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ABSTRACT

A 45-hour three-unit course in research design, data collection techniques, and research report writing was prepared and taught to vocational/technology instructors. The course emphasized the relationship of design and data to the final reports in terms of techniques used. As a result of teaching the course, a second syllabus was developed allowing more time to be spent on the introduction of the subject matter. Both the original and the second syllabus are included in the document. A second result of teaching the course was to recommend that it be taught only to students who had taken a course in technical report writing. (The bulk of the document is devoted to chapters on schematics and statistics to be used in the course. The statistics chapter covers data and its arrenagement; measures of mean, median, mode, and dispersion (range, average deviation, variance, standard deviation); correlation; and linear regression. The schematics chapter discusses coding, electrical and pipe schematics, organization schematics, information and material flow schematics, and related material. Many schematic diagrams are provided as examples.) (AG)

CALIFORNIA STATE DEPARTMENT OF EDUCATION
VOCATIONAL EDUCATION SECTION

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2. Date Funded:

3.0 ABSTRACT

3. TITLE OF PROJECT

Training of Vocational Education Teachers in Research Methodology and Research Report Writing

TYPE OF PROJECT

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PROJECT DIRECTOR

6. NAME	7. POSITION	8. INSTITUTION OR AGENCY	
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16. BRIEF DESCRIPTION *(Write a brief description (not to exceed 500 words) of the proposed project such as might be used in a brochure or by the Educational Resources Information Center (ERIC). Include sufficient detail to provide prospective participants with necessary information as to the project's focus and major components.)*

A forty-five hour (3 unit) course will be prepared and taught to Vocational/Technology Instructors. The course will deal with research design, data collection techniques, and Research report writing. The relationship of design and data collecting techniques to the research report will be emphasized. The requirements for teaching the course, scheduling of the course and the students (V.E. Instructors) are arranged. Students will be required to participate in all phases of the course. Attempts will be made to have the students' research papers published.

CVER-3

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34-30619-A0501-72

CRCU Small Grant Projects

Training of Vocational Education Teachers in Research Methodology and Writing

Abstract

A 45 hour three unit course has been prepared and taught to vocational/technology instructors. The course dealt with research design, data collection techniques, and research report writing. The relationship of design and data to the final reports in terms of techniques used was emphasized. Attempts were made by the students to have some of their research papers published.

From the experience in teaching this particular 45 hour course, we discovered that the timing of the introduction of the subject matter had to be altered. A second syllabus is attached, and this is recommended in place of the original syllabus.

This course appears to be of a level of difficulty that would require another course as a prerequisite. We therefore recommend that this course be a graduate course with a course called "Technical Report Writing" in the upper division.

1. The Problem

1.1 The vocational educational or job-oriented instructors in community colleges do not usually take courses on technical writing, research technology or research methodology, or research report writing.

1.2 A course called "Technical Report Writing" was prepared by California State University, Sacramento, and offered to the B.V.E. candidates. Attached is a syllabus of this course.

1.3 A course for this project was prepared and taught in the fall semester of 1973. (Attached is a syllabus.)

Experience in teaching this course has led us to revise the curriculum as is shown in the second syllabus marked "New Research Methodology Course."

2. Activities Carried Out Under This Project

The syllabus as is attached for this course was taught to 26 students in the Fall of 73.

In order to instruct this course, chapters on schematics and statistics were prepared by the investigator. These are attached.

It has been determined by the investigator, that a course such as this should be a graduate course for Bachelor of Vocational Education candidates. The attached syllabus for V.E. 191, Technical Report Writing, should be a prerequisite to the course prepared for this project.

Evaluation

The project director finds that students have quite a bit of vocabulary to acquire in order to communicate correctly in any research they want to conduct or report on. The second factor that the project director has discovered is that there is a very small number of these type candidates who are capable of handling statistics without some additional training. Terminology, research design factors, built-in biases from the techniques used to collect data, and rigor in writing methods were found to be unfamiliar to the students.

The principle evaluation result is that a pre-course, such as V.E. 191, Technical Report Writing, should be taught to these students in their senior year. The graduate course (this research methodology course) should follow in the first year of the graduate program for the Master's Degree.

<u>Summary</u>

Research Methodology and Research Report Writing should follow the second syllabus attached to this report. Technical Report Writing should precede this course. In the limitations of a single semester, lead time for formulating and finishing an article for publication becomes of utmost importance. It is suggested that perhaps this course should be followed by a writing course, that is the students should then write their research reports for publication. There is not enough time in a semester to write a report, send it off, and get any acceptance or rejection from the normal publishing source.

GNB:jk

6/18/73

First syllabus for a course in research methodology and writing.

Introduction and pre-test in first meeting.

CLASS TIME

1. What is research?
   a. Problem solving
   b. Pure
   c. Basic
   d. Action
   e. Survey
   f. Baselines
   g. Development procedures

1. One 3 hour period.

2. Student activities.
   a. Each student is assigned to the identification of at least 3 of the items of 1.

2. The second period of 3 hours will be spent discussing their results or findings.

3. Data
   a. Identification of data relevant to the research in question.
   b. Collection - methods, reliability, validity, and usefulness.
   c. Statistics - techniques of measurement and interpretation.
   d. Presentation.

3. a. One 3 hours period.
b. One 3 hour period.
c. Two 3 hour periods.
d. One 3 hour period.

4. Student Activities
   a. Each student uses data to illustrate the concepts presented in 3.

4. One 3 hour period.

5. Research Design
   a. Identification of problem.
   b. Analysis of problem.
   c. Delimiting - reasons for and methods
   d. Results - influences and bias which affect result of research.
   e. Identification of factors which control results.

5. One 3 hour period.

6. Presentation
   a. Schematics
   b. Formats
   c. Communication aids

6. a. One 3 hour period.
b.&c. One 3 hour period.

7. Student activities
   a. Each student will prepare and present illustration of 6.

7. a. One 3 hour period.

8. The reader or Customer
   a. Styles - factors that are to be considered in terms of the end use or purpose of the research.

	CLASS TIME
b. Format influence in terms of the reader.	*8. One 3 hour period.*
9. A Research Paper	*9. Two or three 3 hour periods.*

Post Test

BIBLIOGRAPHY AND REFERENCE MATERIAL

Writing a Technical Paper; Menzel, Jones, Boyd; McGraw-Hill Book Co.

Technical and Professional Writing: Estrin, ed.; Harcourt, Brace, & World.

Modern Technical Writing: Sherman; Prentice Hall.

Technical Writing: Mills, Walter; Holt, Rinehart, Winston.

The Stockwell Guide for Technical and Vocational Writing: Stockwell; Cummings Publishing Company.

Introduction to Research: Hillway; Houghton Mifflin Company.

Techniques for Efficient Research: Lloyd; Chemical Publishing Company.

The MLA Style Sheet: Modern Language Association of America.

Writing Business and Economics Papers: Dawe; Littlefield, Adams.

Practical Report Writing: Santmyers; International Textbook Company.

The McGraw-Hill Authors Book: McGraw-Hill Company.

GNB:jk
6/13/73

Second Syllabus for Research Methodology and Writing

V.E. 291 New Research Methodology

SUBJECT MATTER	*TIME*
1. What is research: Problem Solving; Pure; Basic; Action; Survey; Baselines; Development procedures.	1. Two three hour periods.
2. Student Activities: Each student is assigned or picks a proposed research project.	2. Three hour period.
3. Identification of potential publisher. Brief outline in form required by publisher.	3. Three hour period.
4. Data a. Identification of data relevant to the research in question. b. Collection - methods, reliability, validity, and usefulness. c. Statistics - techniques of measurement and interpretation. d. Presentation.	4. Five 3 hour periods.
5. Student Activities a. Each student uses data to illustrate the concepts presented in 4.	5. One three hour period.
6. Research Design a. Identification of problem. b. Analysis of problem. c. Delimiting - reasons for and methods d. Results - influences and bias which affect result of research. e. Identification of factors which control results.	6. One three hour period.
7. Presentation a. Schematics b. Formats c. Communication aids	7. One three hour period.
8. The reader or Customer a. Styles - factors that are to be considered in terms of the end use or purpose of the research.	8. One three hour period.

b. Format influence in terms of the reader.

9. Finish paper in outline form first and in finished form if possible

9. The rest of the semester.

GNB:jk
6/13/73

BACHELOR OF VOCATIONAL EDUCATION

VE 191 Technical Report Writing 3 units

Technical writing, its purpose and style. The formal elements of technical writing. The characteristics of impartiality and objectivity. Basic aspects of technical writing and their end products. Report layouts and types.

Text: Technical Writing, Mills, G.H. and Walter, J.A., Holt, Rinehart, and Winston.

COURSE OUTLINE

Preliminary Problems

Introduction What Technical Writing Is--The Place of Writing in Technical Work--What the Technical Man Is Required to Write--Basic Aspects of Technical Writing--Comments by Eminent Engineers and Scientists.

Five Basic Principles of Good Technical Writing

Style in Technical Writing Introduction--Objectives of This Chapter--Reader Adaptation--The Scientific Attitude--Making Sentences Say What You Mean--Precision in the Use of Words--Sentence Structure and Length--Paragraph Structure and Length--Summary--Common Errors in Usage--Mechanics of Style--Sentences for Revision

Outlines and Abstracts

Special Techniques of Technical Writing

Definition What to Define--Methods of Definition--Placing Definitions in Reports--Summary--Suggestions for Writing

Description of a Mechanism The Introduction--The Part-by-Part Description--The Conclusion of the Description--Summary of the Principles of Organization--Some Other Problems--Suggestions for Writing

Description of a Process The Introduction to the Description--The Chief Steps--The Conclusion--Suggestions for Writing

Classification and Partition Introduction--When Is Classification a Useful Expository Technique?--Suggestions or "Rules" to Follow in Presenting a Classification--A Note on Partition--Conclusion--Suggestions for Writing

Interpretation Introduction--What is to Be Found Out?--How Was Evidence Obtained?--How Should the Main Part of the Interpretation Be Organized? Attitude--Summary--Suggestions for Writing

Transitions, Introductions, and Conclusions

Transitions What a Transition Is--How to Write Transitions--Where to Put Transitions

Introductions Statement of the Subject--Statement of Purpose--Statement of Scope--Statement of Plan of Development--Other Problems--Summary

Conclusions and Summaries

Types of Reports

The Progress Report Introduction--Organization and Development--Form--Suggestions for Writing

Recommendation Reports Introduction--Reader Analysis and Style--How to Phrase Recommendations--Where to Put Recommendations--Suggestions for Writing

Proposals

Forms of Report Organization Introduction--Generalized Forms--Detailed Printed Forms--Conclusion

Oral Reports Introduction--Making a Speech--Conferences--Summary--Suggestions for Speaking

Business Letters The Elements of a Business Letter--Form and Appearance--Style and Tone--Types of Letters--Conclusion--Suggestions for Writing

Writing for Professional Journals

Report Layout

The Format of Reports Introduction--Typescript Standards--Formal Report Format--Informal Report Format--A Final Note: Relation of Format and Style

Graphic Aids Introduction--Charts--Drawings, Diagrams, and Photographs--Tables--Conclusion

The Library Research Report

Finding Published Information Introduction--Books--Periodical Indexes--Abstracts--Bibliographies of Bibliographies--Miscellaneous--Reference Works--Leads to Trade Literature--Conclusion

Writing the Library Research Report Introduction--Selecting a Subject--Making an Initial Plan--Reading and Taking Notes--Completing the Plan and Writing the First Draft--Documenting the Report--Revising the Rough Draft and Preparing the Final Copy--Report Appraisal--Suggestions for Research Report Topics--A Technical Writing Check List

GMB:jr
2/29/72

INTRODUCTION

Graphics or graphical presentation of ideas and solutions of problems is the best method of communication. Although the analytical solution of problems is a basic method, the graphical tools available make communication and solution clear and precise.

Much has been said on the subject of communication. This book is designed to assist in helping to recognize and use the special tools called graphics. The graphic tools described herein will help in communicating with the public and on the job.

Specifically, the graphics described will help:

1. To develop the ability necessary to graphical solution of space problems.
2. To develop the ability to graphically represent data and phenomena.
3. To develop the ability to illustrate problems, thus enabling the student to grasp their nature and to then solve them.
4. To introduce the graphical nature of the more sophisticated and involved problems.
5. To develop the ability to think creatively.
6. To develop the understanding necessary to calculate abstract solutions of involved problems.
7. To graphically illustrate certain mathematically processes and their relation to problem solutions.

It is intended that the general principles discussed be used in applications that are understandable to the student. It is further intended that the principles be available for use later on in the more advanced work. One who continues to use these graphic tools will find that they are highly flexible and valuable at all levels, both to solve problems and to clearly present solutions.

STATISTICS

1.1 Statistics

Throughout most peoples lives today, we find people using numbers and relationships called "statistics." Things are proved and disproved by the manipulation of numbers or data and are accepted because they are statistics. To a great extent, the exact usage of some of the terms is a little vague. Usually, the beginning student finds himself bombarded by statistical terms and usage. For this reason, this chapter is presented to help define some simple terms and to clarify what some statistics mean.

1.2 Data and its Arrangement

One of the first rules in statistical treatment is that there must be sufficient data and that it must be representative of the domain under treatment. Data is the numerical representation of some phenomena. For instance, it is the number of blue-eyed men in the room, or the individual weight of each student or the grade that each person received in the last test. Whatever it represents, it is a group of numbers. Some samples of data are given in figures 1.1 and 1.2. If the numbers involved are few enough, the data may be treated by simple arithmetic. But if the data is sufficiently large, a suitable manner of handling or grouping the data is necessary.

In the treatment of all data, it is always advisable to graphically plot the information. Figure 1.3 shows a typical plot of data. As can be seen, the data assumes a certain distribution. That is, the

Raw Data

32	62	42	58	42	39	50
36	50	42	37	44	50	44
33	53	44	48	49	44	42
31	55	42	50	53	47	48
42	58	37	37	55	53	47
44	59	39	39	42	48	47
39	32	39	39	39	47	48
37	59	33	55	48	44	44
47	36	36	55	42	42	42
48	47	58	44	37	50	53

Figure 1.1

Data Array

31	37	42	44	48	55
32	39	42	44	48	55
32	39	42	47	48	55
33	39	42	47	50	55
33	39	42	47	50	58
36	39	42	47	50	58
36	39	44	47	50	58
36	39	44	47	50	59
37	42	44	47	53	59
37	42	44	48	53	62
37	42	44	48	53	
37	42	44	48	53	

Figure 1.2

data has a range--from low to high, and it tends to average or balance around a midpoint.

The average or mean value of the data is the midpoint of balance if you consider the area under the curve plotted from that data. It is called the arithmetic average, or mean.

The measure of the central tendency or distribution of the data in terms of its closeness or spread from the mean, can be expressed in several ways. These measures of central tendency will be defined in the next section.

1.3 Measures of Central Tendency

1.3-1 Mean

$$\text{Mean} = M = \bar{X} = \frac{X}{N} = \frac{X_1 + X_2 + X_3 \dots}{N}$$

If the data is sufficiently small in number or if the universe is small (N is small) then each numerical value of each item multiplied by the number of times it occurs can be added and the total divided by the number of items (N) and this is called the average or mean.

$$\frac{X_1 + X_2 + X_3 \dots X_{11} = \bar{X}}{N}$$

If N is sufficiently large, this can be rather tedious. By grouping the values into class intervals and treating the groups as a single calculation, a rapid method is provided.

1.3-2 Mode

Mode is the value of the data which occurs most frequently if the variable is discrete. It is a peak value of a frequency distribution.

Bimodal distribution refers to data with two peaks. The mode can be determined by observation as well as calculated from grouped data.

1.3-3 Median

The median is the middle value in a set of data and is determined after the data has been arranged in rank order of magnitude. It is the value above and below which there is an equal number of data observations. Simply, it is one more than half but in grouped data it can be calculated as shown later. The median is a positional value.

1.3-4 Quartile

When the data is arranged in rank order of magnitude, one of the measures of central tendency is the quartile. This is 25% of the values and is identified as Q_1 for the lower 25% or point at which 25% is below. Q_3 represents the value below which 75% of the values fall. Q is,

$$\frac{Q_3 - Q_1}{2}$$

, a specific calculated value. Percentiles are values below which are found that percentage of the total values. i.e., 99 percentile means 99% of the values are below this. Obviously, you cannot have a 100 percentile.

1.3-5 Calculations

Using the following table of data, rapid methods of calculating statistical facts will be shown.

Raw Data

23	70	36	53
45	70	39	53
26	71	39	65
25	72	42	65
53	73	42	63
45	34	39	63
67	34	39	65
53	34	39	65
45	36	42	65
26	45	42	65
29	45	39	63
29	45	39	63
45	61	42	63
45	61	53	63
53	48	53	65
53	61	48	
67	61	48	
70	63	48	
67	61	42	
42	61	48	
42	48	48	
45	48	48	
53	61	53	
65	61	53	
67	61	53	
53	36	48	
53	36	48	
67	36	48	

Data Array

23	45	53	67
25	45	53	67
26	45	53	67
26	45	53	70
29	45	61	70
29	45	61	70
34	45	61	71
34	45	61	72
34	48	61	73
36	48	61	
36	48	61	
36	48	61	
36	48	61	
36	48	63	
39	48	63	
39	48	63	
39	48	63	
39	48	63	
39	48	63	
39	48	63	
39	53	65	
42	53	65	
42	53	65	
42	53	65	
42	53	65	
42	53	65	
42	53	65	
42	53	65	
42	53	67	
42	53	67	

To compute the mean of the data, establish three columns on a sheet of paper. The first column is headed V for the "value" of items to be listed. Any name can be used that describes the data. The second column is headed f for the "frequency" or number of times each value appears in the array. The third column is headed V-f, meaning "value times frequency."

Next, list in column V each value appearing in the array. List each value only once. Now multiply each value by its frequency and place the product in column V-f. Finally, total the f column and total the V-f column. The result appears as follows:

V	f	V-f
23	1	23
25	1	25
26	2	52
29	2	58
34	3	102
36	5	180
39	7	273
42	8	336
45	9	405
48	12	576
53	14	742
61	9	549
63	7	441
65	8	520
67	5	335
70	3	210
71	1	71
72	1	72
73	2	146
	Σf=N=100	ΣV-f=5116

$$\text{Mean} = \bar{X} = \frac{V\text{-}f}{N} = \frac{\Sigma X}{N}$$

$$\bar{X} = \frac{5116}{100} = 51.16$$

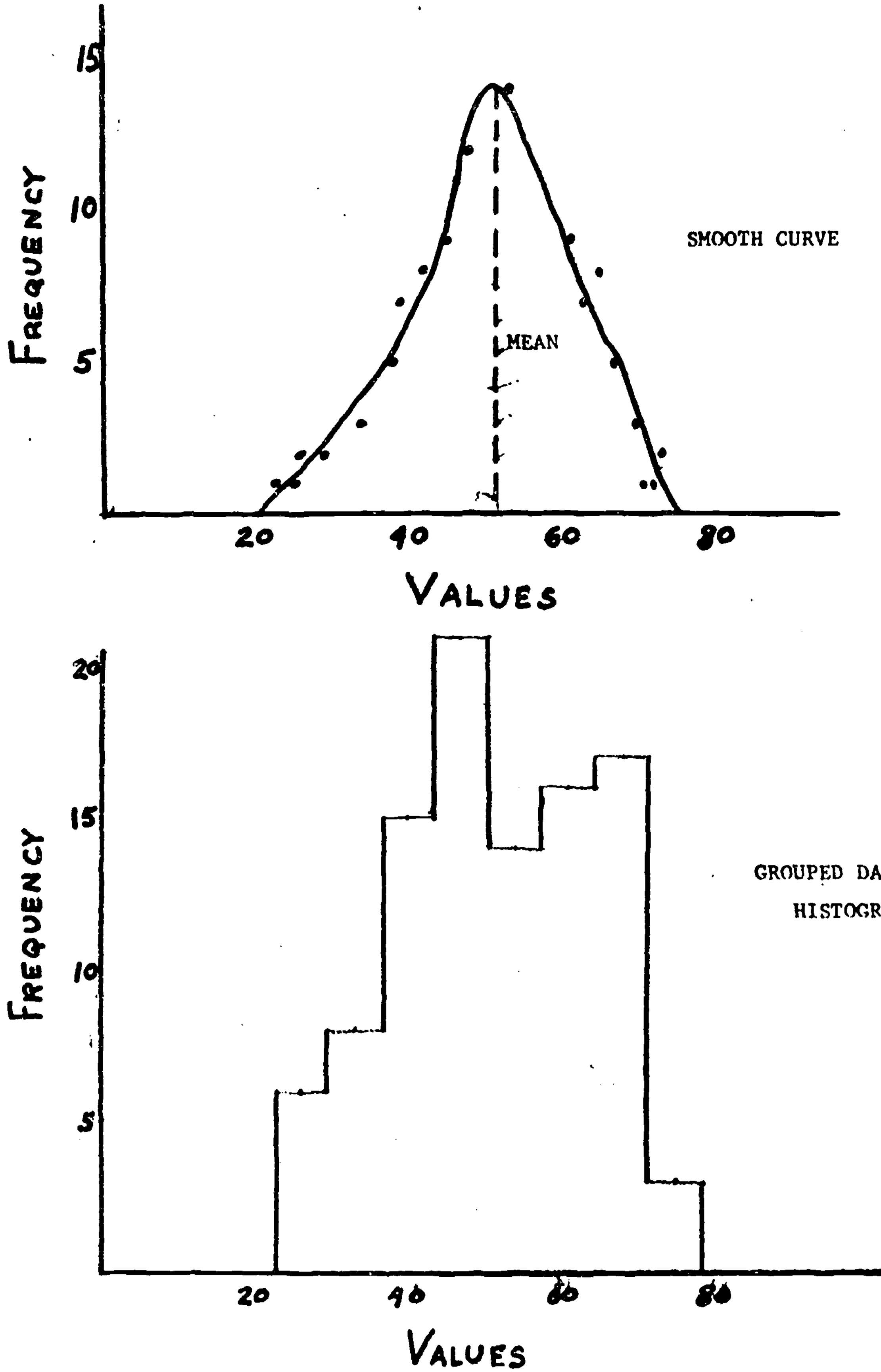
The mean, 51.16 is the one figure which fits the data and is most representative of each value in the numerical array. Since all of the values were used in arriving at the mean, it represents a cross section of all of the data or average.

The formula for obtaining the mean by the short method is:

$$M = AM + \left(\frac{fd}{N}\right) \text{ c.i.}$$

where: M = the mean
AM = the midpoint of the assumed mean class
d = deviation from midpoint by groups or intervals
Σ = (Greek letter, sigma) the sum or summation (total)
fd = the frequency times the deviation
N = the number of cases (total of frequencies)
c.i. = the class interval
f = frequency of occurance

The guessed mean method uses the frequency distribution. From the array the range is (73 - 23) + 1 = 51. To have seven groups or class intervals, a frequency distribution with a class interval of 8 is constructed as follows:



15
10
5
FREQUENCY
MEAN
SMOOTH CURVE
20
40
60
80
VALUES
20
15
10
5
FREQUENCY
GROUPED DATA
HISTOGRAM
20
40
60
80
VALUES

FIGURE 1.3

c.i. class interval	f frequency	d	f-d
23 - 29	6		
30 - 36	8		
37 - 43	15		
44 - 50	21		
51 - 57	14		
58 - 64	16		
65 - 71	17		
72 - 78	3		
	$\Sigma f = N = 100$		

AM = assumed mean

Class interval midpoint
43.5 + (50.5 - 43.5) ÷ 2 = 47
47 = AM

From this table, it can be seen that the midpoint is approximately 50 or in c.i. 44-50. The cluster of the data at this class reveals the central tendency of the entire mass of data. When the frequency distribution is plotted on a chart, there is a hump, or peak at the midpoint. (See figure 1.3)

The line plotted on the graph approaches the normal curve, and the extremes taper away from the peak at a fairly constant rate. Observe that the frequencies are plotted on the vertical axis and that the midpoints of each class are plotted on the horizontal axis.

The third column is d, which stands for deviation from the guessed mean. The fourth column is headed fd, or frequency times deviation.

Now, by inspection guess which class contains the mean. The formula provides a correction which gives a fairly accurate mean as the final answer. Use class 44-50 as a guess. The guessed mean then becomes the midpoint of the guessed mean class, or 47. The midpoint of a class is obtained by adding one-half the class interval to the lower class limit (3.5 + 43.5). Set off class 44-50 by drawing a line above and below it clear across the page. Then place a zero opposite this class in columns d and fd.

Next, complete the deviation column, headed d. The deviation is simply the number of classes any one class is above or below the guessed mean class. Thus, class 37-42 is below class 44-50 in value. It is one deviation below the guessed mean class. Since it is below the guessed mean class in magnitude, the 1 is preceded by a minus sign, place a -1 opposite it in column d. Class 30-36 is two classes away from the guessed mean class. A -2 is placed in column d. Class 23-29 being three classes away and is -3 in column d.

On the other side of the guessed mean, the deviations are assigned in a similar manner, except that since these are greater than the guessed mean class, they are given a plus sign.

The next step is to compute column fd, or f times column d. Remember to carry the sign along with the product.

Now, find fd.

	c.i.	f	d	fd	
	23-29	6	-3	-18	
	30-36	8	-2	-16	+49
	37-43	15	-1	-15	
A.M. =	44-50	21	0	0	
	51-57	14	+1	14	
	58-64	16	+2	32	-109
	65-71	17	+3	51	
	72-78	3	+4	12	

$\Sigma f = 100 = N$ $\qquad$ $\Sigma f\text{-}d = -60$

Thus, fd is -60; the class interval, is 8; N is 100, Σf; and M is 47.

From the formula,

$$M = AM + \left(\frac{fd}{N} \right) c.i.$$

$$M = 47 + \left(\frac{-60}{100} \right) 8$$

$$M = 47 + 4.8$$

$$M = 51.8$$

The mean, as figured by the long method from the numerical array, was 51.16 inches, a 0.74 difference in the two computations. The computed mode and median may give two other values for the average of this data.

The Median The median is the halfway point in the range of values. It is located at the point where one-half of the values fall below it and the other half of the values fall above it. It is not necessary that it be an actual number physically present as one of the values. In the series 2, 3, 4, the median is 3 because 3 divides the series in half. In the values 2, 3, 7, 9, 12, the median is 7 because one-half of the items lie to either side of 7. In the series 2, 3, 4, 5, the median is 3.5 because the exact center of the four numbers falls midway between 3 and 4.

From a numerical array, it is only necessary to count values from one end or the other until the middle value is reached and you have the median. In the array of 100, since 100 is an even number, the median lies between the 50th and 51st items. Since the value of the 50th item is 48 and of the 51st 53, the median is 48 + (53-48) ÷ 2 = 50.5.

Remember that the median is a position first and a value second. The size of the values do not affect the median; it is always in the middle.

Because ungrouped data is cumbersome to work with, another method of finding the median is desirable. The selection of the median from the frequency distribution with the aid of a formula provides a more simplified computation.

Formula,

$$\text{Med} = L_1 + \left(\frac{\frac{N}{2} - f_1}{\text{fmed}} \right) \text{c.i.}$$

where:

Med = the median

L_1 = the lower limit of the class containing the median

$\frac{N}{2}$ = 1/2 the sum of the frequencies

f_1 = the summation of the frequencies of all classes below the class containing the median

fmed = the frequency of the class containing the median

c.i. = the class interval

c.i.	f	cum f	
23-29	6	6	
30-36	8	14	
37-43	15	29	
44-50	21	50	assumed median group
51-57	14	64	
58-64	16	80	
65-71	17	97	
72-78	3	100	

$\Sigma f = N = 100$

First find the value of f_1. The interval chosen is the one in column f which is as close as possible to N/2 but does not exceed it. Since N/2 is 50, the nearest lower value in column f is 50. Therefore, f_1 is 50.

The frequency of the median class is 21. Fmed is 30. The lower class limit of the median class is 43.5 = L_1. The class interval, or c.i., is 8.

By substitution:

$$\text{Med} = L_1 + \left(\frac{\frac{N}{2} - f_1}{\text{fmed}} \right) \text{c.i.}$$

$$\text{Med} = 43.5 + \left(\frac{\frac{100}{2} - 29}{21} \right) .8$$

$$\text{Med} = 50.5$$

Thus, it is found that the median, or exact center of the 100 cases, is 50.5 by either method.

<u>The Mode</u>

The mode, or value which appears most frequently, can be determined from a numerical array by inspection. The mode in this array, by inspection, is 53, that is 53 appears more times than any other value. The mode can also be found when the data has been grouped into a frequency distribution.

(5) $$Mo = L_{mo} + \left(\frac{d_1}{d_1 + d_2} \right) c.i.$$

First, inspect the frequency column and determine the class which contains the greatest number of frequencies. This class is called the modal class. Set it off by drawing lines above and below it.

c.i.	f
23-29	6
30-36	8
37-43	15
44-50	21
51-57	14
58-64	16
65-71	17
72-78	3

In the formula, d_1 is the difference between the frequencies in the modal class and the frequencies of the class immediately under it in magnitude, and d_2 is the difference between the frequencies in the modal class and the frequencies of the next higher class.

Since class 37-43 is the next lower class from modal class 44-50, take the difference between 15 and 21 (the frequencies of the two classes) $d_1 = 6$.

Class 51-57 is the next higher class, take the difference between 14 and 21, $d_2 = 7$.

Substituting in the formula:

$$Mo = L_{mo} + \frac{(d_1)}{d_1 + d_2} c.i.$$

$$Mo = 44 + \left(\frac{6}{6 + 7} \right) .8$$

$$Mo = 44 + 3.69$$

$$Mo = 47.69$$

The mode as computed from the frequency distribution is 47.69 inches. The mode is not affected by extreme values in the series, but to be representative of the data, it must have a cluster of frequencies around it.

	Numerical array	Frequency distribution	Difference
Mean:	51.16	51.80	0.84
Mode:	53.00	47.69	5.31
Median:	50.5	50.5	0.00

It is necessary to have more than one method of computing averages because one average may be more meaningful than another.

There is a definite relationship between each of the statistical averages and the character of the plotted data. These relationships are as follows:

a. The mean and median always move in the direction of skewness.

b. The mode is the value at the highest point in the curve.

c. The median almost always falls numerically between the mode and the mean.

d. In a perfect distribution, the mean, median, and mode will fall at the same point.

The relative positions of the three averages in a curve skewed to the right are shown in figure 1.4. Figure 1.5 also shows the relative position of the three averages, but in this illustration the curve is skewed to the left.

1.4 Measures of Dispersion

Dispersion can be defined most simply as the spread or scatter of

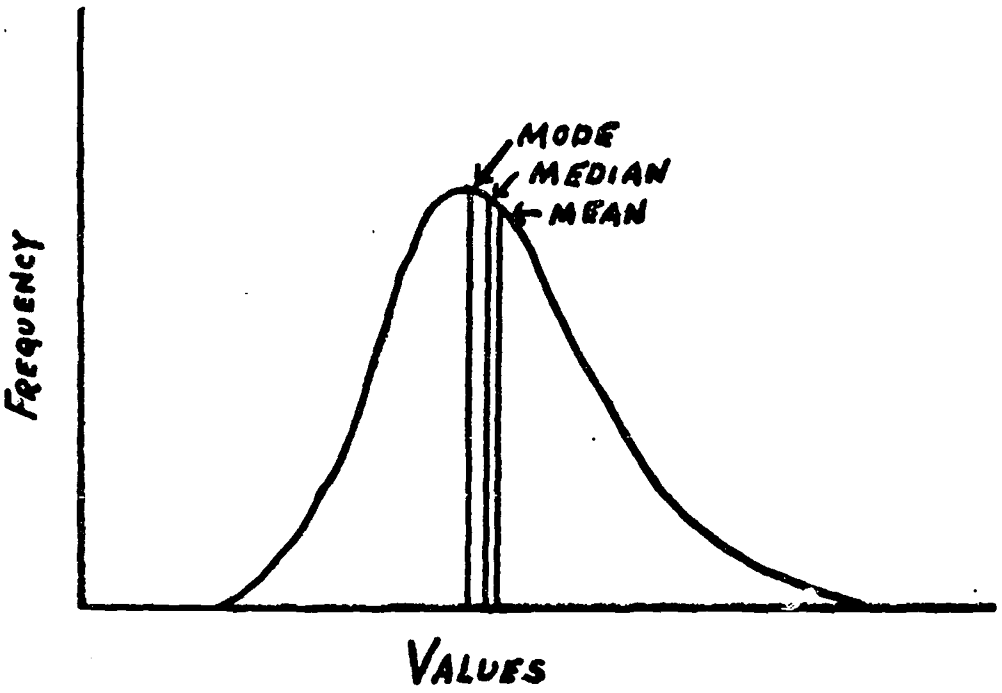


FIGURE 1.4

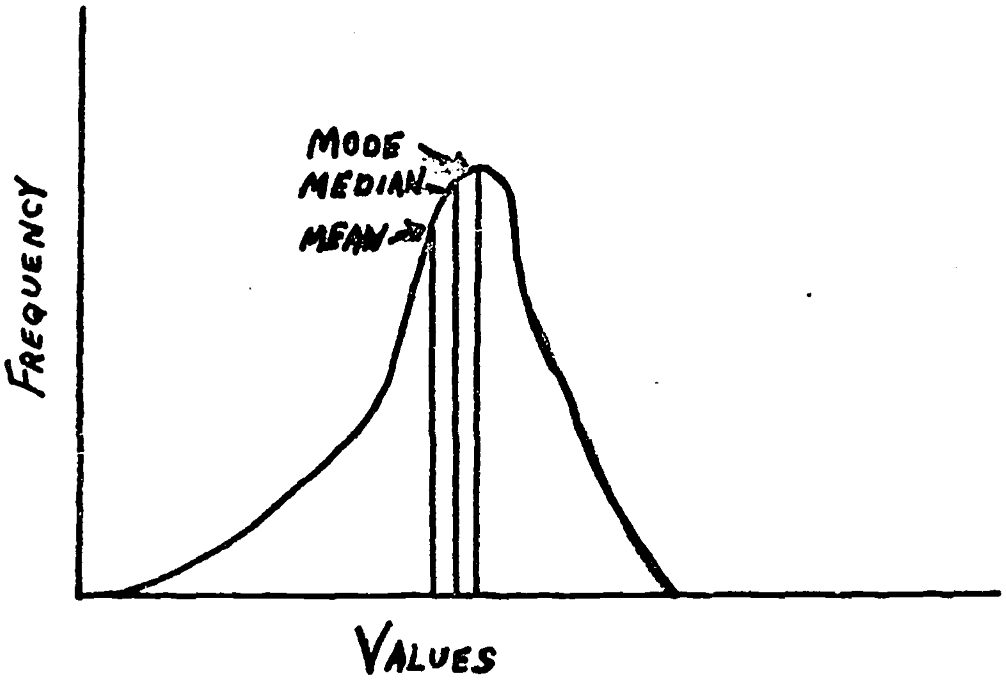


FIGURE 1.5

values in the data.

There are several methods by which one may measure dispersion. Three types are range, average deviation, and standard deviation.

1.4-1 Range

The range is the most readily understood measure of dispersion. It is simply the difference between the highest and lowest values in a study. For example, the average examination grades of 10 students are:

Student No.	Average Grade
1	99%
2	96%
3	94%
4	90%
5	89%
6	86%
7	78%
8	67%
9	50%
10	32%

In this example the lowest grade is 32 percent, and the highest is 99 percent. The difference (99-32) is 67 percent, which is the range of the grades. Sometimes statisticians use a method for computing range which is known as the inclusive range. In this method, the computation is made by finding the difference between the lowest and highest values of a series plus 1. For example, in the series of data containing the 10 students' grades, the inclusive range would be: 99-32 + 1 = 68. For the data given before the range = (73-23) + 1 = 51.

Another method is that of average deviation.

1.4-2 Average Deviation

The second measure of dispersion that we shall consider is average deviation. Average Deviation is usually taken to be the average deviation from the mean without regard to the direction of the deviation. To find the average deviation of a numerical array, simply divide the sum of the differences between the mean and each number in the array by the number of items used.

$$A.D. = \frac{\sum_{i=1}^{n} [x_i - \bar{x}]}{N}$$

To compute the average deviation from a frequency distribution, it is necessary to subtract the mean from the midpoint of each class, then multiply this difference by the frequency of that class, as illustrated below. This mean is 12.83

Class	f	d	fd
0-4	3	-10.33	-30.99
5-9	7	- 5.33	-37.31
10-14	9	- .33	- 2.97
15-19	7	4.67	32.69
20-24	4	9.67	38.68

The true deviation of the midpoint of class 0-4 from the mean is 2.5 minus 12.83 or -10.33. Now, add the frequencies times the deviations without regard to algebraic sign. The sum of the frequencies times deviation (142.64) is divided by the sum of the frequencies (30) to find the average deviation.

$$142.64 \div 30 = 4.75$$

Average deviation may also be found from the median.

1.4-3 Variance

In the above, the sign of the value $x_i - \bar{x}$ was not used. If the signed values had been used, the effect of larger deviations would have been abnormal. A more precise measure of dispersion is used called mean square deviation or variance. It is defined as

$$\delta^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{N}$$

1.4-4 Standard Deviation

Standard deviations is the square root of the sum of the deviation squared, divided by the total number of items in the study. It is perhaps better to define standard deviation by the use of a formula:

$$\sigma = \sqrt{\sigma^2} = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{N}}$$

where

σ (lower case Greek letter sigma) is the standard deviation

$(x_1 - \bar{x}^2)$ is the deviation from the mean squared

N is the total number of items in the study

Because standard deviation is the quadratic mean of the deviation from the arithmetic mean, it is sometimes called the root mean square.

The above formula works well on upgrouped data, but it will not work on data that has been grouped into a frequency distribution. Using the following grouped array of data the method is as follows:

Scores	f
80-85	4
86-91	5
92-97	13
98-103	14
104-109	15
110-115	23
116-121	17
122-127	9
128-133	8
134-139	4
140-145	3
146-151	2
152-157	2
158-163	1

Class Interval	f	d	fd
80-85	4	-5	-20
86-91	5	-4	-20
92-97	13	-3	-39
98-103	14	-2	-28
104-109	15	-1	-15
110-115	23	0	
116-121	17	1	17
122-127	9	2	18
128-133	8	3	24
134-139	4	4	16
140-145	3	5	15
146-151	2	6	12
152-157	2	7	14
158-163	1	8	8
	N = 120		fd = 2

For the standard deviation of the above distribution, formula:

$$\delta = \frac{\sqrt{\Sigma f_i d_i^{\,2} - \frac{(\Sigma f_i d_i)^2}{N}}}{N} \quad c.i.$$

where

δ is the standard deviation

fd^2 is the sum of the frequencies times the squared of the deviations

fd is the sume of the frequencies times the deviation

c.i. is the class interval

N is the total number of cases

Class Interval	f	d	fd	fd^2
80-85	4	-5	-20	100
86-91	5	-4	-20	80
92-97	13	-3	-39	117
98-103	14	-2	-29	56
104-109	15	-1	-15	15
110-115	23	0		
116-121	17	+1	+17	17
122-127	9	+2	+18	36
128-133	8	+3	+24	72
134-139	4	+4	+16	64
140-145	3	+5	+15	75
146-151	2	+6	+12	72
152-157	2	+7	+14	98
158-163	1	+8	+ 8	64
	N = 120		fd = 1	fd^2 = 866

$$\sigma = \frac{\sqrt{866 - \frac{1}{120}}}{120} \, .6$$

$$= 16.08$$

In a normal distribution, 68.26 percent of all the cases in a study will lie between -1 standard deviation and +1 standard deviation (see figure 1.6.) Two standard deviations extending in each direction from the mean include about 94 percent of the cases, while 3 standard deviations extending in each direction from the mean include approximately 99.75 percent of the cases. While in some rare instances there have been cases that will deviate as much as 5 standard deviations, for practical purposes, 3 standard deviations may be considered to include 100 percent of a universe.

1.5 Correlation

The relationship which exists between two or more variables is known as correlation and the mathematical description of this relationship is known as correlation coefficients.

1.5-1 Types of Correlation

Linear correlation may be either positive (direct) or negative (indirect or inverse). Positive correlation simply means that, as the value of one variable goes up, the value of the other also goes up. In negative correlation, on the other hand, when the value of one goes up, the value of the other goes down.

An example of positive correlation, is speed's relation to horsepower. The gradual increase of horsepower of internal combustion engines has given parallel increase in the speed possible in automobiles. The development of extremely high horsepower motors has resulted in the March 1, 2, and 3 speeds of aircraft.

An example of negative correlation may be found in rifle range practice. As distance increases accuracy decreases. As distance decreases, accuracy increases.

One way of showing correlation graphically is by the use of a scatter diagram. The scatter diagram is simply a graph in which each point represents two values. (See figure 1.7).

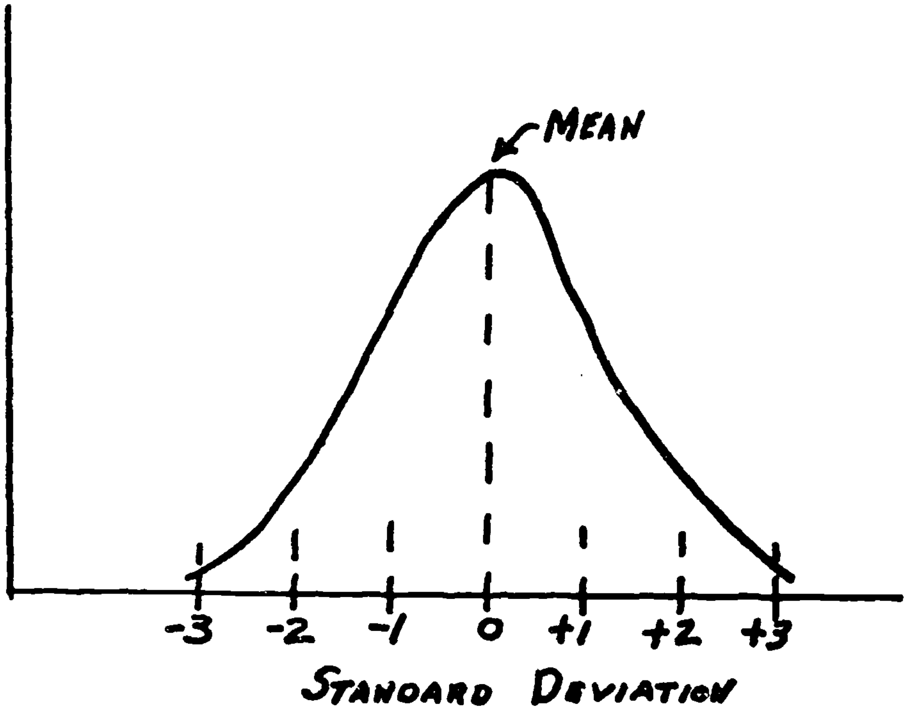


FIGURE 1.6

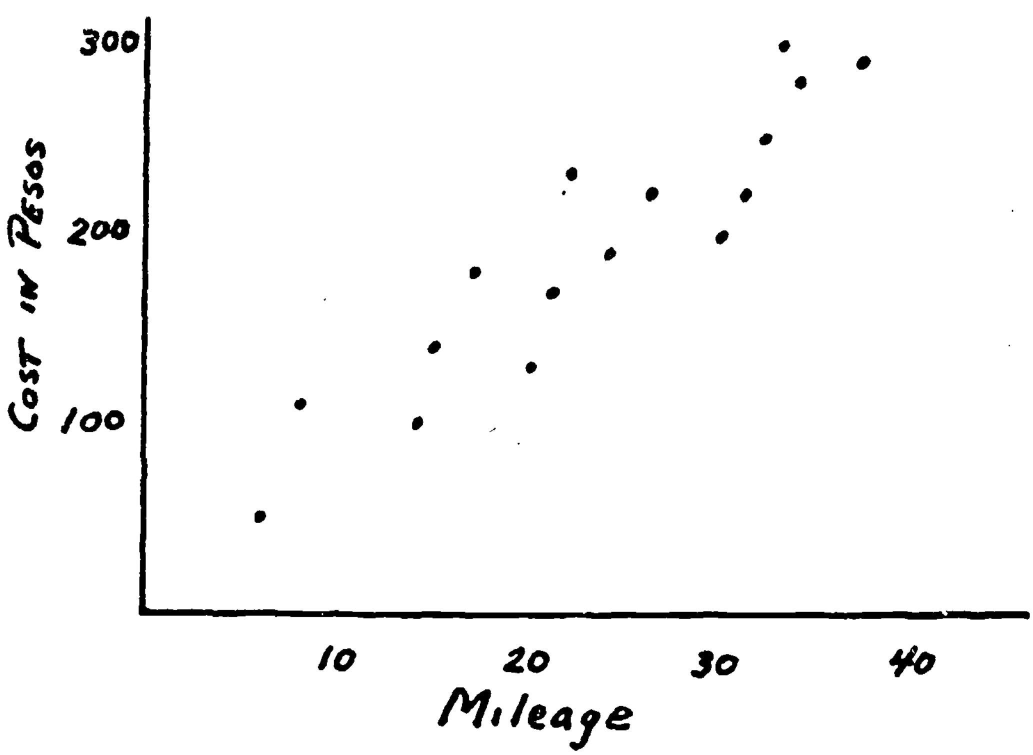


FIGURE 1.7

Here is a table of data.

Date	Number of Trips	Total Tons
2	55	400
3	175	1150
4	160	1100
5	240	1250
6	210	1210
7	135	780
8	110	660
9	190	1050
10	175	980
11	120	700
12	150	900
13	210	1250
14	180	1110
15	160	1000
16	190	1150
17	175	1150
18	190	1150
19	205	1220
20	190	1190
21	175	1050
22	230	1400

This information has been used to plot figure 1.8. The uppermost dot in figure 1.8 represents the data for 22 of the month.

It will be noted that the general pattern for the group runs from the lower left corner of the scatter diagram to the upper right corner. It should also be noted that the dots deviate only slightly from a straight line. This would indicate a fairly strong correlation. If all the dots fell on a straight line running from the lower left to the upper right, then we would have a perfect positive correlation.

In looking at different patterns formed by a scatter diagram, we find each pattern tells something about the correlation. Figure 1.9 shows some common patterns and their meanings.

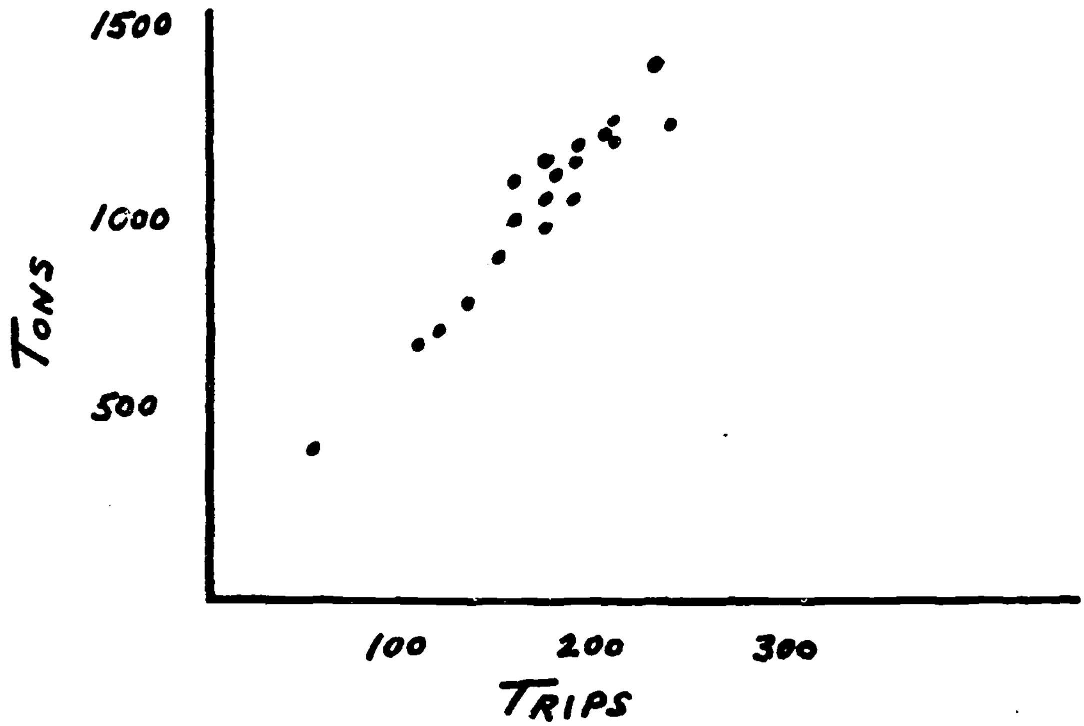
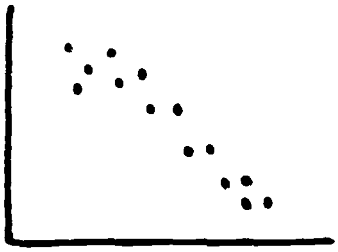


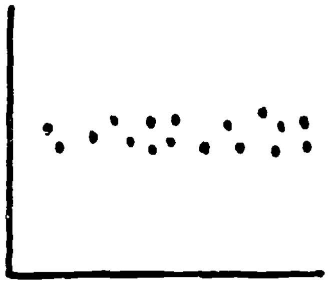
FIGURE 1.8

FIGURE 1.9

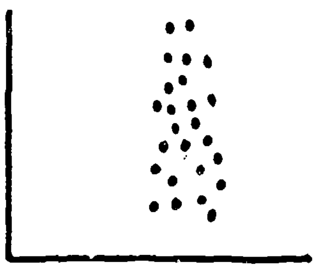
POSITIVE CORRELATION



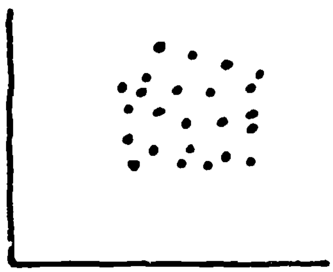
NEGATIVE CORRELATION



No Correlation



No Correlation



No Correlation

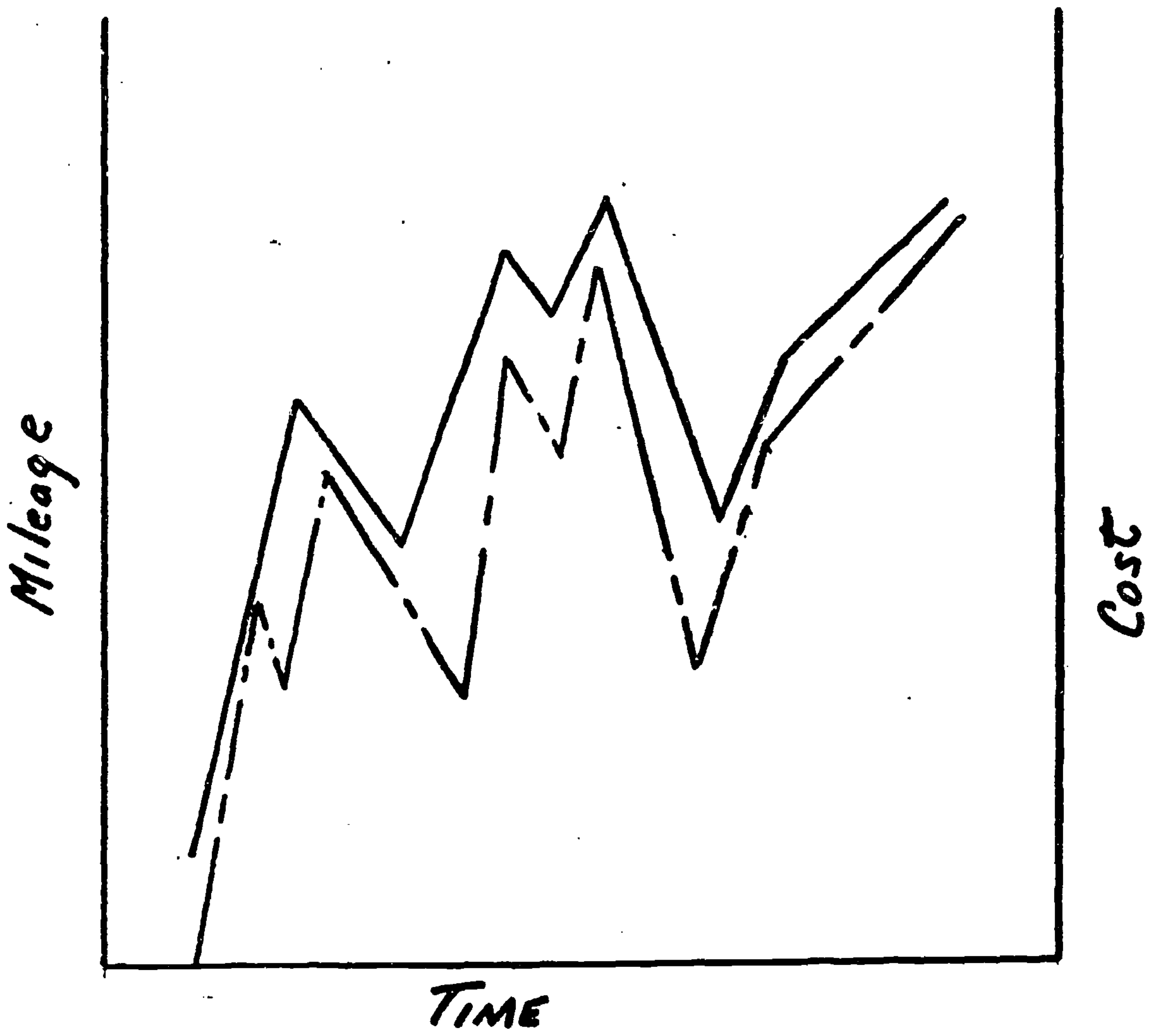


FIGURE 1.10

Correlation may also be shown through the use of multiple-line charts, figure 1.10.

Notice that as one line goes up, the other does also. This would indicate a fairly strong positive correlation. If the peaks of one line and the troughs of the other were in the same or approximately same vertical plane, then we would have a negative correlation.

While the indication of correlation shown graphically is sufficient, the relationship can also be expressed mathematically. The expression of correlation mathematically is known as the correlation coefficient, or the coefficient of correlation.

1.5-2 Correlation Coefficients

Correlation coefficients range from a -1 (perfect negative) to a +1 (perfect positive) correlation.

Correlation coefficients must not be confused with percentage. If the correlation of x to y is .75, this does not mean that we can predict y's exactly 75 percent of the time.

The rank-difference method of finding correlation coefficients is valuable in finding Trends. To find the true relationship between two variables requires a fairly large number of measurements. Trends, however, may be established with a relatively small number of measurements, with less than 25 pairs of measurements to establish a trend, the rank-difference method is particularly valuable.

Using the same information that we portrayed graphically in figure 1.8, the correlation coefficient of the number of trips to the tons hauled can be shown. The first step in finding this coefficient is the ranking of each measure. In this case, the number of trips is ranked in column R_1 and the number of tons in column R_2. To rank the trips, we find the highest number of trips (240) and assign it the rank of 1. The next highest number of trips (230) we assign rank 2. When there is a tie for a particular rank, we simply take an average of all the rank positions for which there was a tie and assign this average to all numbers. For example, in the following list, 210 gives us a tie for the 3rd and 4th rank positions. The average (3.5) is assigned to each and we continue with the next unused rank, which is 5. The next tie (190) is for rank 6, 7, 8, and 9. The average (7.5) is assigned to all 190's and we continue with rank 10, etc. through 21.

The number of tons hauled are ranked in a manner similar to that shown in column R_2.

The pairs may be ranked in either ascending or descending order, provided both series are handled in the same manner.

Date	No. of Trips	R_1	Tons of Cargo	R_2
Jan. 2	55	21	400	21
3	175	12.5	1150	8.5
4	160	15.5	1100	12
5	240	1	1250	2.5
6	210	3.5	1210	5
7	135	18	780	18
8	110	20	660	20
9	190	7.5	1050	13.5
10	175	12.5	980	16
11	120	19	700	19
12	150	17	900	17
13	210	3.5	1250	2.5
14	180	10	1110	11
15	160	15.5	1000	15
16	190	7.5	1150	8.5
17	175	12.5	1150	8.5
18	190	7.5	1150	8.5
19	205	5	1220	4
20	190	7.5	1190	6
21	175	12.5	1050	13.5
22	230	2	1400	1

After we have ranked each series in the pair, we take the absolute difference (D) between the ranks (R_1 and R_2); hence, it is named the rank-difference method of finding the coefficient of correlation. Then we square the difference (D^2).

R_1	R_2	D	D^2
21	21	0	0
12.5	8.5	4	16
15.5	12	3.5	12.25
1	2.5	1.5	2.25
3.5	5	1.5	2.25
18	18	0	0
20	20	0	0
7.5	13.5	6	36
12.5	16	3.5	12.25
19	19	0	0
17	17	0	0
3.5	2.5	1	1
10	11	1	1
15.5	15	0.5	0.25
7.5	8.5	4	16
7.5	8.5	1	1
5	4	1	1
7.5	6	1.5	2.25
12.5	13.5	1	1
2	1	1	1
			$\Sigma D^2 = 106.5$

Now compute the correlation coefficient. The formula is:

$$\rho = \frac{-\ 6\Sigma D^2}{N(N^2 - 1)}$$

where:

ρ (Greek letter rho) is the coefficient of correlation

D is the difference between the ranks

N is the number of pairs of measurements

with 21 pairs of measurements

$$\rho = 1 - \frac{6(106.5)}{21(441-1)}$$

It can be seen that a correlation coefficient of .93 confirms the earlier predictions from the graphs of a strong positive correlation.

1.5-3 Linear Regression

If we consider two variables or two sets of data and are interested in the variability relationship, this can be expressed as an association of one variable to the other. Using a line representing the "best-fit" of the data (x, y - two variable) we can express the line as $y = mx + b$ where:

m = slope of line

b = y intercept at $x = 0$

That is, given any value of x, y can be predicted by formula $y = mx + b$, the relation between x and y.

To calculate this formula the following steps are used.

$$m = \frac{N\ \Sigma xy - \Sigma x \cdot \Sigma y}{N\ \Sigma x^2 - (\Sigma x)^2}$$

$$b = \frac{\Sigma x^2 \ \Sigma y - \Sigma x \ \Sigma xy}{N \ \Sigma x^2 - (\Sigma x)^2}$$

The best method to use is to arrange the data in table form as shown below.

	x	y	x^2	xy
	10	17	100	170
	12	19	144	228
	14	20	196	280
	17	23	289	391
	20	25	400	500
	22	26	484	572
Σ =	95	130	1613	2141

$$m = \frac{6 \cdot 2141 - 95 \cdot 130}{6 \cdot 1613 - (95)^2}$$

$$= \frac{12846 - 12350}{9678 - 9025}$$

$$= \frac{496}{653}$$

$$= .759$$

$$b = \frac{1613 \cdot 130 - 95 \cdot 2141}{6 \cdot 1613 - (95)^2}$$

$$= \frac{209690 - 203395}{9678 - 9025}$$

$$= \frac{6295}{653}$$

$$= 9.64$$

$\therefore$ y = .759x + 9.64 for these data.

1.5-4 Product Moment Correlation

Another form of correlation is the product-moment coefficient of correlation which shows the extent variations of two factors agree in direction and relative size. This correlation is represented by

$$r = \frac{\Sigma\, xy}{\sqrt{\Sigma\, x^2 \cdot \Sigma\, y^2}}$$

To calculate this relationship the following procedure is used.

1) The two factors (data) are arranged in columns.

2) The mean is calculated for each factor.

3) The deviation from the mean is noted, plus for above and minus for below.

4) The deviations are multiplied ($x \cdot y$) and given the sign derived.

5) The deviations are squared (∴ plus values).

6) The values are substituted in the above formula.

For example:

Element	Factor 1 (X)	Factor 2 (Y)	Deviations from the Mean				
			x	y	x^2	y^2	xy
A	65	31	+2	+1	4	1	2
B	64	27	+1	-3	1	9	-3
C	62	29	-1	-1	1	1	1
D	64	31	+1	+1	1	1	2
E	60	32	-3	+2	9	4	-6
Mean	63	30			16	16	-4

$$r = \frac{\Sigma\, xy}{\sqrt{\Sigma\, x^2 \cdot \Sigma\, y^2}} = \frac{-4}{\sqrt{16 \cdot 16}} = -1/4 = -0.25$$

1.6 Problems

1.6.1 Using tables A and B of Figure 1.11 calculate
- a). All measures of central tendency
- b). All measures of dispersion
- c). Three correlcations

1.6.2 The diamers of a sample of bolts were (in inches)

1.440	1.420	1.495	1.501	1.542	1.501
1.500	1.505	1.541	1.495	1.507	1.506
1.540	1.520	1.521	1.503	1.516	1.517
1.515	1.507	1.422	1.521	1.503	1.508
1.530	1.517	1.518	1.507	1.496	1.518
1.444	1.501	1.463	1.478	1.470	1.508
1.475	1.497	1.471	1.502	1.497	1.460
1.498	1.518	1.506	1.457	1.461	1.462
1.472	1.477	1.477	1.471	1.471	1.501
1.575	1.455	1.456	1.500	1.476	1.479
				1.531	1.532

- a). Make a frequency table.
- b). Calculate mean, mode, median, variance, standard deviation.
- c). What percentage of the bolts are over 3 standard deviations out of tolerance?

A.

Value	Frequency
30	1
32	3
34	3
35	4
37	10
38	9
42	17
44	31
47	34
48	28
50	15
53	14
56	10
58	4
62	6
63	3
64	1

N = 193

B.

Value	Frequency
133	1
138	1
143	6
149	7
151	8
158	15
167	20
192	27
208	31
219	33
225	31
227	25
239	17
254	12
270	6
276	4
290	2
294	2

N = 225

FIGURE 1.11

SCHEMATICS

2.1 Schematics

Schematics is defined by Webster to be the arrangement of constituents or parts into a pattern or a scheme of things. In graphics, shematic means the representation of any data or phenomena in a diagrammatic manner.

The important part of the definition is the fact that any data or phenomena can be represented in a graphic manner. It can be in two or three dimensions. The details are important only to the correct portrayal of the broad principle.[1]

If the broad problem is one of solving space relationships, then the model used would be scaled and representing three dimensions.[2] If the broad problem is one of relationship in time, then the detail would not necessarily be scaled. A schematic, then, is the pictorial representation of data in order to quickly and accurately indicate not only the facts but also their relationship of one to another.

2.2 Limitations

Schematics are generally thought of in relation to electrical or pipe circuits. This might be a good starting point - but only a starting point. For schematics are limited in applications only by the imagination

---

(1) Sketching the facts of a problem is a schematic. Pictorially representing the design of any concept is also a schematic.

(2) This could be anything from the assembly of the parts of a toy or wheelbarrow to the scaled diagram of the location of components in an internal combustion motor.

of the individual.

Schematics have been developed for use in practically all lines of endeavor. Physics, chemistry, mathematics, philosophy, law, to mention but a few of the disciplines, use schematics. Without schematics to simplify the problem, advanced electronic layouts for control of space launching stations, etc., would be almost impossibly difficult.

The following paragraphs will give some principles and examples of schematics used in various fields. The examples will indicate principles that apply to each field. Please note that the principles could be applied to other areas and, in fact, the application of schematic principles of one field to another field suggests a limitless advantage for the solution of problems.

2.3 Coding

The use of a shorthand method of description is necessary for the realization of economy of effort in schematics. The use of a universal type code symbol suggests interchangeability and expanded usage. When using schematics standard handbook symbols are suggested. ASTM symbols, mechanical chemical and civil engineering handbook symbols are all usable.

As each drawing is developed it is advisable to indicate the code symbols used and their source or a table of definitions in some standard manner.(3) When no code symbols are used, then a simple block system may be used. A sample of this procedure is shown in figure 2.7.

---

(3) Regardless of whether standard symbols are used or special symbols are created for each case, a note or table is required for clarification. Each schematic must have indicated either the code used or a reference to a standard code.

2.4 Electrical Schematics

Inside the case of most television sets and radios is found the most usual type schematic, the tube layout or diagram of your set. Figure 2.4-1 shows a typical schematic. Here the code is the universal number assigned by the industry to tubes, condensers, etc.

Another sample of an electrical schematic is shown in Figure 2.4-2. Note here the standard symbols used to indicate the components.

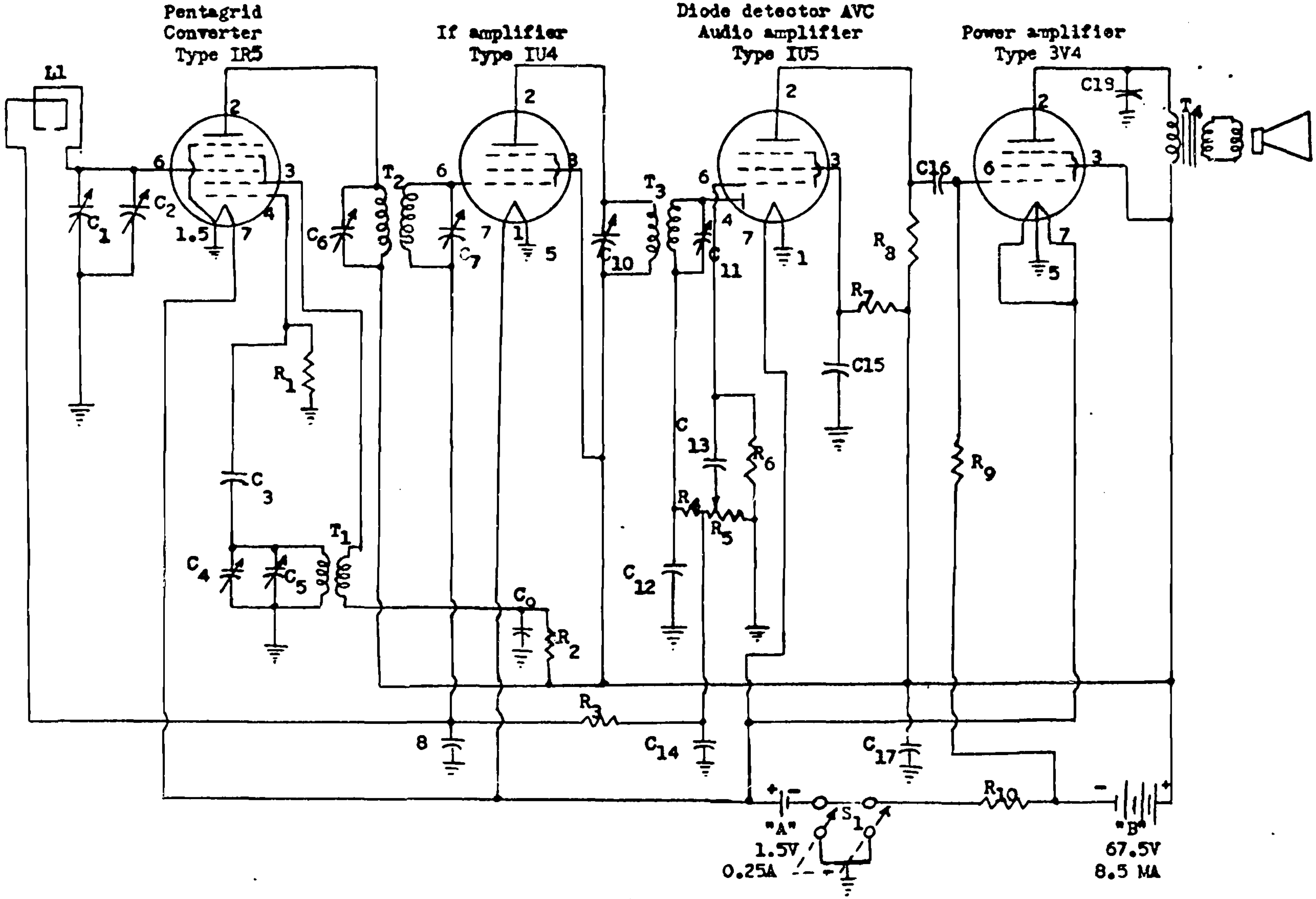
From these simpler illustrations let us step to the more complex. Figure 2.4-3 includes an electric system and a representation of its control.

2.5 Pipe Schematics

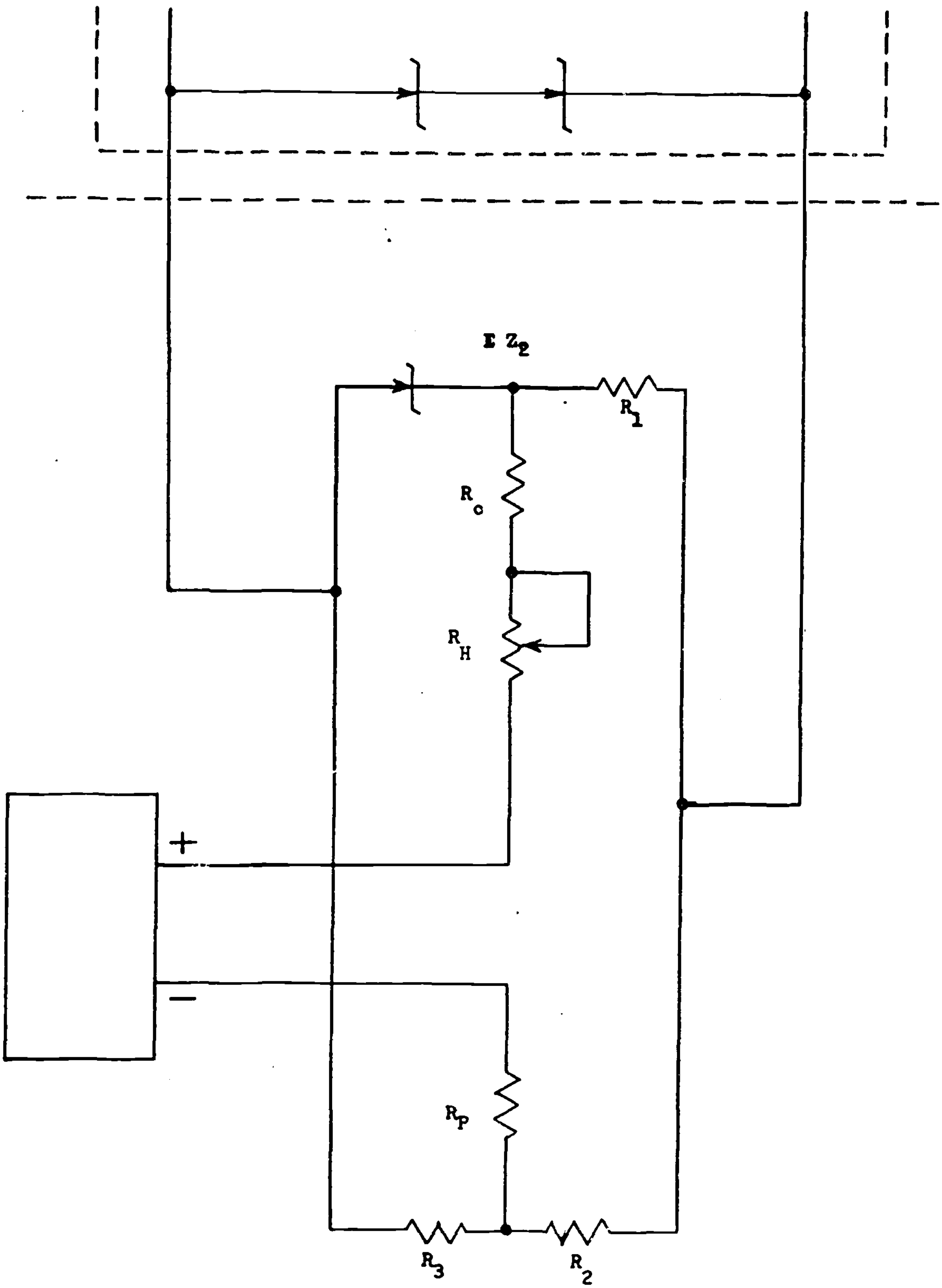
To the engineer who is responsible for planning liquid and gas flow, a basic tool is the pipe layout or line flow schematic. In petroleum plants, chemical plants, in fact, in practically all plants, some part of the design involves flow lines. The efficient design of the plant is dependent on the flow pattern conceived. Pressure drops, line sizes, valves, pressure vessels, retainers, and other important feature of the system can be considered on the schematic layout.

Figure 2.5-1 is a typical chemical plant layout with flow, tanks, vessels, and pumps shown. Standard chemical engineering symbols are used. Figure 2.5-2 is the same.

PORTABLE BATTERY - OPERATED RECEIVER

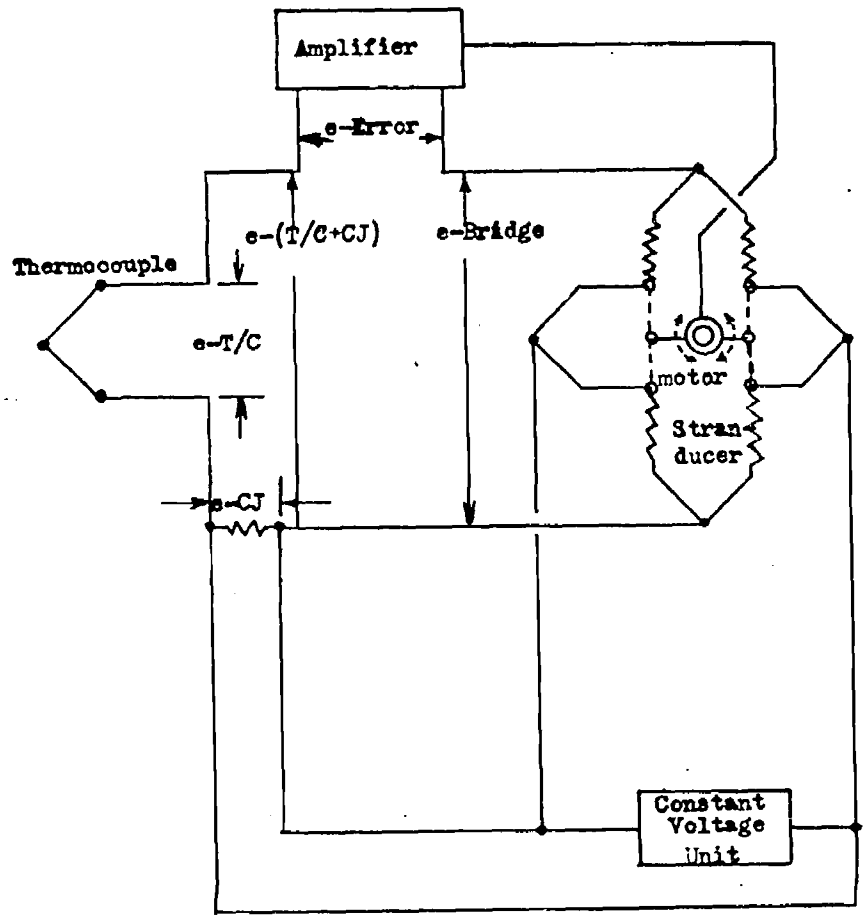


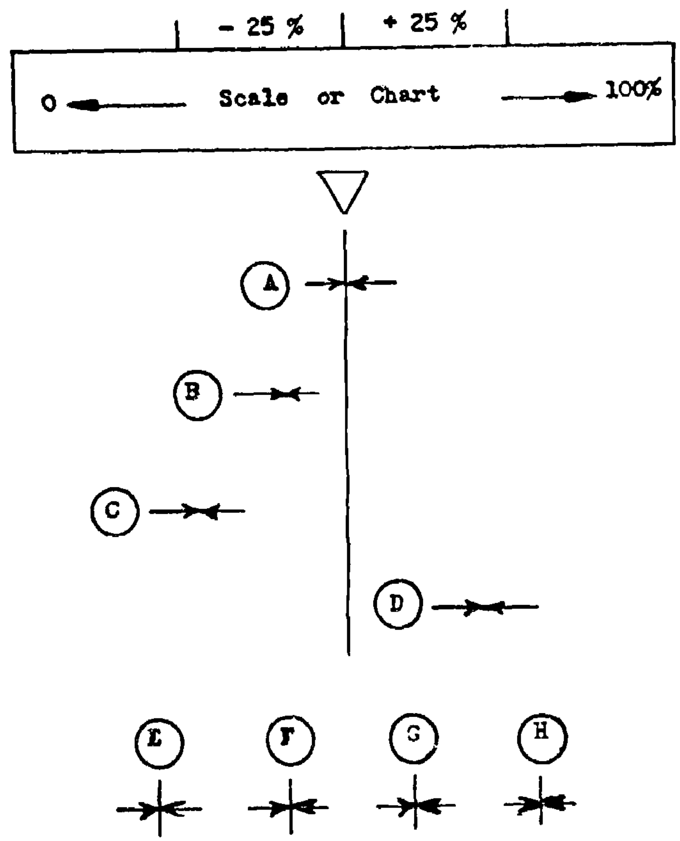
2.4-1



Typical electrical schematic

2.4-2



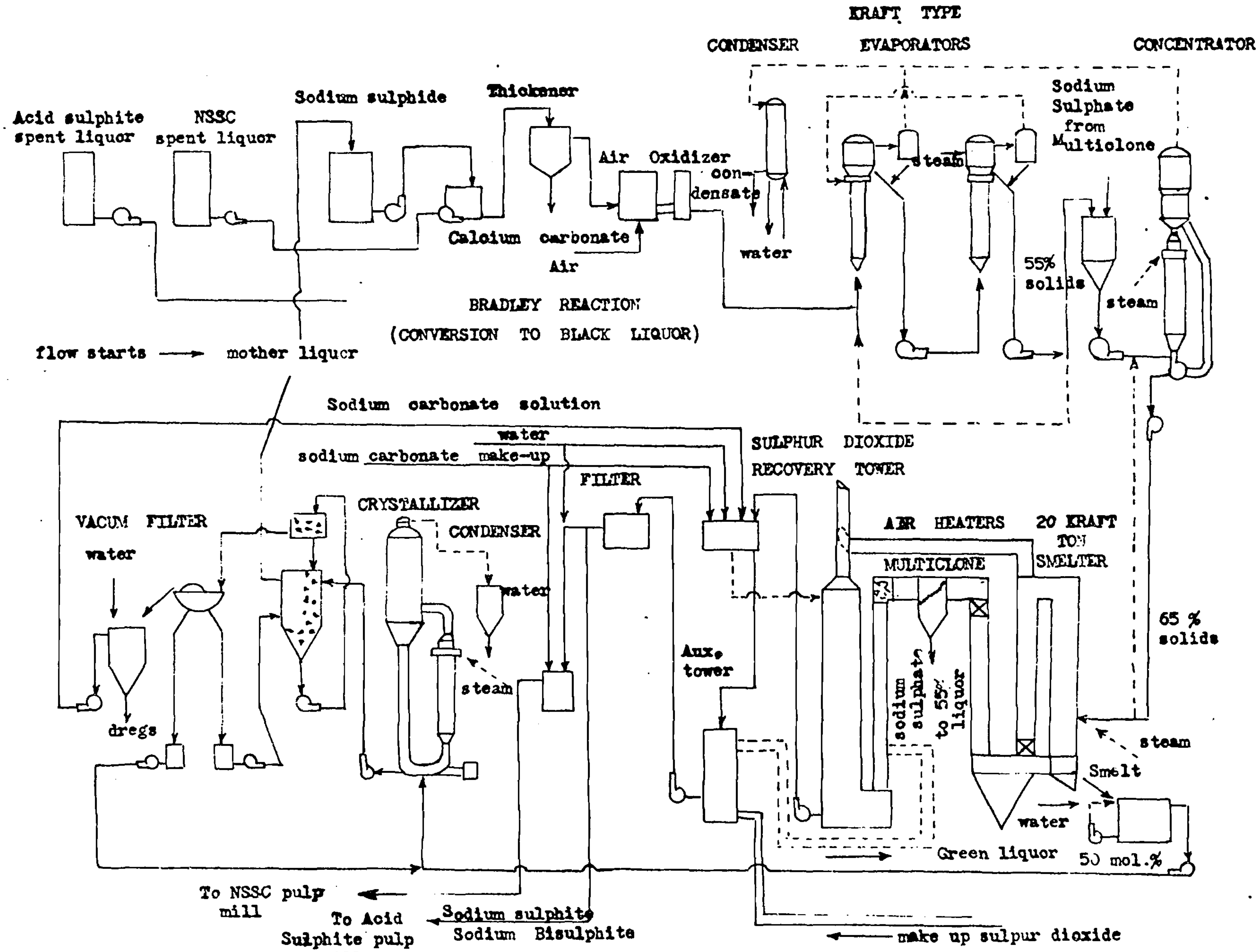


Legend: Contacts that move with control index
(A) Primary (main) contact
(B), (C), (D) up to 3 zone contacts set anywhere within + 25 % of scale span from primary contact.
Auxiliary pen-operated contacts
(E), (F), (G), (H) up to 4 contacts set anywhere between 0 and 100 % of scale.

Typical electrical schematic

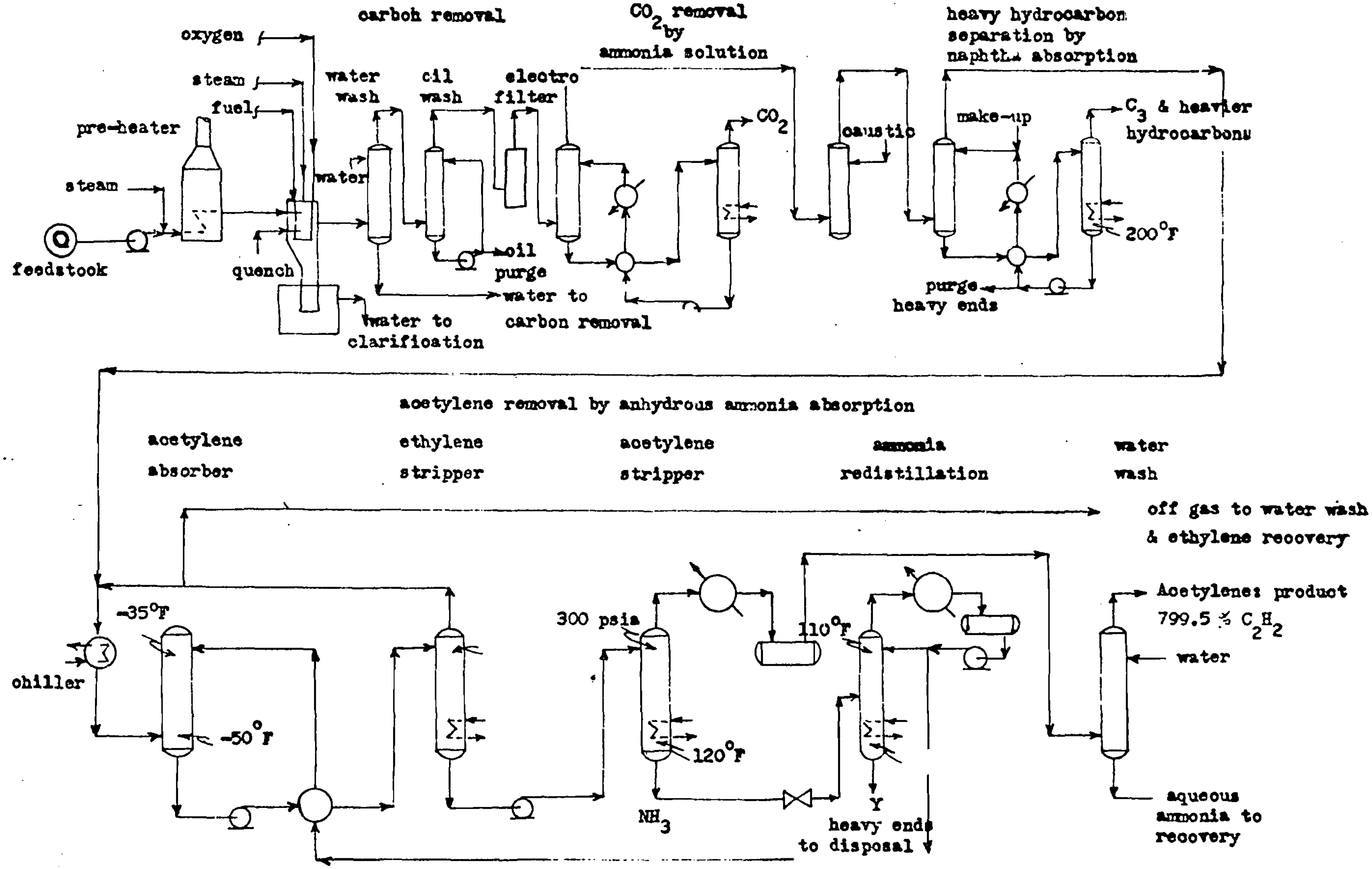
2.4-3

Electric contact control



2.5-1

Experimental recovery plant flow chart



2.5-2

Process for acetylene and ethylene from naphtha

Figure 2.5-3 indicates one line in a system. The parts of the system related to the line are also shown. Emphasis is the line drawn as a "double-line."

Figure 2.5-4 is a simplified chemical process schematic.

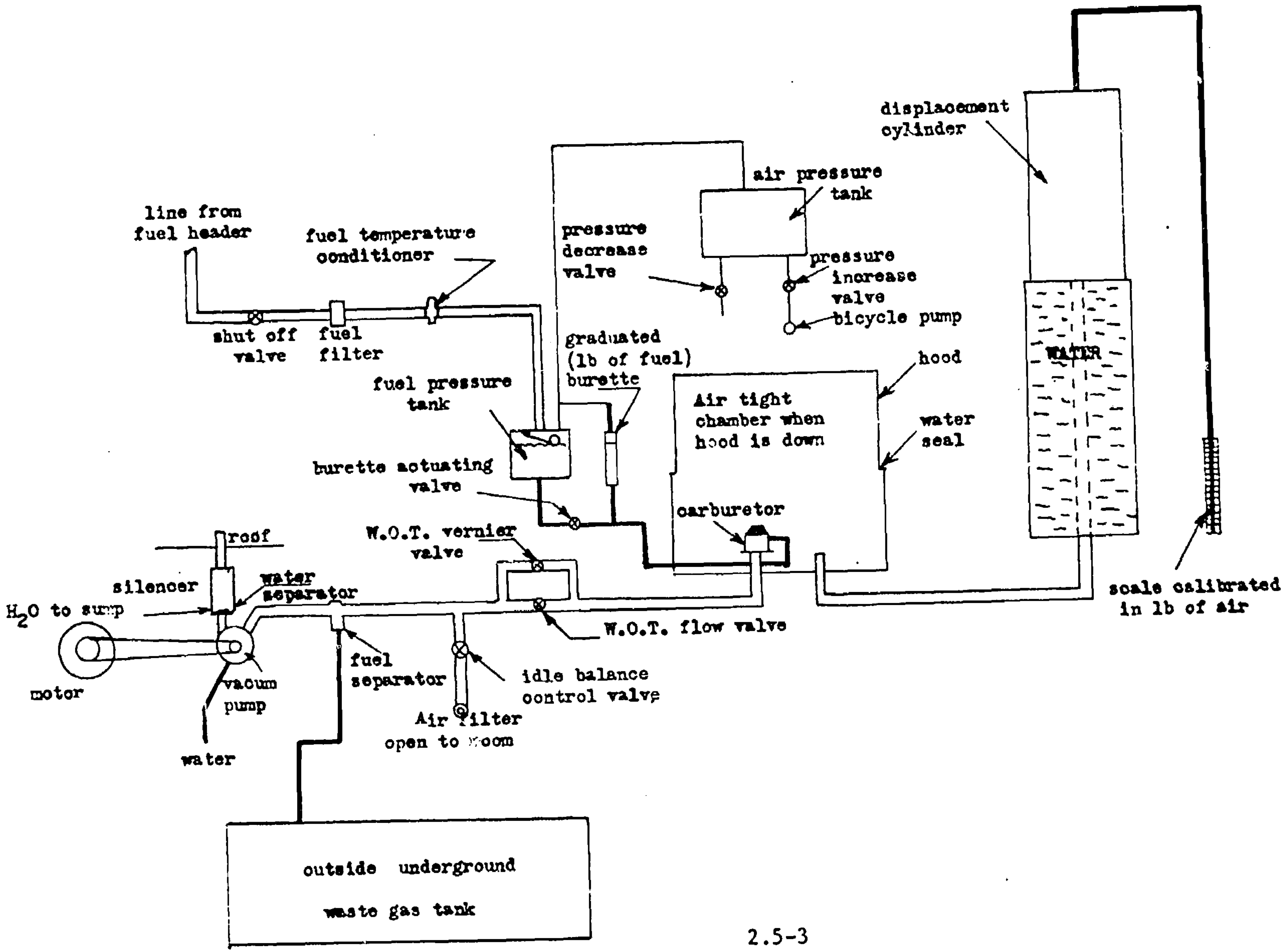
2.6 Organization

The organization of a company, school, agency, government, or any body of people bound together with a common purpose or function has a decided influence on its success, level of efficiency and even its life. A pictorial representation of relations, flow of authority, communication, purpose, etc., will often focus attention of obvious cause and effect relations. One look may make obvious the solution of many problems that become graphically obvious.

Figure 2.6-1 is a schematic illustrating the relationship of basic sciences to activity fields. Specifics to generalizations become apparent.

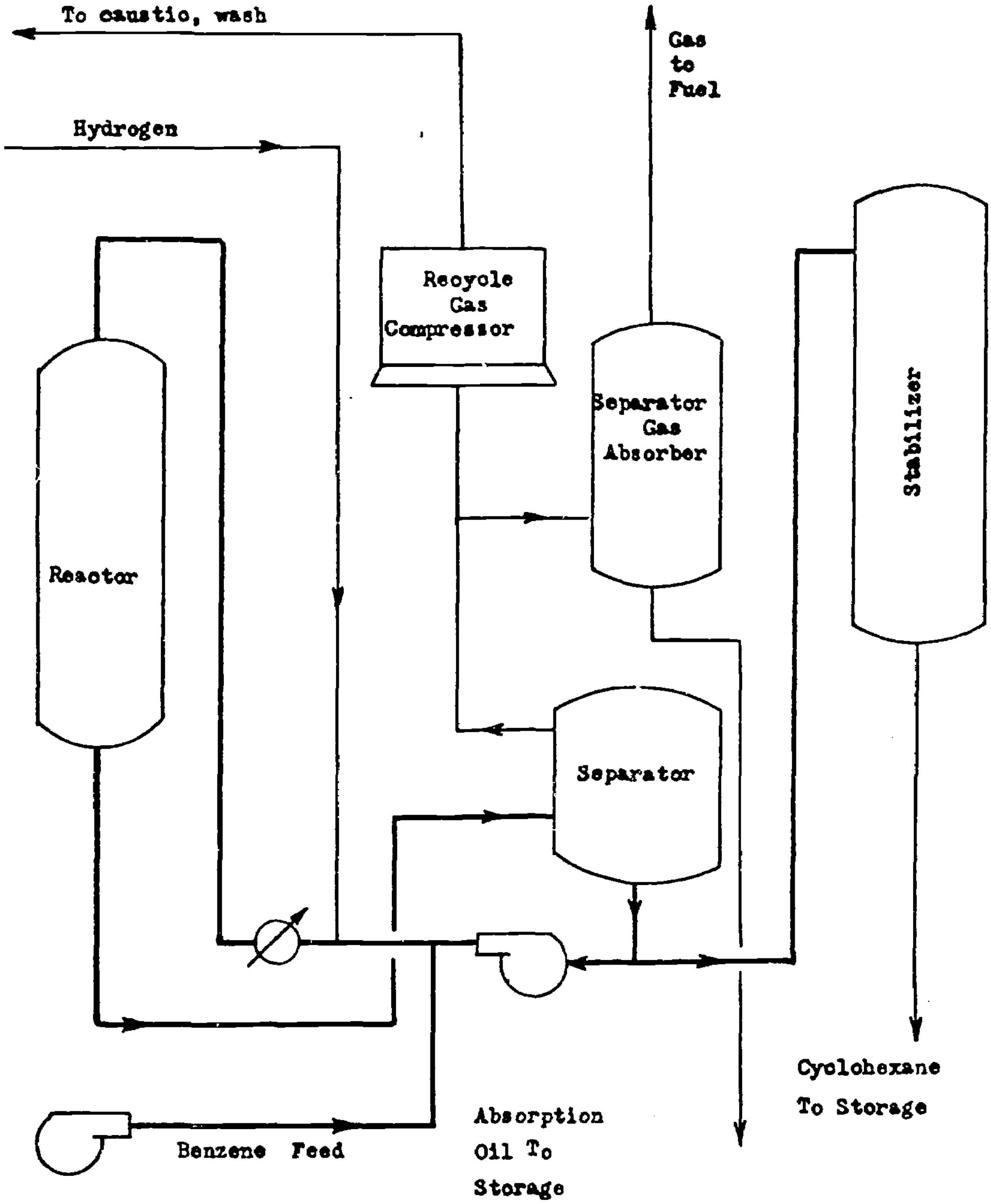
Figure 2.6-2 illustrates a system of responsibility. Solid lines indicate authority, dotted lines indicate staff or consulting.

Figure 2.6-3 illustrates a safety system. This offers a quick view of the whole system and shows if any necessary flow of command has been overlooked. Figure 2.64 relates control through computors to a dispatch system. The actual system is not shown but the control aspects are clearly illustrated.



2.5-3

Schematic diagram of displacement type flow box

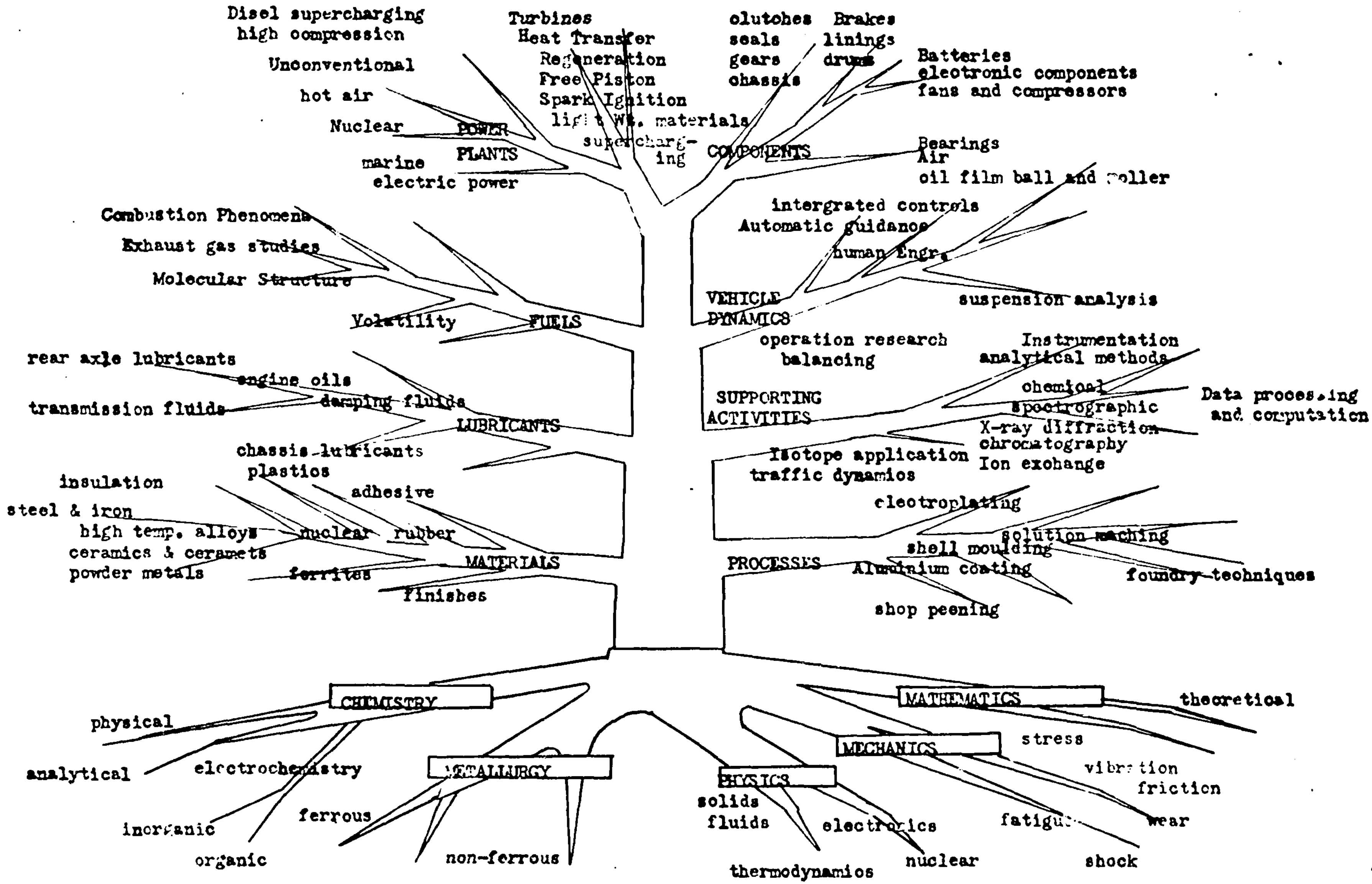


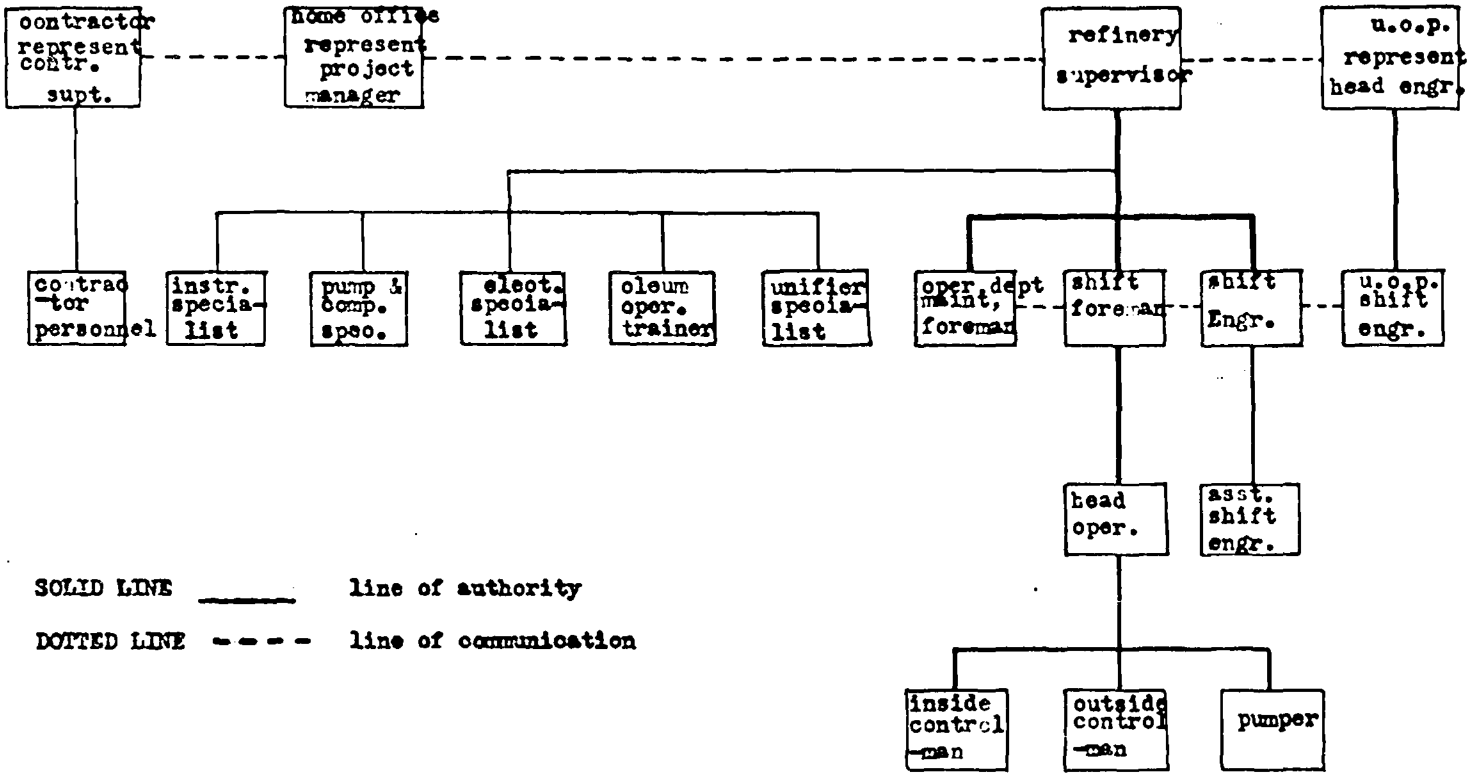
2.5-4

CYCLOHEXANE FROM BENZENE

LABORATORY FIELDS OF ACTIVITY

2.6-1

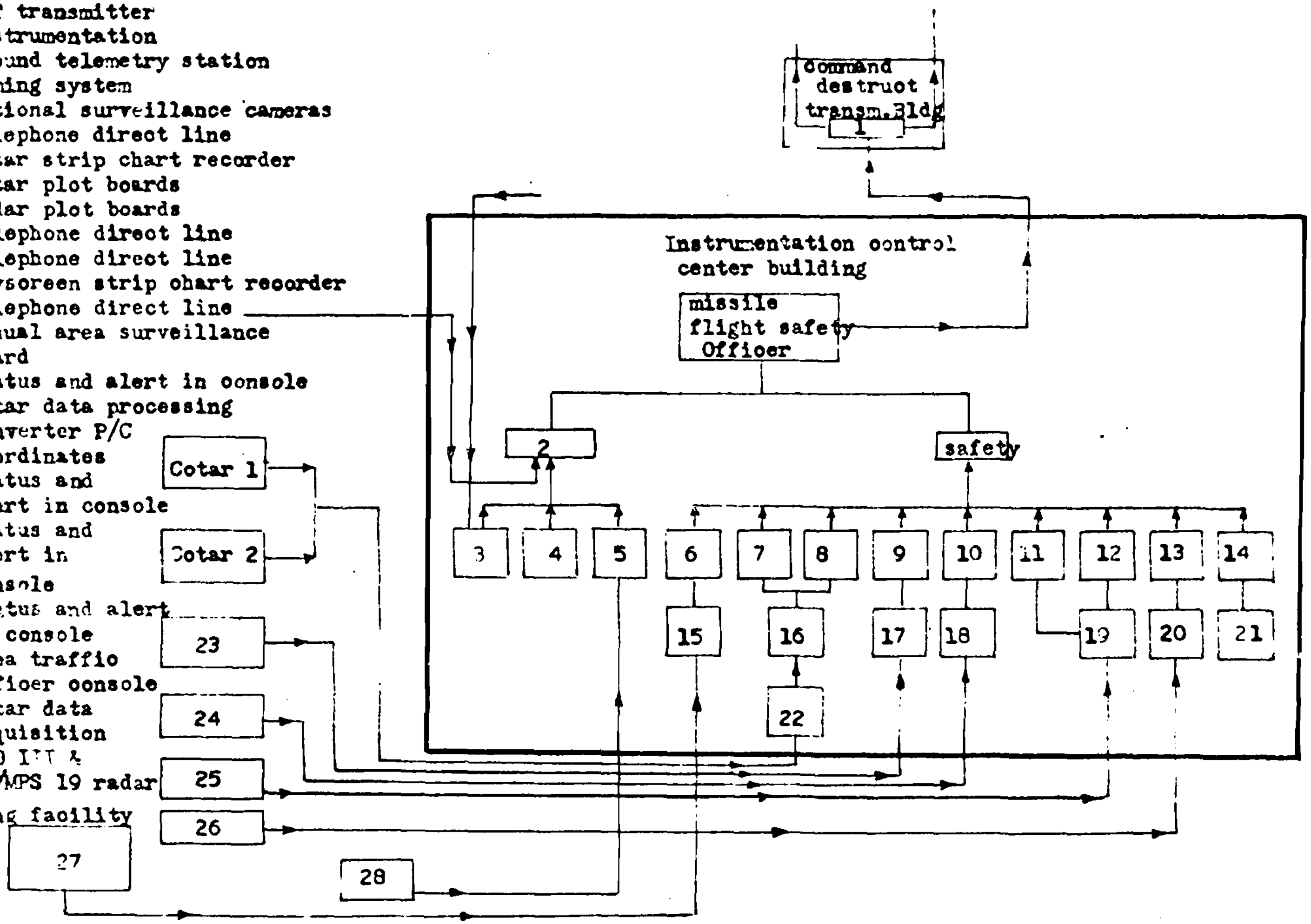




STARTUP ORGANIZATION CHART

2.6-2

1 CDT transmitter
2 Instrumentation
3 Ground telemetry station
4 Timing system
5 Optional surveillance cameras
6 Telephone direct line
7 Cotar strip chart recorder
8 Cotar plot boards
9 Radar plot boards
10 Telephone direct line
11 Telephone direct line
12 Skyscreen strip chart recorder
13 Telephone direct line
14 Manual area surveillance board
15 Status and alert in console
16 Cotar data processing
17 Converter P/C coordinates
18 Status and alert in console
19 Status and alert in console
20 Status and alert in console
21 Area traffic officer console
22 Cotar data Acquisition
23 MOD I?T & AN/MPS 19 radar tracking facility
24 Radar skyscreen
25 Optical skycreen
26 Wire skyscreen
27 Blockhouse operation & checkout console
28 Camera



2.6-3

INSTRUMENTATION AND RANGE SAFETY SYSTEM

2.7 Flow of Information

Information flow and/or communications schematics can be of several types and can actually belong in one of the other categories listed. A simple form is shown in Figure 2.7-1. Note that inter and intra relationships become immediately apparent.

Figure 2.7-2 illustrates forms used for data control. Two forms are shown with the information inserted. From these data, flow charts are designed.

Figure 2.7-3 illustrates a complete production reporting system including computor recording. This illustrates key actions in a production record system.

Figure 2.7-4 is a status chart used to predict production schedules, lead times, and completion dates.

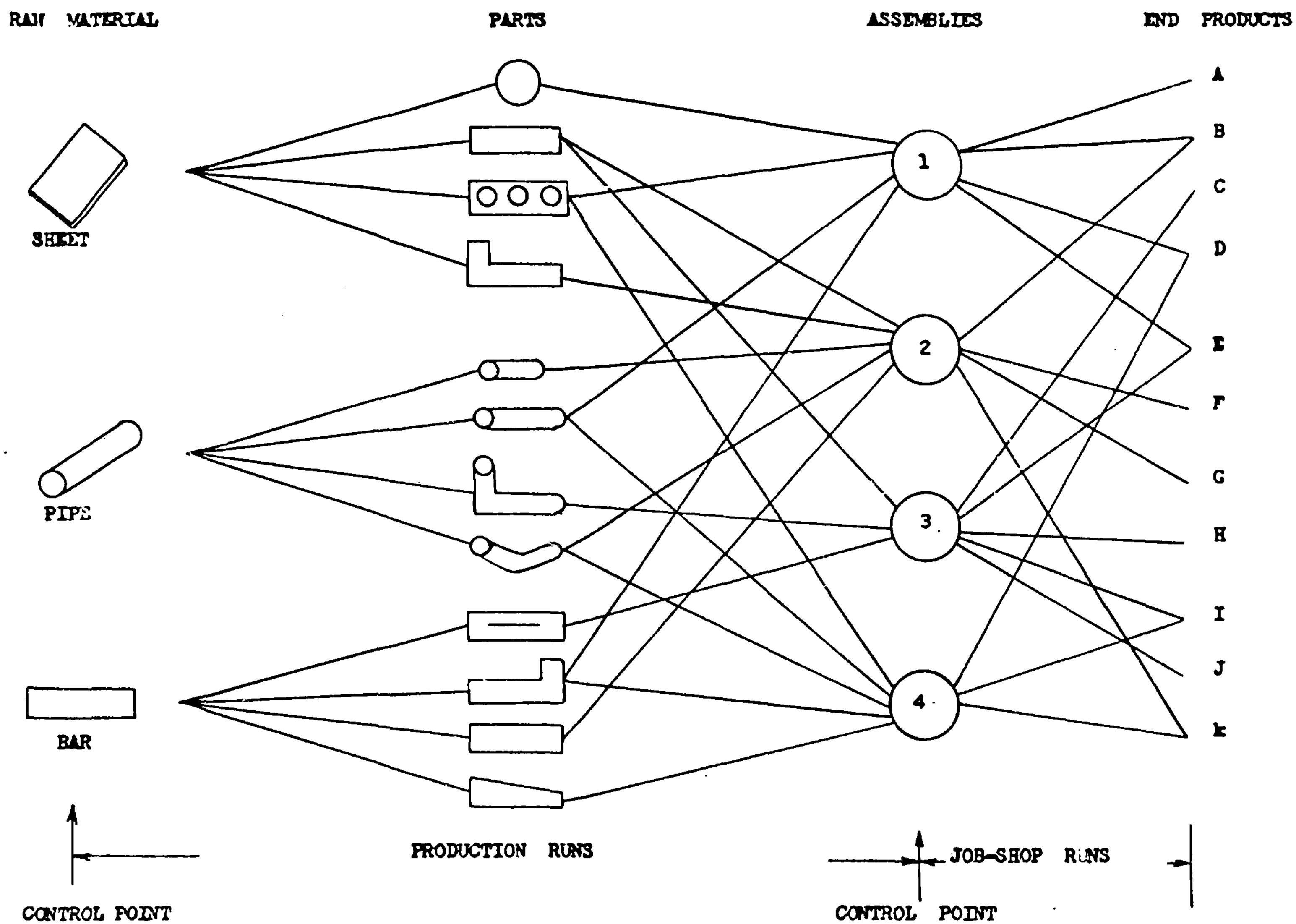
2.8 Plant Layout Schematics

Figure 2.8-1 illustrates a simple plant layout. Note the symbols used related to actual lookalikes. This schematic relates to one utility in a plant and is of prime importance to the engineer charged with this specific detail - the instrument air system.

In figure 2.8-2 the actual electrical distribution system of the plant is shown. Actual physical locations and relations are illustrated.

2.9 Material Flow Schematics

Figures 2.9-1 through 2.9-3 illustrate simple to rather detailed schematics that show material flow. Solids lines, double lines, dotted lines, graphs, and symbols are varied to make the meaning more clear.



2.7-1

INVENTORY CENTRAL CHART

2.7-2

Representative work control sheets used at various stages of startup to anticipate future maintenace problems

SPARE PARTS ANALYSIS SHEET

BPF NO 134681   E.P. NO. 1074-418 -47,73,129   E.M. 418-47.10

Stock No	No/EQ PC	Description	Material	Vendor Minimum	Stock Max	Stock Min
J-70-1-158	1	Bearing Housing # 4	C.I.	1	0	0
J-70-1-159	1	Ooutboard bearing cover	C.I.	1	0	0
J-70-11-70	1	Bearing adaptor locknut	Steel	1	1	1
J-70-16-9	1	Outboard bearing Adaptor	Ni-R	1	1	1
J-70-4-20	1	Inboard bearing	Steel	0	1	1
J-70-4-20	1	Outboard bearing	Steel	0	1	1

Equipment Po. description   Durirron WHK 4 cent Pump

Original order No: PAC 5772½

Orignial Vendor: Durriron

Consider: Delivery - Weeks

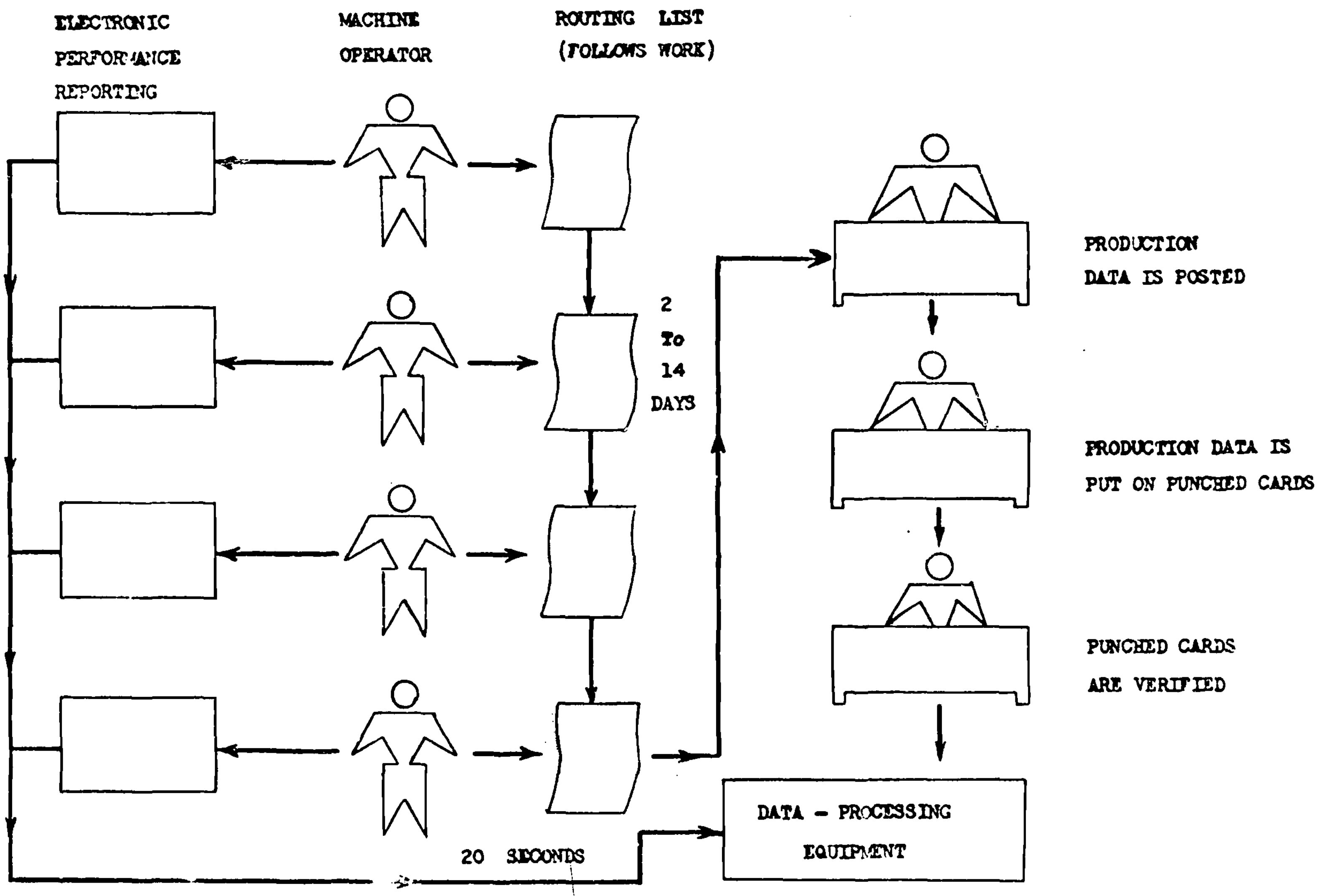
Unit cost

Estimated Life in Months

PUMP CLEARANCES & RUN - OUT TOLERANCES

For Pumps P1 - P2; Model SHB 2

DESCRIPTION	DIMENSION
1. Throttle bushing clearnace	0.006" - 0.010"
2. Shaft end play	0.001" TIR.
3. Shaft radial play	
(a) Coupling end	0.002" TIR.
(b) Inboard end	0.002" TIR.
4. Shaft run out at stuffing box	0.004" TIR.
5. Diametral wear ring clearance	0.010" - 0.030"
6. Impeller front clearance	0.025"
7. Coupling face to face	4"
8. Seal perpendicular to shaft	0.0005" maximum

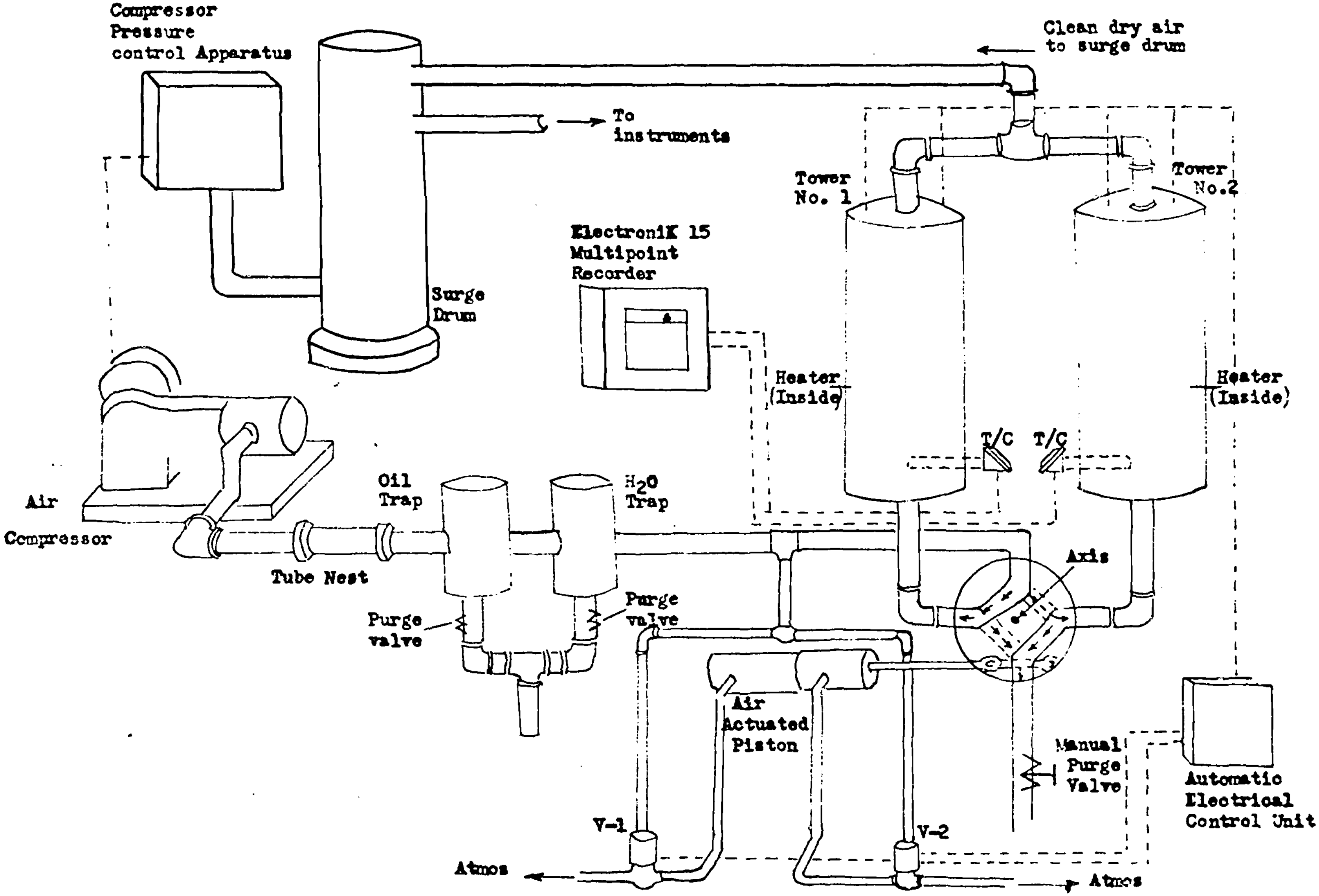


2.7-3

PRODUCTION REPORTING

STATUS CHART

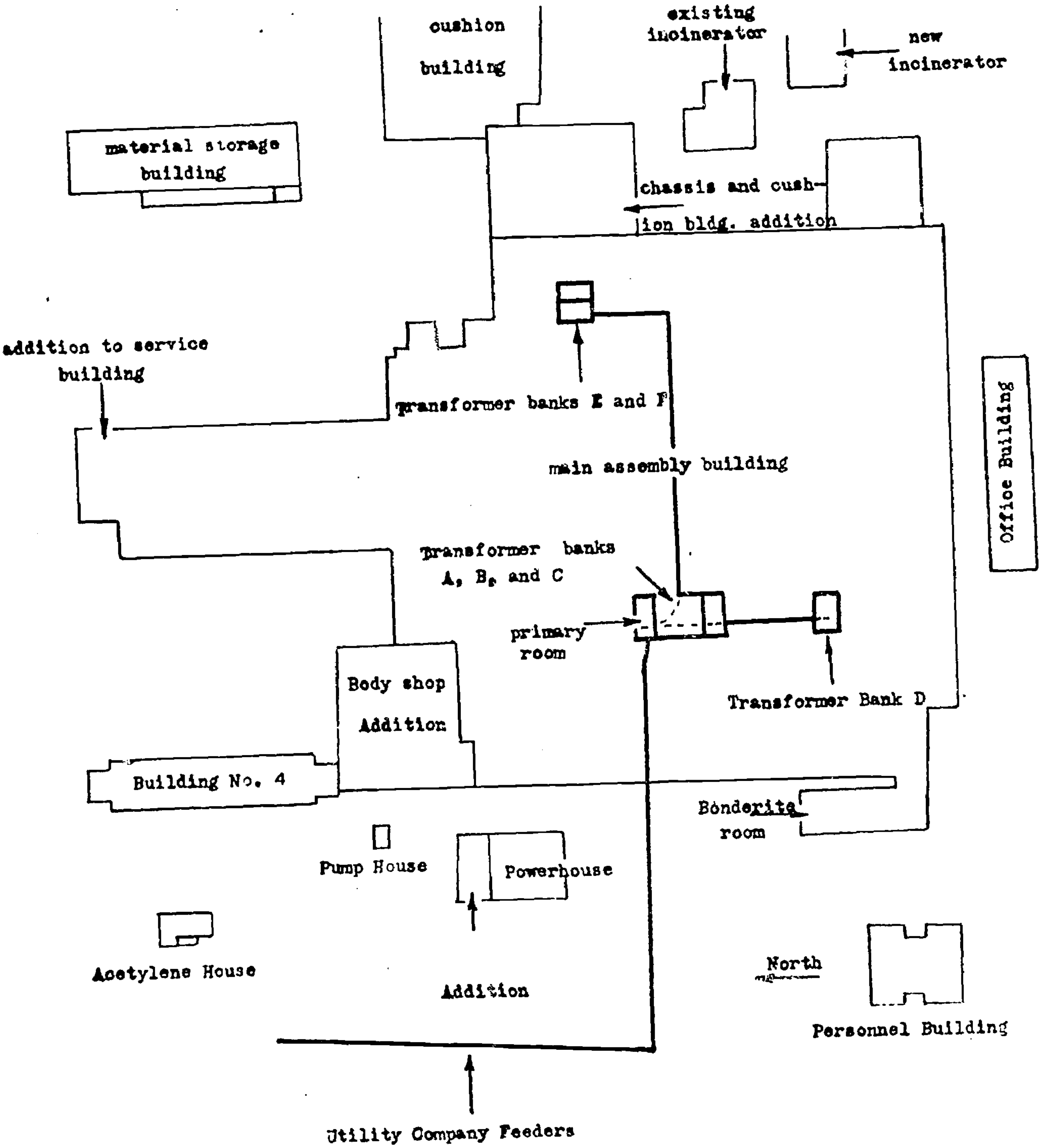
Contractor and proj. Managers	Source	Cont. Number	Level of support (Millions)	Duration	Started	Remarks
Aerojet-Gen.	AFOSR	AF49(638)-656	$0.094	12 mos.	Mar'60	Basic studies of charged oil droplet formation Hohlraum source (includes neutralization and negative ion generation)
Allison (Rosebrock)	In-house effort					Theoretical analysis
Convair-Ft.Worth (Spearman)	In-house effort					Duoplasmatron development
EOS (Forrester)	WADD (ARPA)	AF33(616)-6958	1.190	15 mos.	Mar'60	Alkali metal ion engine. Classified objectives
(Teem)	NASA	NAS5-604	.084	12 mos.	Sep'60	General investigation of copious and efficient negative ion sources
GE (Baldwin)	NASA	NAS8-29				Included in ion rocket performance evaluation
(Edwards)	NASA	NAS8-29	.015	3 mos.	Aug'60	Cesium ion rocket performance evaluation, neutralization studies (Continuation of ABMA contract)
(Edwards)	NASA	NAS8-623	.043	12 mos.	Oct'60	Alternate ion optics- computer program
(Stauffer)	NASA	NAS8-628	.043	12 mos.	Oct'60	Electrical conduction in cesium vapour
GHVA (Nablo)	WADD	AF33(616)-7178	.280	12 mos.	Mar'60	Duoplasmatron. Classified objectives (study of change exchange neutralization)
Hughes (Currie)	NASA	NAS5-515	.490	12 mos.	Oct'60	Alkali metal ion engine. Classified objectives
Marquardt (Pitkin)	In-house effort					Sputtering, secondary emission, digital-computer beam studies
Martin	In-house effort					Theoretical analysis
NASA Lewis (Childs)	In-house effort					General R&D, 15 man years plus equipment
(Kaufman)	In-house effort					Bombardment type ion engine
Pratt& Whitney (UAC) (Meyerand)	In-house effort					Peening source, general research
Reaction motors (Wolfhard)	AFOSR	AF49(638)-657	.153	12 mos.	Dec'59	Behavior of metallic dust during charging process
Rocketdyne (Mc Dole)	In-house effort					Continuation of program proposed to NASA
(Mc Dole)	WADD	AF33(616)-5927	.100	12 mos.	June60	Pore size, materials, Cs vapor pressure, field gradient at surface of emitter
(McDole)	WADD	AF33(616)-7622	.100	12 mos.	June60	
STL (Krohn	WADD	AF33(616-6775	.137	18 mos.	Aug'59	Basic studies of charged dropletsof liquid Woods metal
(Langmuir)	SASA	NAS8-41	.097	12 mos	Oct'60	Ion-atom ratio; surface diffusion coefficient of Cs on W; shaping; emission dependence on pore size: density, temperature, etc.
TRW (Langmuir)	AFOSR	AF49(638)-886	.092	12 mos.	May'60	General neutralization studies
TRW (Tapco) (French)	NASA	NAS8-42	.092	12 mos.	Oct'60	Annular duoplasmatron, improvement of 3 in. diam. source; continous operation



2.8-1

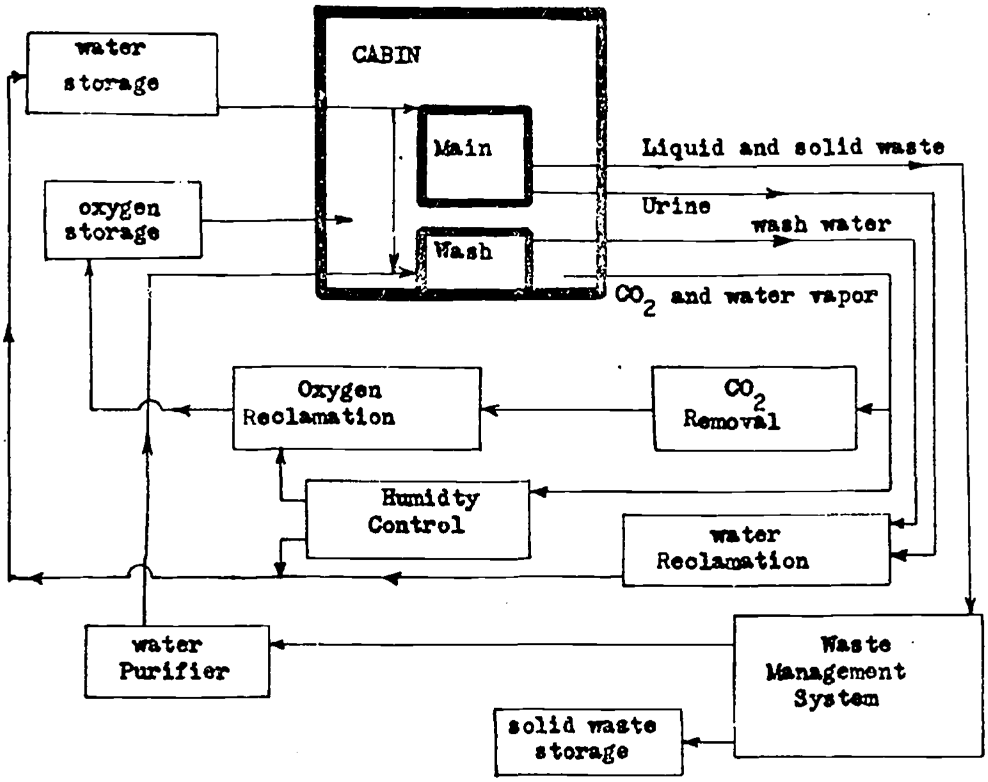
Instrument supply air Schematic

?.8-1

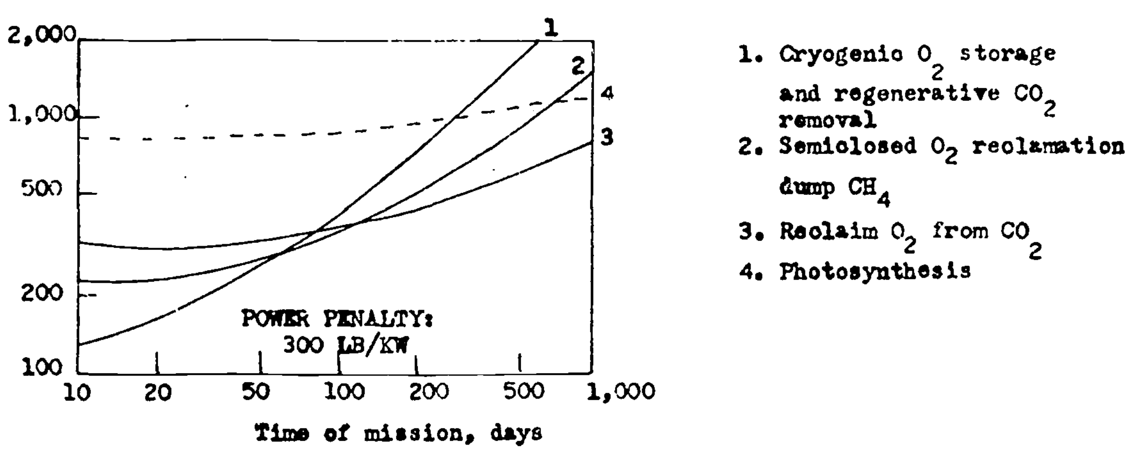


ELECTRICAL DISTRIBUTION SYSTEM

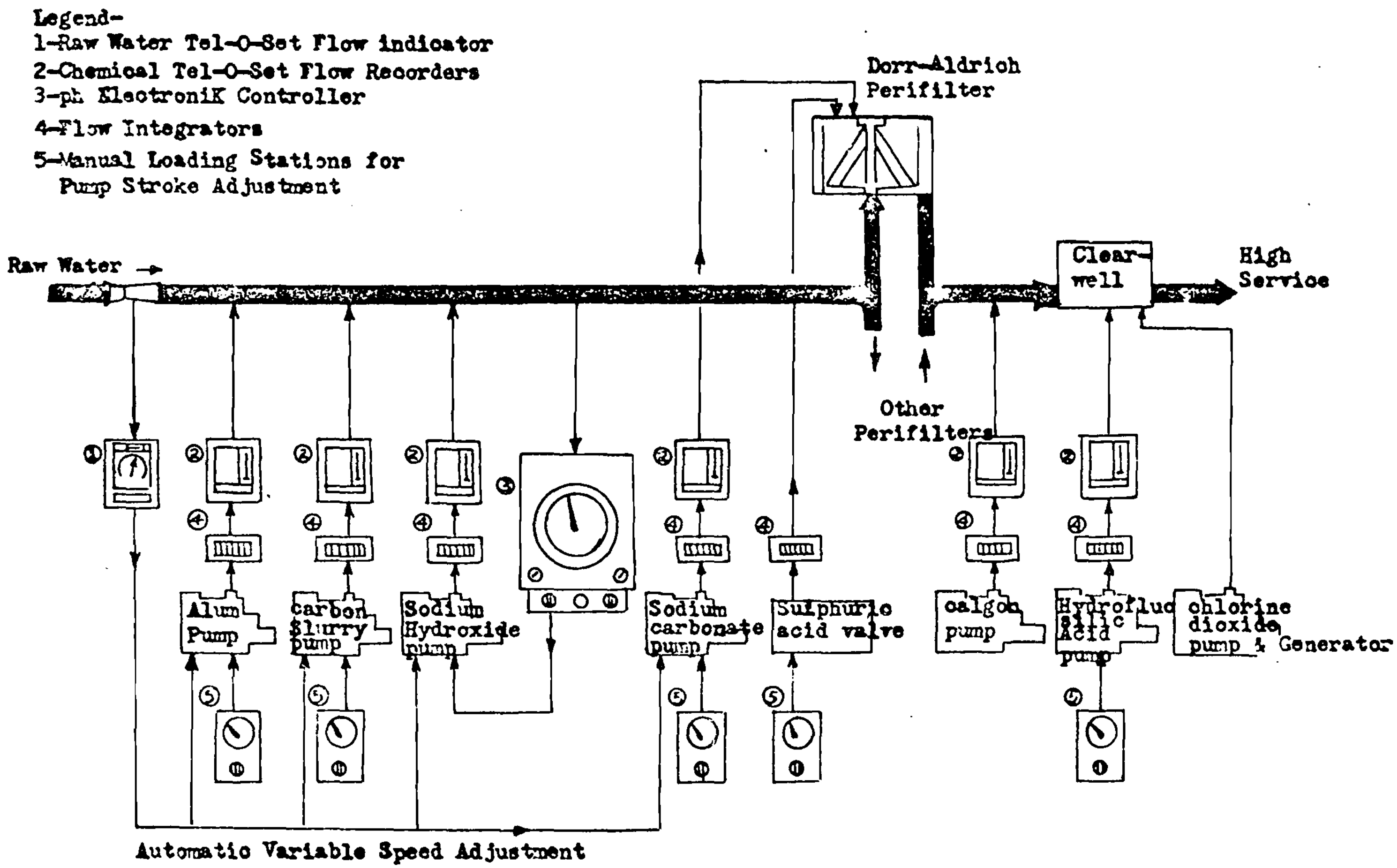
2.9-1



LIFE-SUPPORT SYSTEM FOR MEDIUM-DURATION MISSION

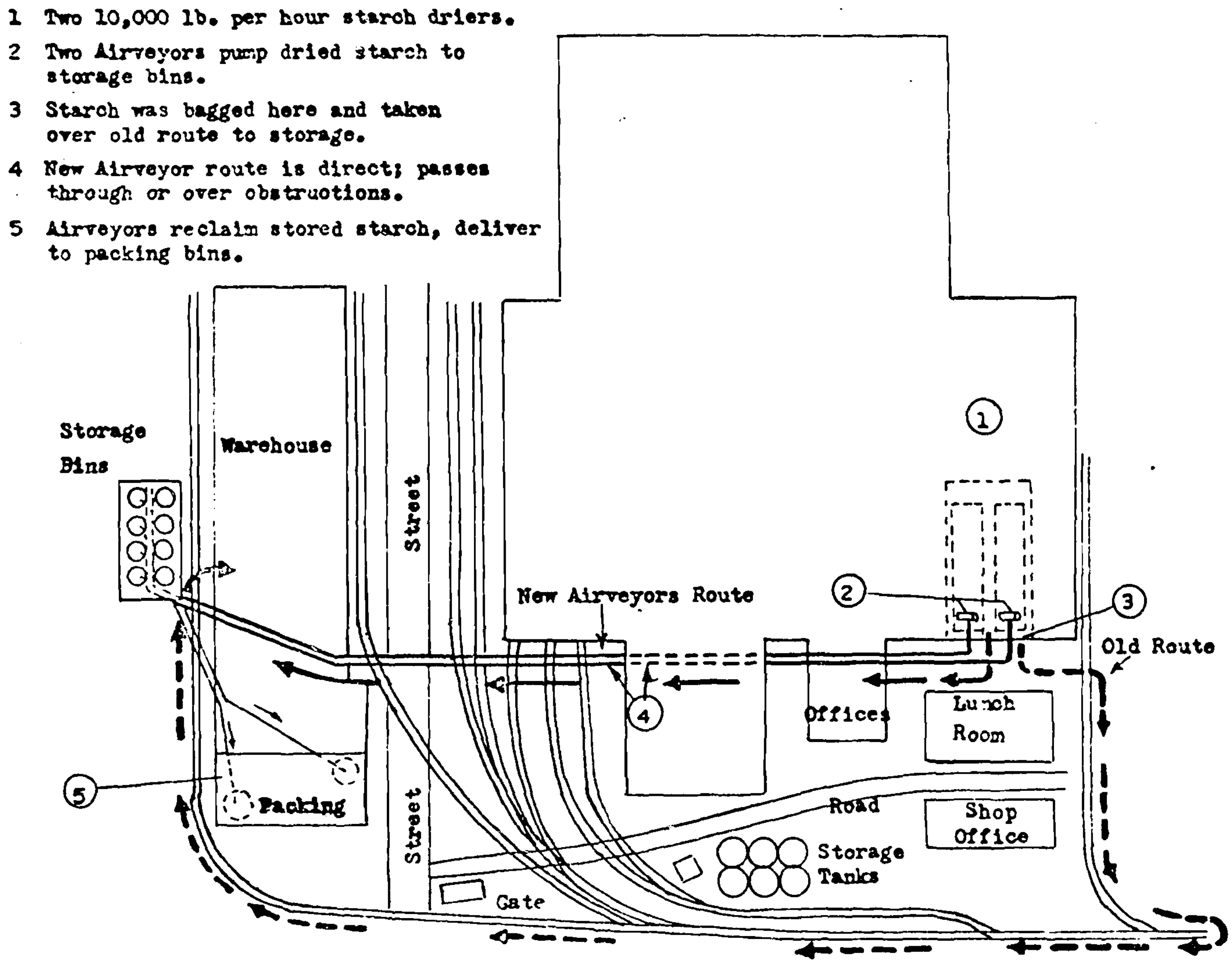


ENVIRONMENTAL-CONTROL SYSTEM



2.9-2

Automatic chemical feed system



PNEUMATIC CONVEYING SYSTEM

2.9-3

2.10 Incidental Type

Figure 2.10-1 illustrates dimensions of pump operating characteristics and it is possible to look at this and quickly find a pump which fits specific needs. Three variables and one constant are shown in each diagram.

Figure 2.10-2 is a unique illustration of a process chart. This illustrates the system in terms of generalized concepts but not in actual specifics.

Figure 2.10-3 pictorially illustrates several aspects of manned space flight.

2.11 Process Systems

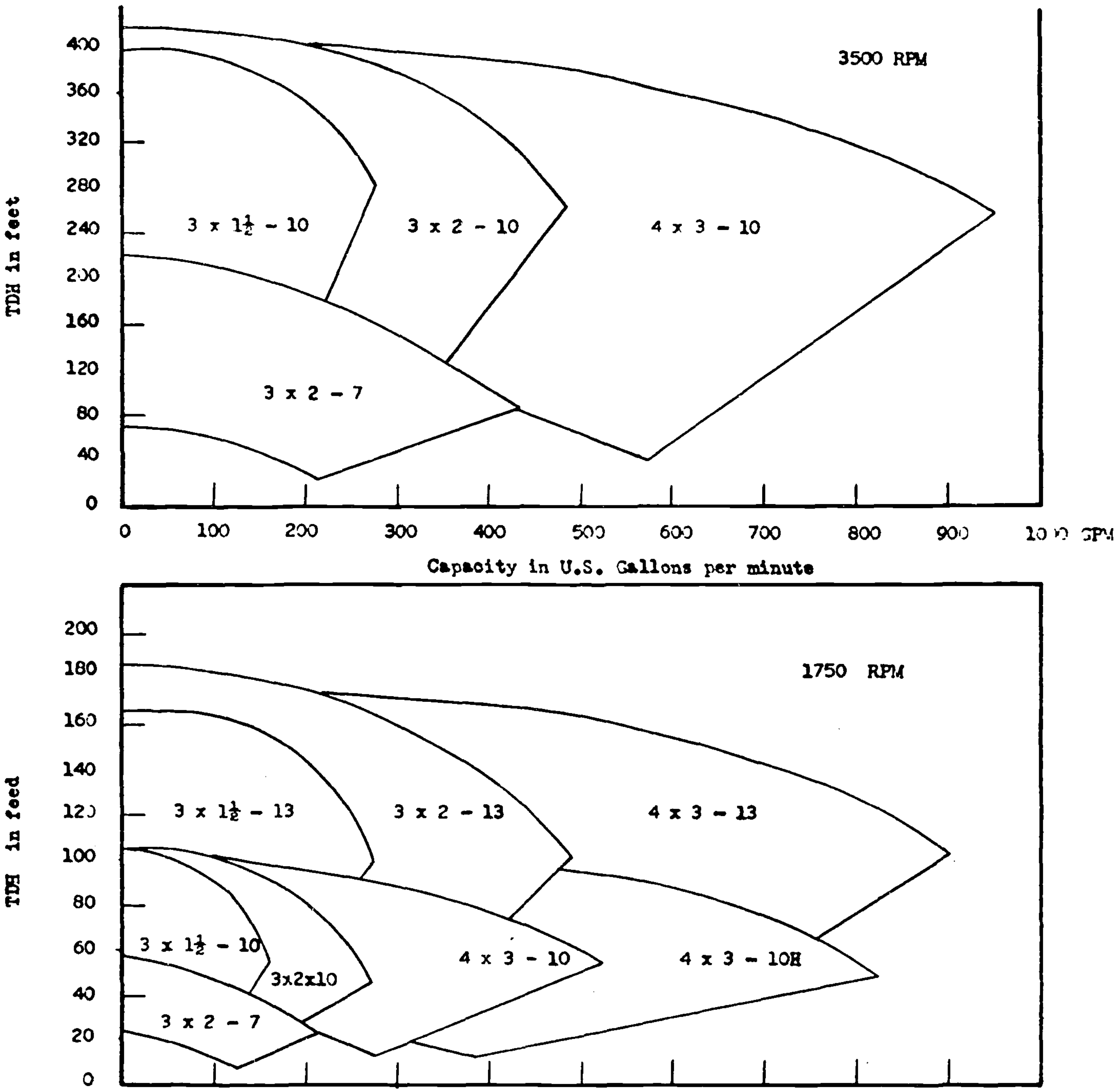
In figure 2.11-1 the three components of a reactor process are shown. The product, radiation, and its control can be visualized from the drawing. Figure 2.11-2 illustrates the operation of a modern fuel cell.

2.12 Mathematics and Equations

In figure 2.12-1 the equation for measuring properties and relating these properties mathematically is represented. Figure 2.12-2 is a schematic representation of a nomograph. Figure 2.12-3 is a chart schematic which relates circuitry to mathematical equations.

2.13 SUMMARY

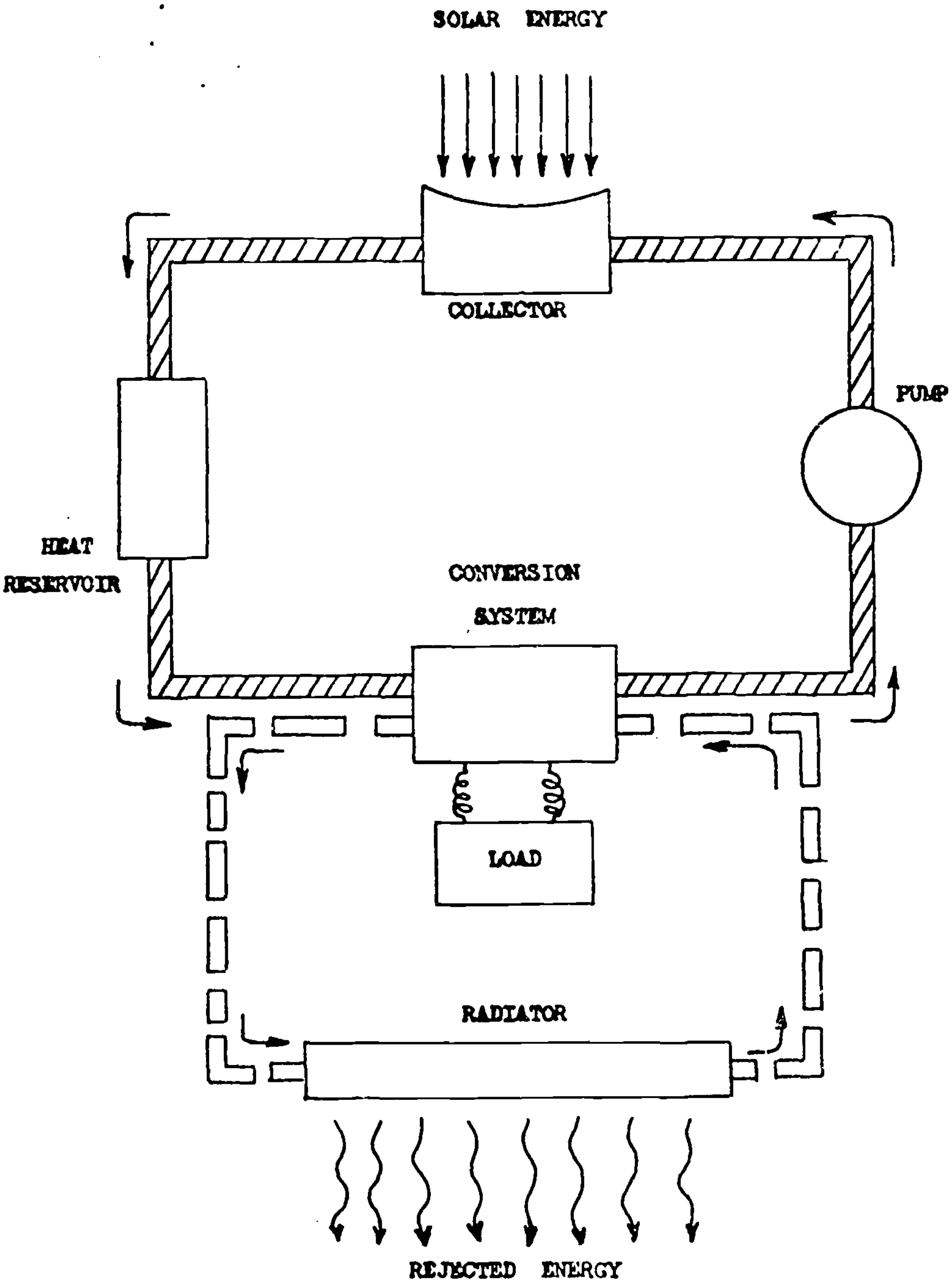
From the examples shown it is obvious that schematics have applications in many fields. It is suggested that the absolute limit to the use of schematics



2.10-1

PUMP CHARACTERISTICS

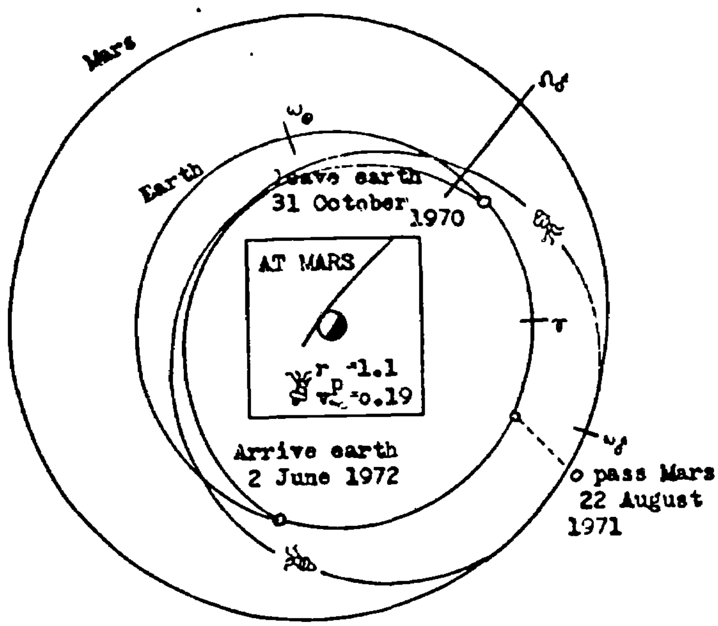
2 10-2



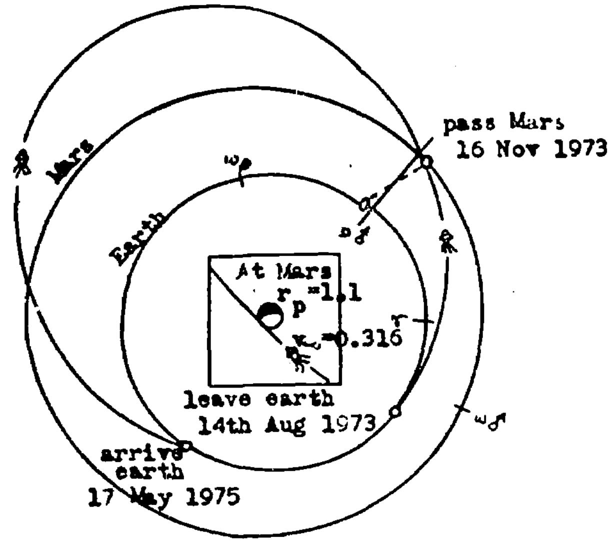
Solar-to-electrical energy conversion system

HIGH-ENERGY NONSTOP FLYBY PAST MARS

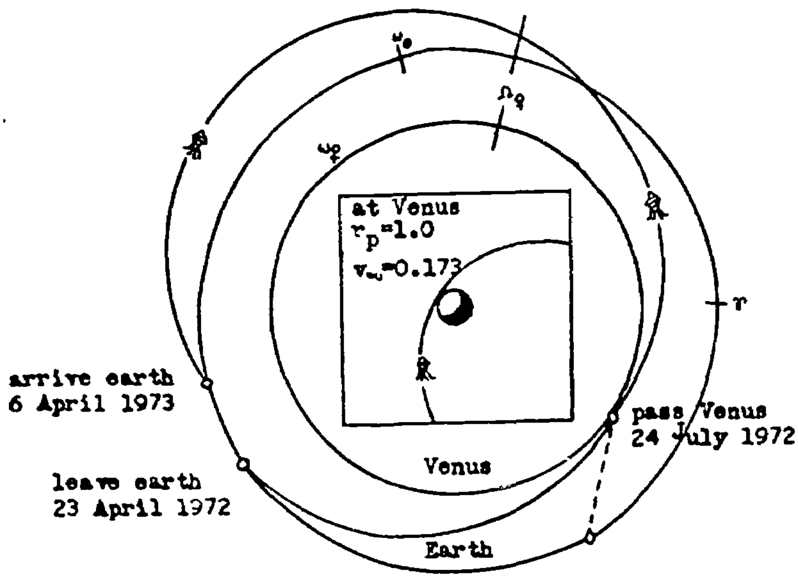
2.10-3



LOW-ENERGY NONSTOP FLYBY PAST MARS

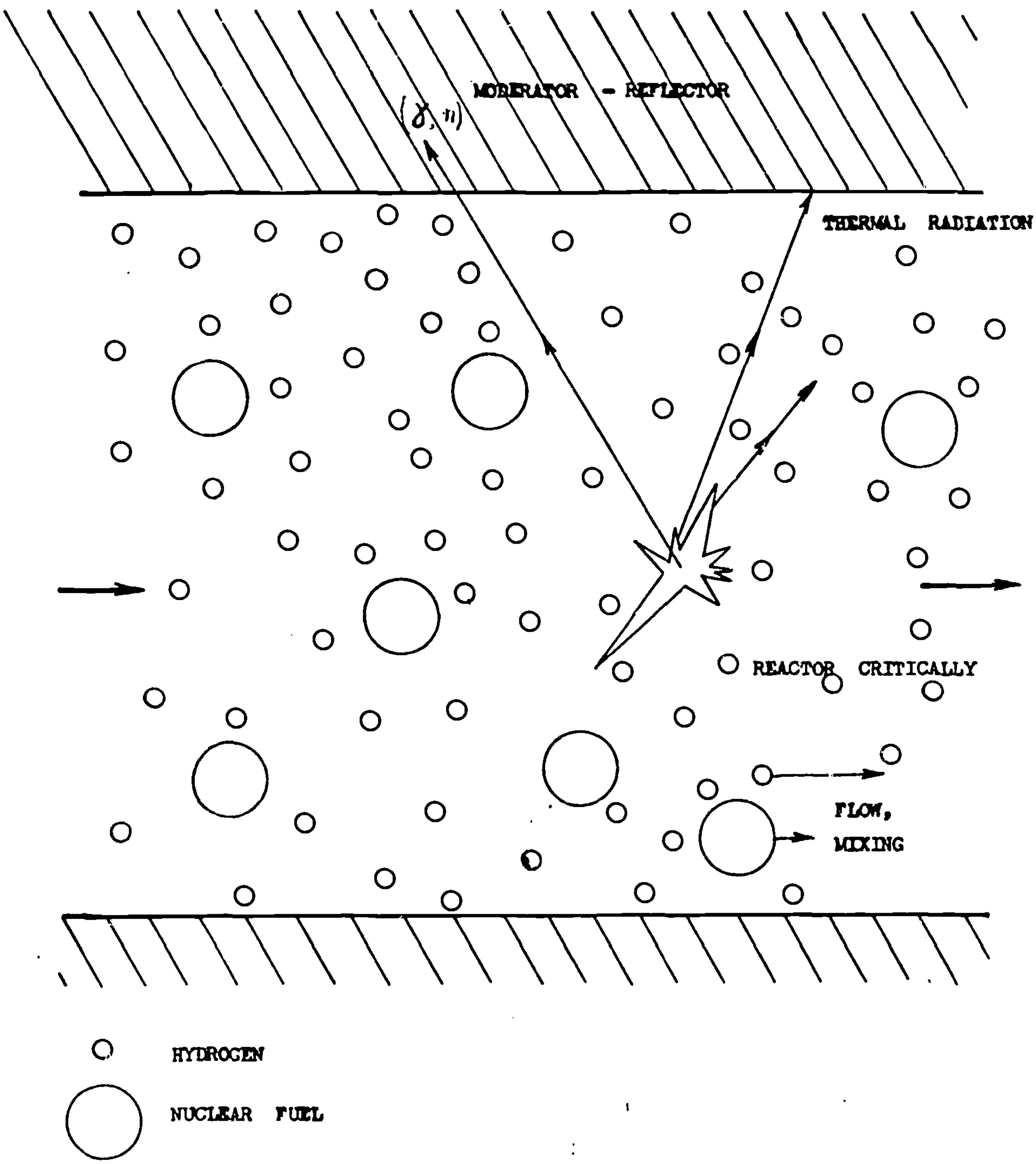


NONSTOP FLYBY PAST VENUS

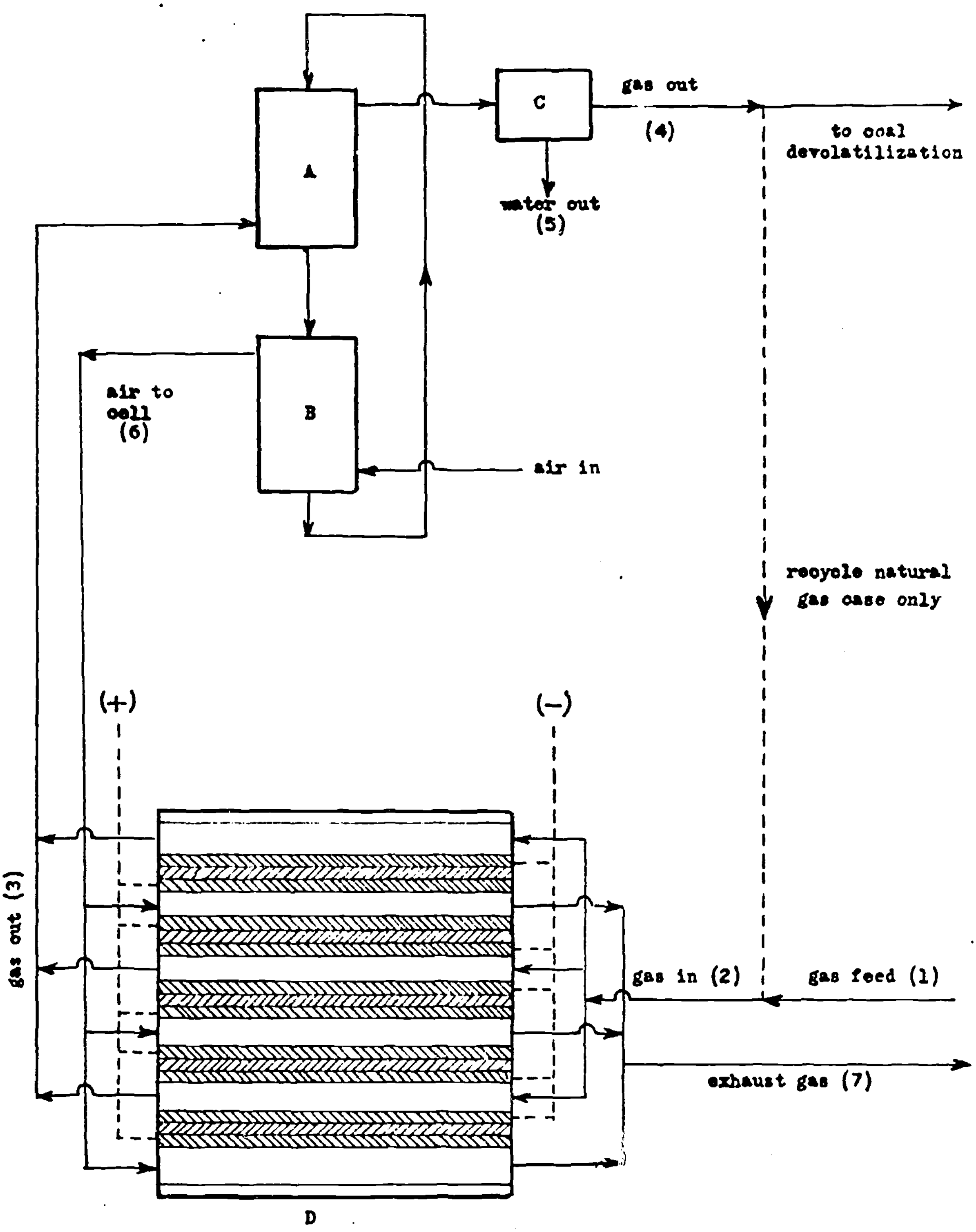


Simulated Flight Schematic

2.11-1



FUNDAMENTAL GASEOUS REACTOR PROCESSES

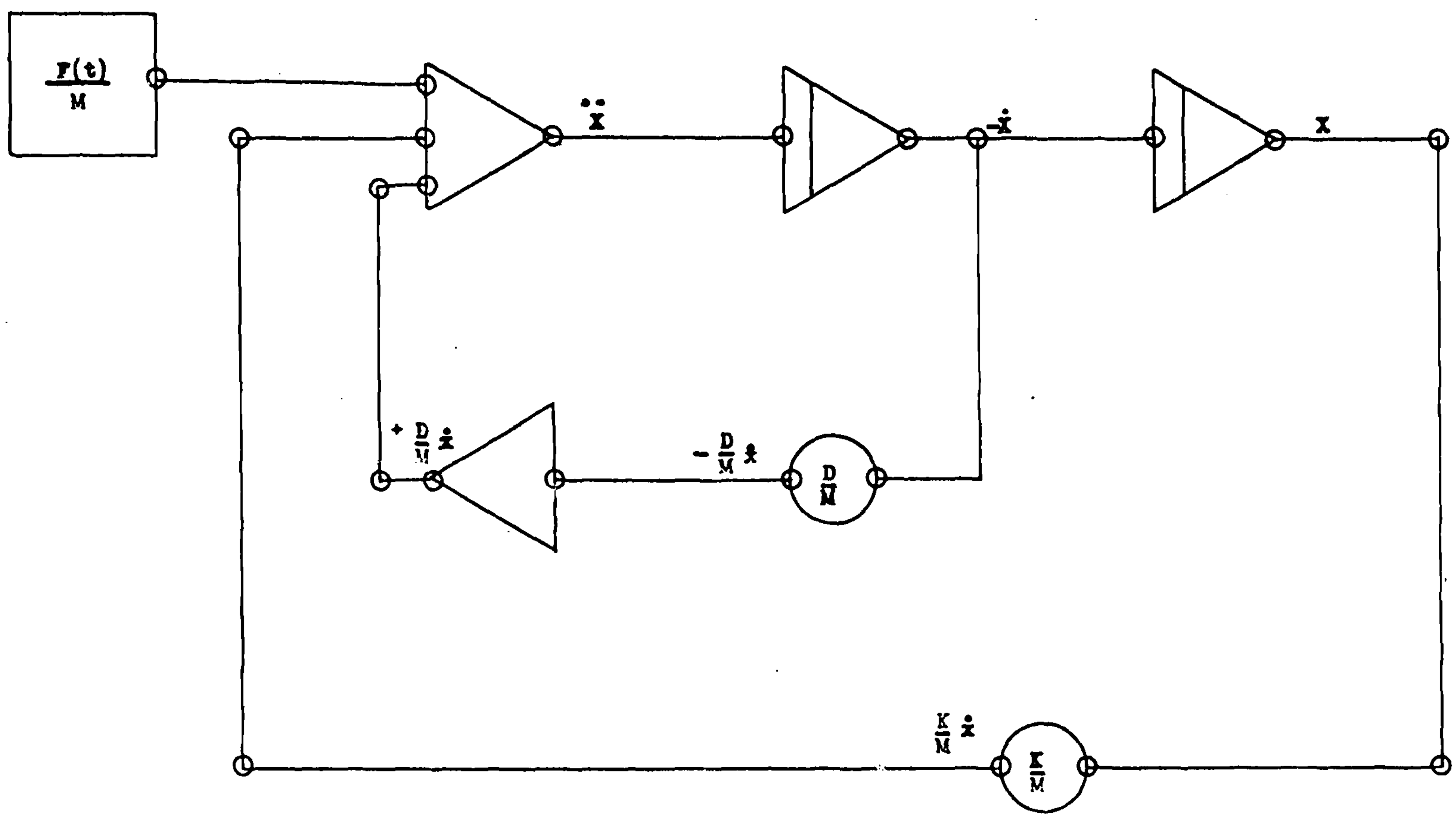


Schematic of integrated fuel cell system

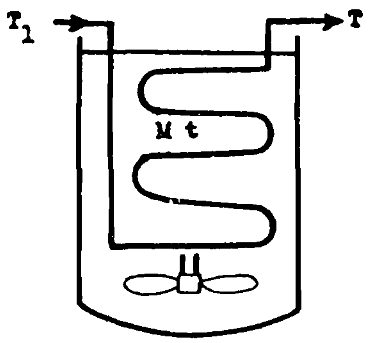
2.12-1

$$M\ddot{x} + D\dot{x} + Kx = F(t)$$

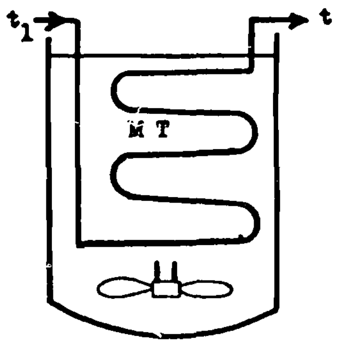
$$\ddot{X} = \frac{F(t)}{M} - \frac{D}{M}\dot{x} - \frac{K}{M}x$$



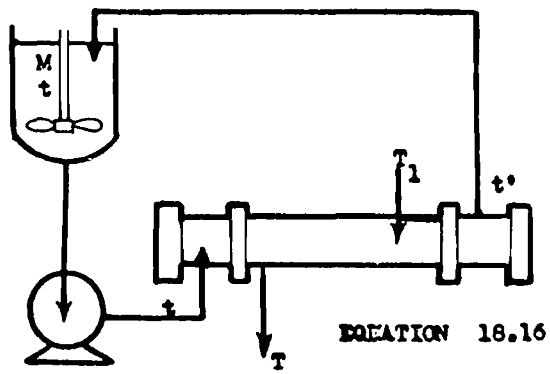
Basic diagram used to begin the solution of air equation



Equation 18.9



Equation 18.11



EQUATION 18.16

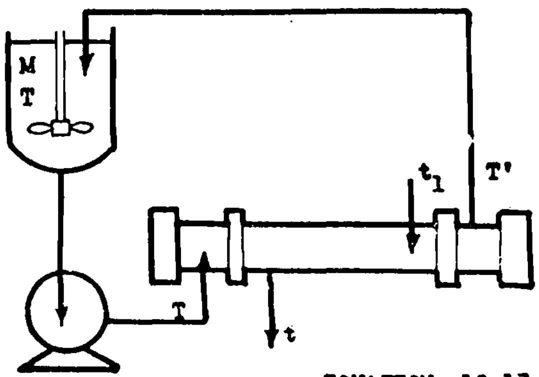
EXPLANATION OF SYMBOLS

EQUATION 18.9 Heating with a jacketed vessel or coil in tank

EQUATION 18.11 Cooling with a jacketed vessel or coil in tank

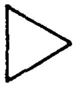
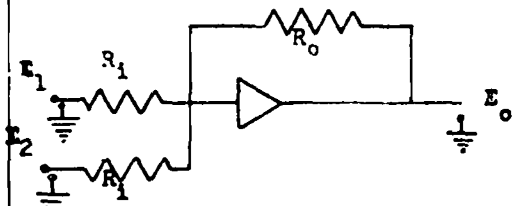
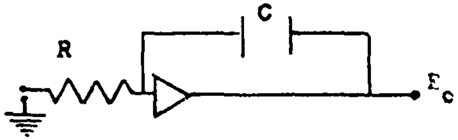
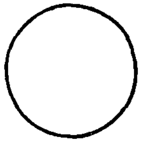
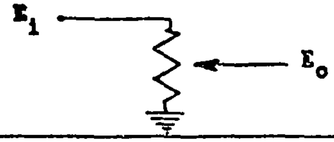
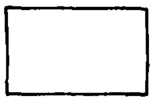
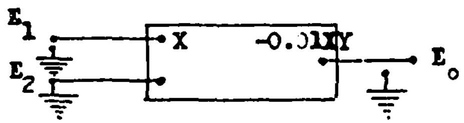
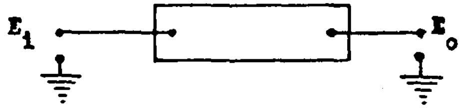
EQUATION 18.16 Heating with an external exchanger

EQUATION 18.17 Cooling with an external exchanger



EQUATION 18.17

Equation nomograph Schematic

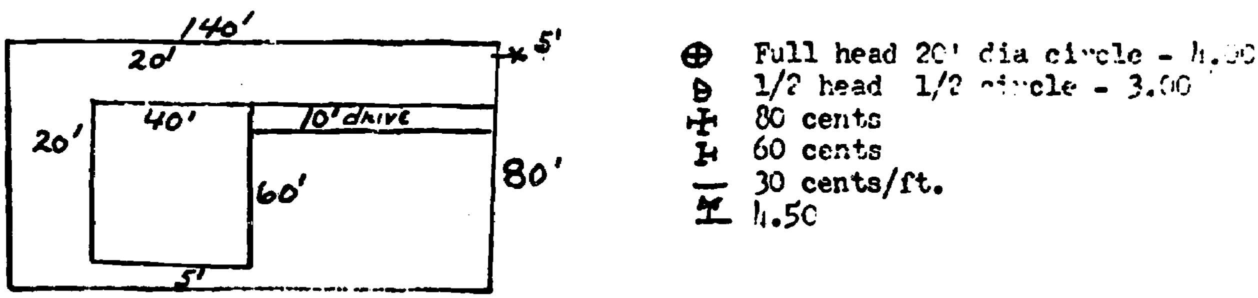
COMPONENT	SYMBOL	CIRCUIT	MATHEMATICAL OPERATION
HIGH GAIN OPERATIONAL AMPLIFIER			
OPERATIONAL AMPLIFIER USED AS A SUMMER AND SIGN CHANGER			$E_o = -\frac{Ro}{R_1}(E_1 + E_2)$
OPERATIONAL AMPLIFIER USED AS AN INTEGRATOR			$E_o = -\frac{1}{RC}\int_c^t E_1 dt$
POTENTIOMETER ATTENUATOR			$E_o = XE_1$ (X 1)
ELECTRONIC MULTIPLIER (2 VARIABLES)			$E_o = -\frac{E_1E_2}{100}$
FUNCTION GENERATOR			$E_o = f(E_1)$

Primary functional components of an analog computer is only the limit of the imagination of man. Any time a simplified layout or picture of a difficult problem, in any field, presents itself, the application of a schematic may make it possible to identify the exact problem and also to suggest alternative solutions.

The procedures suggested are meant to prepare you to think in terms of alternatives, they are not meant to be limiting nor to be all inclusive. To further broaden your insight into uses of schematics here are some problem sets.

2.14 <u>Problems</u>

1. With the following lot layout show a schematic of the lowest cost sprinkler system that fits the lot. Overlaps are permitted. No uncovered areas allowed.



2. Make a schematic of the college registration system. Put suggested improvements on the system.

3. Show a home with 3 outside doors and 4 outside lights. Indicate complete on-off control with minimum switches at each door. 2 circuits only outside.

4. Draw a schematic of a coin changer. 4 coins and slugs.

5. Illustrate a 3-dimensional toilet layout for 3 fixtures in a bathroom on 2 walls min.

6. Make a Table representation of the steps in requisition supplies for a military unit.