provided extending very nearly to the ceiling. The higher the windows the deeper light will travel inward. To eliminate glare, which is serious in high windows, blinds or frosted glass must be used. Heat loss, which is great with large window area, can be reduced by snug fitting sash and better location of heating system, for example, along the wall below the windows.

The laboratories now being constructed are installing steel window frames and sashes in preference to wood because, if coated properly, it is more durable than wood. Since the dimensions of steel sashes are smaller, window area is increased slightly.

FIGURE 13

HUNG CEILING

Furniture. While the laboratory is in the process of construction it is important that the walls and particularly the floor be laid out plumb and straight. This will reduce alterations, at the time of installing furniture, to a minimum, and a saving in labor costs will result.

Laboratory furniture supply houses carry a wide selection of standard size furniture units. For example, it is possible to buy student tables in sizes which will accommodate four, six, or eight students. It is less costly to purchase furniture pieces from standard stock than to have specific size units built.

Tables are the areas upon which students do their laboratory wok. Usually the table has drawers which supply storage space for the students' possessions. Materials used for table tops should be resistant to acids, bases, and solvents. Soapstone is one of the most resistant and durable materials used. Wood table tops are made of strips of birch or maple, up to three inches wide, glued together with a final thickness of one and one-fourth to one and five-sixteenths inches. Such wood is not resistant to acids, bases, and solvents until it is treated or coated. An old reliable treatment, which has proven to be satisfactory, is given in Chapter II, page 9. A very desirable feature of

the wood top is that it can be resurfaced, recoated, and retreated readily, which is not true of the other materials. Other table top materials are: (1) sandstone, which is attacked to some extent by strong oxidizing acids, (2) slate, which is very resistant, but has a tendency to flake off, and (3) plastic tile, which is somewhat soluble in solvents.

The function of cabinets is: (1) to provide storage space, (2) to increase support to table tops and sinks, and (3) to provide housing for the concealment of service piping. Cabinets are made from wood or steel. Steel cabinets readily corrode unless thoroughly and completely covered with a protective coating. This coating can be a paint or baked enamel, which is more lasting. Steel has a tendency to be noisy in operation, but on the other hand, it does not absorb moisture, and offers greater protection against fire. Wood cabinets are light in weight, quiet in operation, resistant to corrosion, and have a natural warmth and beauty. Wood, which has a low resistance to fire, is somewhat absorbent of moisture and suffers from the attacks of it.

There is the open and closed type of cabinet. The closed cabinet is provided with either sliding or swinging doors or glass, wood, or metal. The open cabinet should be

used when the storage materials are in heavy demand, such as reagents. The closed type is more suitable for the storage of delicate instruments, and solutions which need protection against dust. The fact that students need a safe place to store equipment gives priority to the closed cabinet.

Service lines. Water lines should be galvanized standard weight steel or genuine wrought iron with fittings of cast iron. Globe valves should be used for lines under one and one-fourth inches in diameter and gate valves for diameters above this.

The chemistry laboratory utilizing compressed air requires a pressure of five to ten pounds per square inch. To supply compressed air a motor-driven rotary pump is needed. The size of the air compressor is a matter of good judgment rather than calculations. To prevent the compressor from running continuously, there should be a storage tank in the system. The storage tank should have a pressure gauge, safety valve, and bottom drain for removal of moisture. The pressure in the storage tank can be much higher than is called for at the outlet because a pressure regulator can maintain a constant reduced pressure. Pipe used should be standard weight black steel, using white lead in linseed oil, or other suitable compound, to seal joints.

The rotary vacuum system in a school laboratory, if one is used, should have a pressure of fourteen to twenty inchres of mercury. A vacuum greater than this will cause filter papers to break through when the student is in the process of filtration. A good grade rotary vacuum pump will readily take care of the above needs. Black steel piping with globe valves for lines less than one and one-fourth inches in diameter and gate valves for lines larger than this should be used. Threads on pipe and fittings should be accurately cut, and dissolved beeswax or varnish should be applied to threads while under vacuum to prevent leakage. To avert water from being pulled into the vacuum pump, a trap should be provided in the line ahead of the pump.

When natural gas is used, the normal laboratory pressure should be six inches of water, but a pressure of three and one-half inches is sufficient to operate a bunsen burner properly. Gas pipe should be standard weight black steel with joints sealed in a compound of white lead in linseed oil.

Since hydrogen sulfide is a poisonous and corrosive gas with an unpleasant odor, it should be used under a hood at all times. It is obtainable in standardized cylinders having a pressure of 252 pounds per square inch. The gas

can be piped through brass, hard rubber, or aluminum tubing.

Materials used in waste piping must be highly resistant to the corrosion effects of acids and bases. Such materials are lead, stoneware, high silicon iron, glass, and synthetic resins. The most satisfactory material is high silicon iron which is extremely brittle. If traps are made of lead, it must be pure lead because lead which contains small amounts of impurities, such as zinc, does not hold up. Joints should be either burned or wiped, and if wiped a satisfactory corrosion resistant solder must be used. Packing should be pure asbestos rope impregnated with graphite or mastic, since hemp and oakum, which are commonly used, are not acid resistant.

Sinks. Some small sinks are in the shape of a large coffee cup, and appropriately are called cup sinks. Others suitable for washing glassware are much larger. A sink is subjected to attacks of strong acids and bases. These attacks may remain active for long periods of time unless some self-flushing means is provided. The material that goes into a sink must be the most resistant obtainable, such as soapstone and high silicon cast iron.

Lighting. The purpose of lighting is to provide efficient and comfortable vision as an aid in carrying out laboratory operations. Lighting is good when: (1) brightness is agreeable and beneficial to the user, and (2) it permits a high degree of visibility with minimum effort. The controlling factors in vision are: (1) the task performed, (2) the amount of light, and (3) the surrounding conditions. Table X presents the recommended values of illumination.

The different types of lighting systems[1] are: (1) indirect; 90 to 100 per cent of the luminaire output is first reflected off the ceiling and upper walls, (2) semi-indirect; 60 to 90 per cent of the luminaire output is directed upward toward the ceiling and upper walls with the rest directed downward, (3) general diffuse; 50 per cent of the luminaire output is directed upward, and an equal amount downward, (4) semi-direct; 60 to 90 per cent of the luminaire output is directed downward, and (5) direct; 90 to 100 per cent of the luminaire output is directed downward.

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[1] H. S. Coleman (ed.), Laboratory Design (New York: Reinhold Publishing Corporation, 1951), pp. 51-52.

TABLE X

RECOMMENDED VALUES OF ILLUMINATION*

Task	Foot-candles
1. Difficult seeing involving:	50
a) Discrimination of fine details.	
b) Poor contrast.	
c) Long periods of time.	
2. Ordinary seeing involving:	30
a) Discrimination of moderately fine detail.	
b) Better than average contrast.	
c) Intermittent periods of time.	
3. Casual seeing, such as:	10
a) Reception rooms.	
b) Stairways.	
c) Washrooms, and other service areas.	
4. Simple seeing, such as:	5
a) Hallways and cooridors.	
b) Passageways.	

*H. S. Coleman (ed.), Laboratory Design, p. 47.

The comparison between fluorescent and incandescent light of Table XI shows that fluorescent light has color similar to daylight, is inexpensive to operate, and more efficient because of direct line in which the light travels.

In order that light sources may deliver to maximum capacity, it is necessary to clean walls, windows, light fixtures, luminaries, and ceilings periodically. It may be necessary to replace deficient lamps, which could lose up to 30 per cent of their output.

Glare is caused by high brightness, and large brightness differences within the field of vision. The field of vision from the horizontal to an angle of forty-five degrees above the horizontal is very susceptible to glare, which makes it necessary to shield this area. Moderate glare is often unnoticed and the cumulative effect causes undue eyestrain.

The presence of shadows on work surfaces are annoying and cause eye fatigue. It is never possible to completely eliminate shadows, but they can be reduced to a minimum by the use of diffused light. Walls and ceiling of mat finish and light in color are a secondary source of diffused light and help in the elimination of shadows. The following light reflection percentages should be established in the laboratory: ceiling, 85 per cent; walls, 60 per cent;

TABLE XI

COMPARISON OF INCANDESCENT AND FLUORESCENT LIGHTING

Fluorescent Light	Incandescent Light
1. Produces a blue-white light.	Produces a yellow light.
2. High initial cost of installing.	Low initial cost of installing.
3. Low operating cost.	High operating cost.
4. More use is made of direct lighting.	More dependent upon the use of indirect lighting.
5. Cool light.	Hot light.

desk top, 35 per cent; and floors, 30 per cent.

Ventilation. Ventilation may be defined as the rate of air flow in cubic feet per minute in a given room.[2] The function of ventilation is to prevent the building up of air impurities, and an improper temperature within the workroom. There are two ways in which ventilation is accomplished: (1) by diluting the air within the room, and (2) by exhausting the stagnant air.

The most practical way of ventilating the laboratory is through the use of hoods. If designed and installed correctly, they will prevent the spilling of obnoxious gases, and at the same time draw fresh air into the room. Spillage of obnoxious gases from hoods into the laboratory can be prevented by: (1) proper withdrawal rate, (2) proper design of ducts, (3) proper setting of baffles, and (4) elimination of air disturbances in the laboratory.

The proper removal of contaminated air is principally controlled by the exhaust fan of the hood. If the removal rate is too fast air will move across the working surface too fast to permit a flame to burn like that of a bunsen burner. Also, if the removal rate is too fast there will

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[2] *Ibid.*, p. 61.

be an excessive loss in heat, thereby increasing the fuel bill. The use of heat-producing equipment, for instance a hot plate or bunsen burner, under the hood causes an increased upward flow in proportion to the increase in temperature. If the capacity of the fan is insufficient, fumes will spill out into the room. For a hood to function properly air should be moving at a rate of sixty to eighty linear feet per minute. When the removal rate drops below sixty linear feet per minute contaminated air begins to spill into the room.

Ducts aid in preventing spillage if they are of ample size, circular in cross section, and free from sharp bends. Static pressure will then be reduced to a minimum and fume removal made easier. If a branch duct is to discharge into the main duct, it must be done by means of a "Y" connection.

One of the two exhaust slots in a hood must be located at the top nearest the front edge of the case to draw off vapors flowing in an upward direction. The other slot must be situated at or near bench top level to draw off fumes that are being liberated at this level. If a hood has only the top slot there will be an increased movement of air at the top rim, and spillage takes place at the lower level. (See Figure 14.) When heat is produced in the hood there is an increased movement of

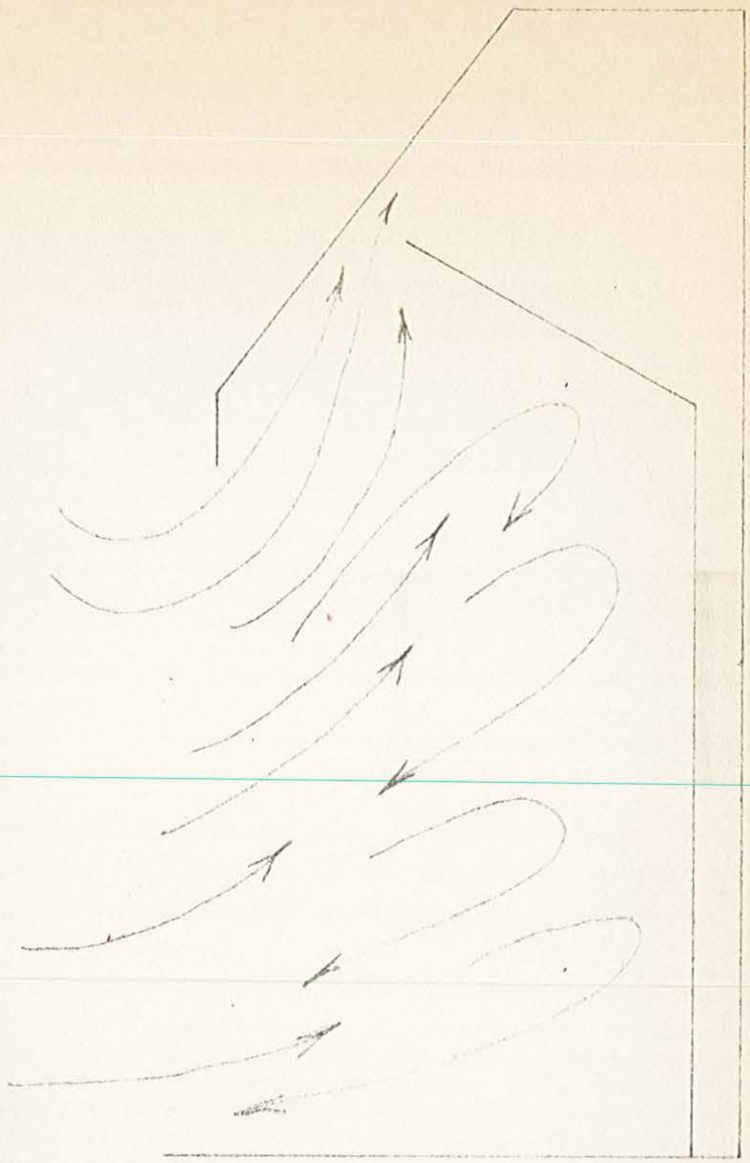

FIGURE 14

HOOD SUPER-STRUCTURE WITH TOP EXHAUST SLOT ONLY

upward air currents. Since the air is moving upward there is little need for the lower slot being open so it should be closed down. If heat is not being produced in the hood, the lower baffle must be opened to prevent the spillage mentioned above. Upper level spillage can also be controlled in hoods with windows by lowering the sash.

Air disturbances adjacent to the hood openings will cause the spillage of bad fumes. The cause of such disturbances are movements of the students, window drafts, and improper location of air supply grills. Positioning of the hoods should be made with great care and study.

The open hood is preferred to the sash type hood in most instances because the open type is simpler in design and less expensive to construct. The open hood will eliminate about 90 per cent of all objectionable fumes, and allow the student much greater freedom in conducting and observing his experiment. When working with explosives or inflammables, the sash type hood is preferred because of protection offered. Sash glass should be the safety type glass impregnated with chicken wire to minimize the amount of flying glass.

Safety. In case of an emergency, controls to service piping should be readily and quickly accessible, and should close down the whole laboratory. An emergency shower

should be situated above the door of the laboratory, where it is easily reached. It should be the deluge type supplied by at least one inch pipe with quick acting valve operated by a pull chain.

To extinguish a clothes fire a woolen fire blanket should be provided. It should be the type which can be stored in a vertical container with a handle extended. Then all the victim has to do is grab the handle and turn into the blanket.

An adequate number of fire extinguishers must be located near the door of the laboratory, or at a reasonable distance from a fire hazard. For electrical fires, carbon dioxide, dry powder, or vaporizing liquid extinguishers should be provided. Ordinary foam extinguishers should not be used where water soluble inflammable liquids are a hazard because these liquids destroy the foam.

II. LAYOUT OF A TYPICAL GENERAL CHEMISTRY LABORATORY

The laboratory must be planned from the inside out rather than from the outside in. It must be planned from the long-range point of view by allowing changes to be made as times change. Since a wall cannot be moved to any convenient distance, it becomes necessary to design the laboratory around an established basic unit called a module.

A module is the distance from the center of one bay to the center of the next.

The chemistry laboratory as seen in Figure 15 is only one room in a hypothetical single story science building. The plan presents a basic framework for construction rather than any last word in design. The twenty-eight by thirty-two foot laboratory is planned for twenty-four[3] students with three rows of tables and eight students per row (four on each side). The aisles between tables are five feet, and between the table ends and the window wall is a two foot aisle. General chemistry laboratories at University of California at Los Angeles have aisles of this width, which Robertson[4] says are ample. The aisle between table ends and the corridor wall is five feet, and the two between the table and end walls of the laboratory are four feet. An eight foot chalkboard is centrally located along the corridor wall with an unobstructed view. Hood ducts, and plumbing, are concealed in the corridor wall, and a reagent shelf with weighing bench is placed at each end of the room close to the corridor wall. The usable area of this laboratory is approximately 70 per cent of the total floor area.

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[3]_Ibid._, p. 99.

[4]"Proceedings of the Pacific Southwest Association of Chemistry Teachers," _Journal of Chemical Education_, 31:269, May, 1954.

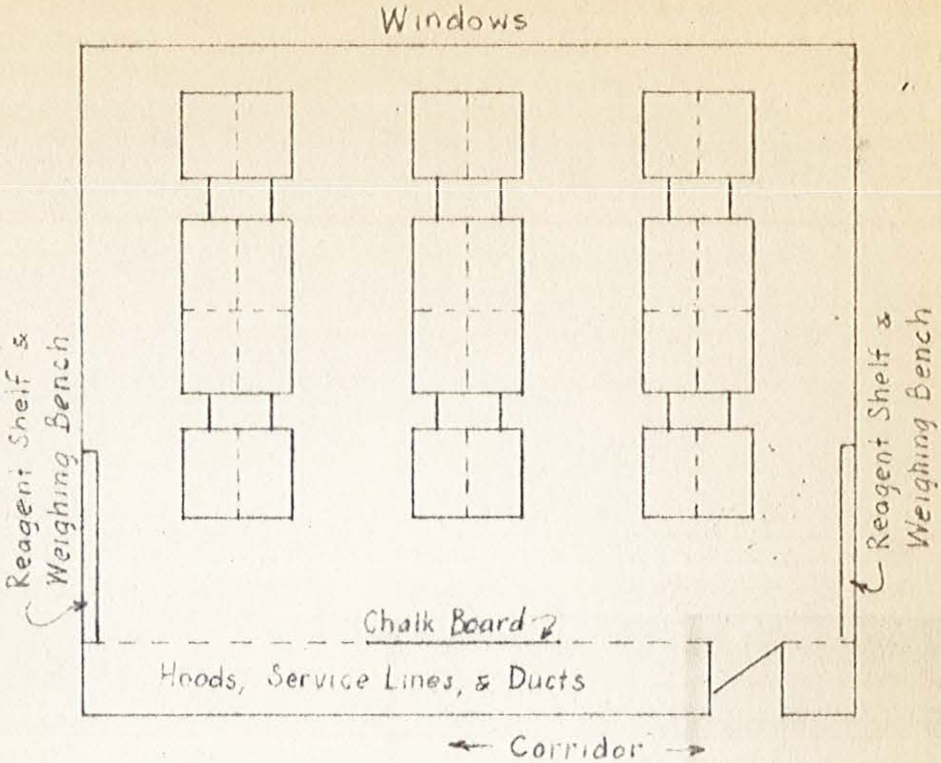

FIGURE 15

BASIC FLOOR PLAN OF GENERAL CHEMISTRY LABORATORY

SCALE 1/8"=1.0'

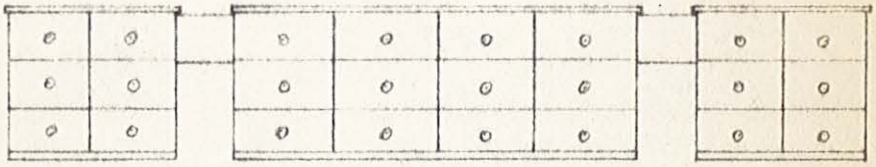

FIGURE 16

SIDE VIEW OF STUDENT DEAK

SCALE 1/4"=1.0'

Each table has twenty-four drawers which means that six sections of four students per section can be accommodated. (See Figure 16, page 102.) The total number of students that can be handled by this laboratory is seventy-two.

The walls, except for the structural wall on the window side, are of hallow tile which has a smooth surface resistant to fumes and easily cleaned. Metal channels are built into the walls for the purpose of hanging charts, shelves, and other objects. The outside structural wall is of concrete.

The floor is concrete slab covered with asphalt tile. Concrete is used because it is economical and fireproof. The color of the asphalt tile should match the color of the mess that is spilled on it. A mottled yellow and brown is selected for this reason.

Porous acoustic plaster is used for the ceiling because of its textured surface as it diffuses and reflects light sufficiently with very little glare and practically eliminates reverberation of sound. With tile walls which reflect sound, it becomes increasingly important that the ceiling be made of acoustic material.

The windows extend from approximately three feet above the floor to within six inches of the ceiling. They

are single hung with coated steel sashes. The outside wall provides for as much window area as possible to admit the full potential of daylight.

On the basis of survey results (page 73) student desks selected have laminated wood tops, hardwood cabinets, stone sinks, and service lines for cold water, gas, and electricity (alternating current). Aspirators are connected to the water tap as a source of vacuum. An upright rod with flush plate is used instead of the ring stand which is used most commonly.

Each student has a desk top work area of three and one-half by two feet, and a drawer eighteen inches wide, seventeen inches long by nine inches deep, locked with a master keyed combination padlock. Common equipment, for example, support rings, burette holders, utility clamps, and deflagrating spoons, are to be stored in the hood cabinets. (See page 75.)

Each of three hoods is approximately five fee wide having a hardwood cabinet base with Alberene stone top. It is the open front hood with asbestos composition board super-structure having service connections for cold water, electricity, gas, and cup sink. (See page 76.)

All hardware, such as hinges, padlocks, gas cocks, water taps, aspirators, and so forth are good quality

corrosion resistant material.

Artificial lighting is provided by fluorescent light fixtures emitting sufficient light to provide from thirty to fifty foot-candles at the desk top of well diffused light.

The room is heated by means of forced warm air delivered by ducts from the central heating system. The delivery duct has a control for regulating the flow of air.

In the interest of safety, two dry carbon dioxide fire extinguishers are placed so that one is close to the door, and the other is at the opposite end. A fire blanket is also placed near the door opening into the hall. A safety shower fed by one inch water line with chain attached to a quick opening valve, which automatically remains open when released is placed directly over the door in the laboratory. (See page 77.) This water line must not run close to steam pipes.

Economy in construction is considered when the width of aisle next to the windows is reduced from the usual five feet to two feet, when concrete floor is used instead of wood, when wood table tops are used instead of stone or synthetic, and when recessed door is used, decreasing the width of the corridor from the usual ten feet to eight feet. (See Figure 15, page 102.)

Organization of the laboratory. This laboratory is so organized that the students and instructor waste as little time as possible. It has been found that students needlessly lose valuable time by frequent trips to the storeroom and because necessary reagents, chemicals, and unknowns are not prepared ready for use. Students make trips to the storeroom to get equipment, chemicals, reagent bottles refilled, and unknown samples. With proper planning by the student some of these trips could be eliminated, but many could not. To eliminate needless trips to the storeroom, two steps are taken: (1) make student lockers as complete with equipment as possible without overcrowding; (2) make the storeroom manager a full-time job. His responsibilities are to see that reagent bottles are full, that chemicals are set out on the weighing bench as needed, and that unknowns are prepared in advance. In the absence of a storeroom manager the responsibilities enumerated above fall upon the instructor, which means diverting his attention from teaching or supervision.

Proper care of analytical balance weights is a problem that is partially solved by thorough instructions on the use and care of weights, assigning each student to a specific balance and set of weights, providing a drawer (see page 78) either in the balance or bench below for

locking weights, and leaving the rider on the beam when the balance is not in use.

An effective way of eliminating waste of distilled or demineralized water is to remove it from the convenience of the student. One such method has been described on page 79 and is put into practice in this laboratory. The problem of still deposits has been eliminated by the installation of a demineralizer, which is less troublesome and less expensive to operate.

III. SUMMARY

The plan presented stresses the point of view of a classroom teacher. Since the classroom teacher is the individual who has the major responsibility for teaching chemistry, this person should play a dominant role on the planning committee. Other members of the planning committee, functioning cooperatively and harmoniously, should be school administrators, architects, school maintenance, and students.

CHAPTER VII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary. The history and purposes of the laboratory, and how the "scientific method" can be implemented has been presented. Consideration was given to the facilities required to do the job most efficiently. The poor conditions existing at Modesto Junior College were surveyed followed by suggestions for improvement. Acceptable standards for lighting, heating, desks, ventilation, construction materials, service lines, and safety features were proposed.

Conclusions. This study has disclosed that implementing the scientific method is a matter of teaching procedure rather than laboratory design and organization. As a review of the proper teaching procedure to implement the scientific method, the chemistry instructor: (1) selects experiments with unknowns, (2) omits detailed instructions to the experiment, (3) has the students use experimental results to plan further work, and (4) assigns laboratory experiments before the material is discussed in class or assigned as outside reading.

Recommendations. In accordance with what has been presented, the most practical solution to the problem is for Modesto Junior College to build a new science building in which to house the chemistry. Not only are laboratory conditions poor for chemistry, but for most of the other sciences as well. Since chemistry is in a separate building at a considerable distance from the rest of the sciences, a building is urgently needed to put the sciences under one roof. This will help to alleviate the mix-up between the sciences when receiving supplies, and bring the instructors together as a unit. It was mentioned in Chapter I, page 3, that ideas acquired in this paper will be incorporated in the new laboratory which is in the planning stage. This new laboratory will be one unit in the new science building being planned. It is realized that not all the features of a desirable laboratory can be introduced in the new laboratory because funds are limited. However, those features deemed most essential, such as student capacity, lighting, desks, ventilation, service lines, and safety, will be used.

Further study is needed to determine the future of science enrollments by investigating trends. The trend for engineers, which make up a large segment of the freshman chemistry enrollment, is toward more emphasis on the study of the humanities. According to Kelly and Snowden an

increasing number of engineers spend a brief period as engineers, followed by a relatively long period in planning and management.[1] The College of Engineering at the University of California has invited John L. Burchard, Dean of Humanities at Massachusetts Institute of Technology, to recommend the kind of humanities program that will broaden the engineers' curriculum. If courses in the humanities are to be added to the program of the engineers, does this mean that chemistry, or some other science is to be dropped, or does it mean adding one more year to their curriculum?

Modesto Junior College, in the fall of 1954, experienced a considerable increase in enrollment, and a further increase is anticipated for the fall of 1955. The chemistry department in 1954 experienced a greater growth than the college as a whole. Does this mean that 1955 will follow suit? Are college enrollments on an increase, and, if so, will it continue? If this be the case, then the science building must be designed and planned for expansion.

A study such as this should be made by the physics, biology, botany, geology, zoology, anatomy, and physiology,

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[1]Joe W. Kelly and Wayne H. Snowden, "Introducing Our Engineers," California Monthly, 65:11, February, 1955.

astronomy, bacteriology, and photography instructors, to determine what has to be done, how it is to be done, and what is needed to do it. Thus, the problems related to the purpose, design, and organization of laboratories or science buildings would be resolved.

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School ______________________ Date ______________

CHECKLIST FOR LABORATORY OBSERVATION

1. Construction material
   a) Walls
   b) Ceiling
   c) Floor
2. Lighting
   a) Type of lights
   b) Window area
   c) Lighting obstruction, if any
3. Laboratory dimensions
   a) Length
   b) Width
   c) Height
4. Type of heating system
5. Ventilation
   a) Windows, doors
   b) Grills for incoming and outgoing air
   c) Hoods
6. Student desks
   a) Width of aisles
   b) Dimensions
   c) Desk top material.

d) Cabinet material

e) Height

7. Are stools used?

8. Lockers

a) Number

b) Method of locking

c) Method of issue at beginning of semester

d) Equipment kept under lock

e) Commonly stored equipment

9. Sinks

a) Material

b) Size

10. Service lines

a) Water (hot or cold)

b) Gas (natural or bottled)

c) Electricity (A.C. or D.C. or both)

d) Steam

e) Vacuum

f) Air

g) Provision for accessibility

h) In hoods

11. Drain pipe

a) Material

12. Hoods
    - a) Material
    - b) Size
    - c) Open or closed
13. Safety
    - a) Fire extinguishers
    - b) Fire blanket
    - c) Shower
    - d) First aid kit
14. Distilled or demineralized water
    - a) Type still or demineralizer
    - b) Distribution system
15. Storeroom
    - a) Central type or other
    - b) Does solution room accompany it?
16. Balance room
    - a) Location
    - b) Ventilation
    - c) Do students sit or stand to do their weighing?
    - d) Are students assigned a definite analytical balance to use?
    - e) How are the balance weights handled?
17. Student capacity
18. Ease of supervision

19. Provision for expansion

20. Duties of laboratory assistant

21. Laboratory manual used

22. Chemistry courses offered