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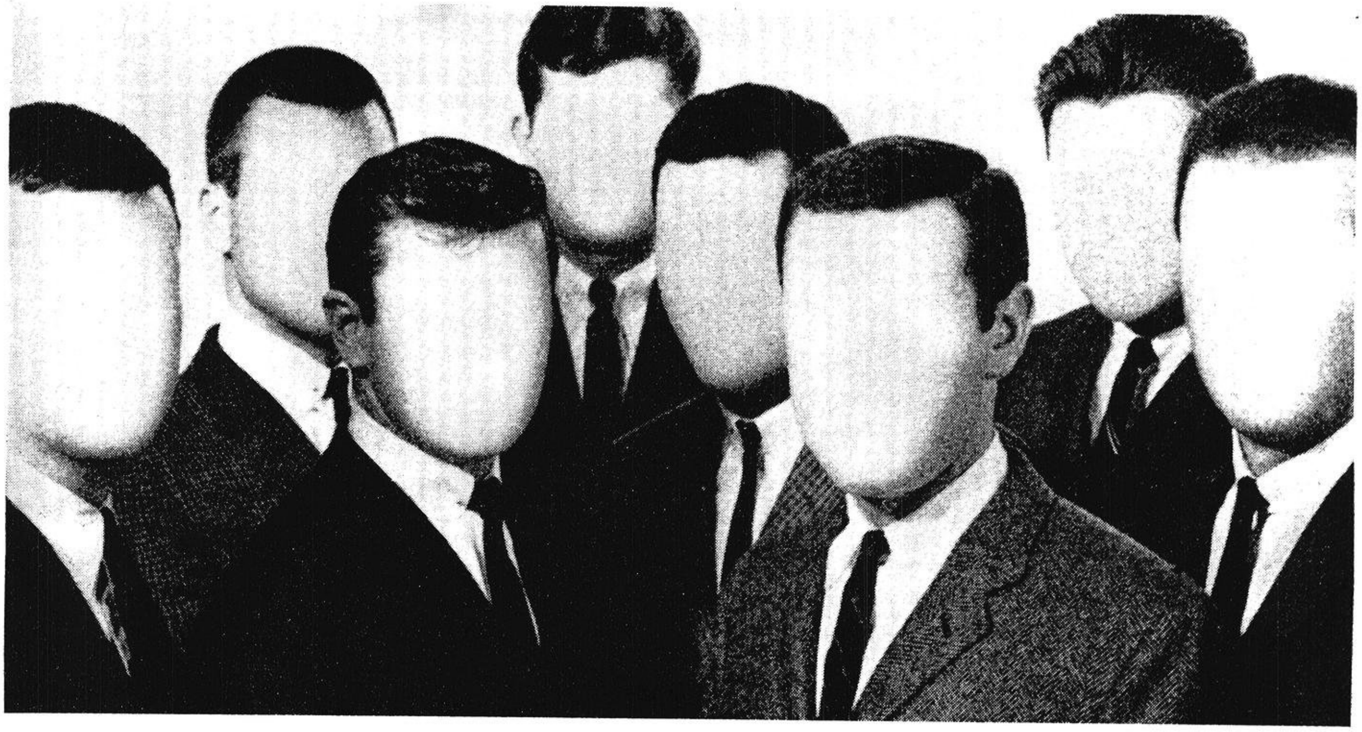
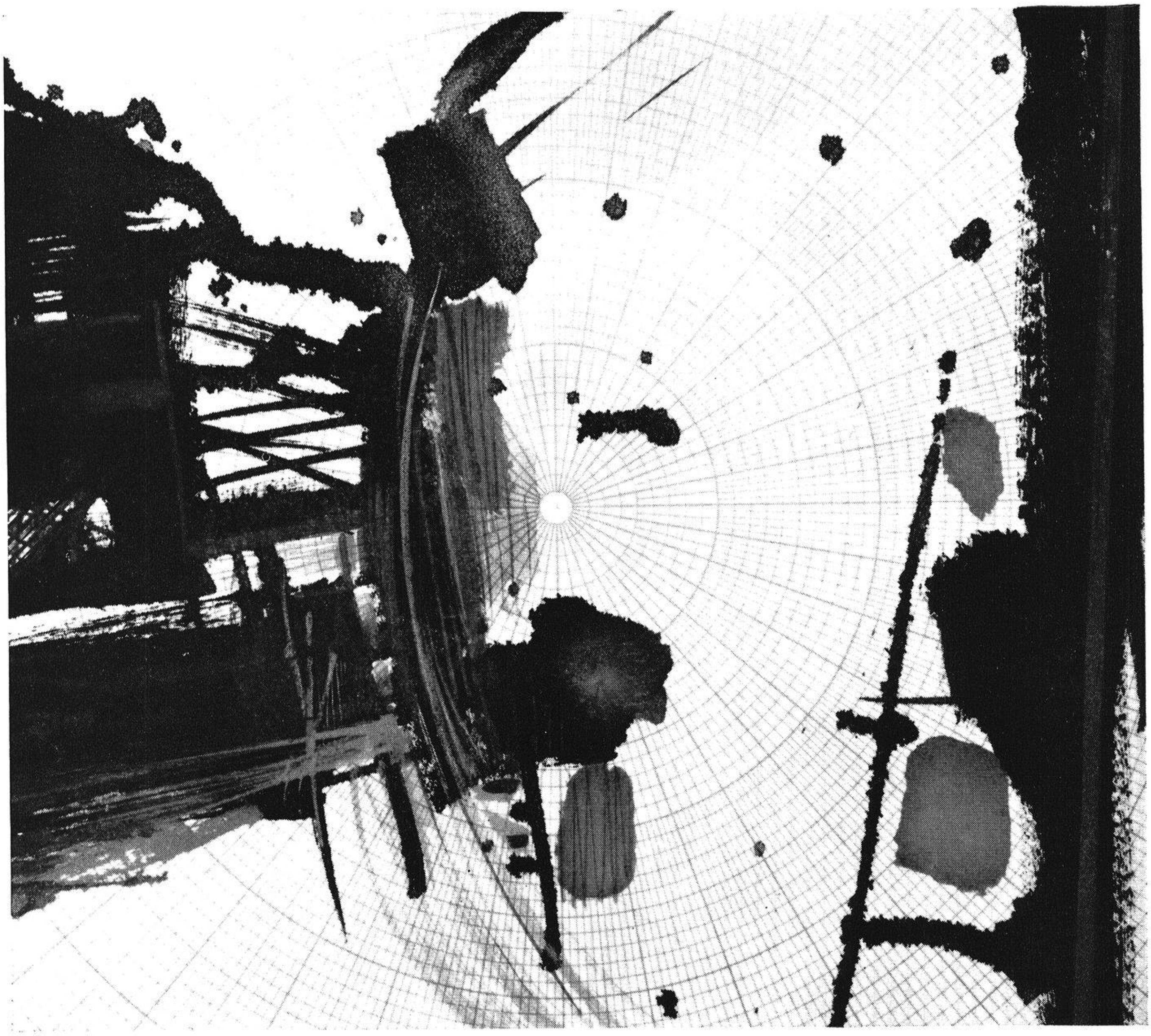
THE WISCONSIN

ENGINEER

MARCH 1964 • 25 CENTS

MEMBER E. C. M. A.





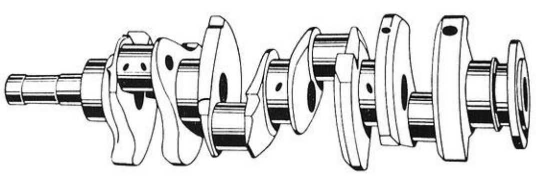
How To Solve Wear Problems With Pearlitic Malleable Castings

A little known but extremely valuable property of pearlitic Malleable iron is its excellent wear resistance. Pearlitic Malleable castings have good natural wear resistance and can be selectively surface hardened to 60 Rockwell C. Any of the common methods of hardening may be used — induction, flame, salt or lead bath, or heat-treating furnaces.

Properties of Three Representative Grades of Pearlitic Malleable Iron

Tensile Strength — P.S.I.	Yield Strength — P.S.I.	Typical Brinell Hardness Range	Selectively Hardenable To: (Rockwell C)
80,000	53,000	197-241	55-60
80,000	60,000	197-255	55-60
100,000	80,000	241-269	55-60

The current trend from steel to pearlitic Malleable castings for automotive crankshafts and connecting rods demonstrates the practicality of pearlitic Malleable for high wear applications.



Here are typical comparisons of the wear resistance of unhardened pearlitic Malleable crankshafts with unhardened steel crankshafts. These figures are based on 50,000 mile proving ground tests in 13 automobiles.

Wear Comparisons

Pearlitic Malleable Crankshafts vs. Steel Crankshafts

	Average Wear Reading — Steel	Average Wear Reading — Pearlitic Malleable
Wear on Journal Diameter —		
Manual Transmission	.0004	.0002
Automatic Transmission	.0003	.0001
Wear on Crankpin Diameters —		
Manual Transmission	.0005	.0001
Automatic Transmission	.0001	.0001

Other critical wear applications for pearlitic Malleable castings include transmission gears, pistons, spring hangers, chain links, rolls and rocker arms.

This pearlitic Malleable transmission gear with induction hardened teeth replaces a through-hardened steel gear. Important advantages of the pearlitic Malleable are reduced distortion during hardening, simpler method of hardening, lower purchase cost and lower machining costs.

Excellent wear resistance, with or without hardening, combined with economy, quality, strength and machinability, place pearlitic Malleable castings at the top of the list of engineering materials for vital parts. Get complete information on how you can improve your products with Malleable and pearlitic Malleable castings from any company that displays this symbol —

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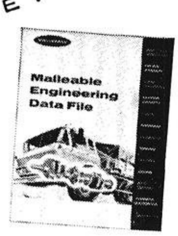
Send for your free copy of this 16 page "Malleable Engineering Data File." You will find it is an excellent reference piece.



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ARTICLES

THE WISCONSIN ENGINEER

The Student Engineer's Magazine Founded in 1896

FEATURES

THIS MONTH'S COVER

This month's cover is a charcoal sketch, drawing your attention to the articles in this issue. The artist is Jim Lawton.

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THE MAPI SYSTEM
For Equipment Investment Analysis

By LLOYD J. PACKER M.E.'65

Lloyd is from Sheboygan, Wis., and is interested in Industrial Engineering. After graduation he plans on getting his M.B.A. from the School of Commerce. His activities include Pi Tau Sigma and ASME.

IT IS important for any business utilizing production equipment to have a reliable system of equipment investment analysis. Correct investment decisions concerning the replacement of production equipment are important because of the large commitment of capital involved and because of the irreversible nature of the investment decision.

The MAPI system is designed to yearly analyze re-equipment projects and determine their profitability.

BACKGROUND OF MAPI

History

The Machinery and Allied Products Institute (MAPI) is a federation of trade associations in the field of industrial equipment. In 1943, the Institute decided to make a formal study of equipment replacement policies and procedures in the United States. To accomplish this task, MAPI set up a special committee on business investment policy.

One of the committee's primary findings was that while management techniques in other areas of business have changed and improved through the years, the techniques of analyzing the replacement of production facilities have not changed considerably for a century. These replacement analysis techniques have been handed down from one generation of managers to the next, and today are "industrial folklore". In order to develop better managerial tools to analyze investment projects, MAPI decided to re-examine the fundamental theory of replacement analysis.

In 1949, the first major step to formulate a logical replacement system was presented by MAPI in the form of a book called *Dynamic Equipment Analysis.* This book was primarily a theoretical dissertation on equipment replacement, but it did include a practicable system for analyzing and appraising replacement projects.

The work by the Institute was at least partially responsible for an increased interest in investment policy by businessmen. In the years 1950 to 1958 there were sufficient ideas accumulated through practical application of the MAPI system to revise the original work and add further developments.

In 1958, *Business Investment Policy* by George Terborgh was published. This book contains the assumptions and instructions of the present MAPI system.

The new MAPI system has several improvements over the original. Briefly, the new system approaches the equipment replacement problem in a broader prospective, it is simpler to understand and apply, and its results can be expressed in more useable ways. The new system is a big step towards the goals of the Institute.

Objectives

Over the years the objectives of MAPI concerning the development of a good investment analysis system have remained basically the same. These objectives were stated in the Foreword of *Dynamic Equip* in the Foreword of *Dynamic Equipment Analysis* (1949):

> "While the significance of this study to industry is thus quite obvious, this is secondary, in our judgment, to its significance to the country at large. A dynamic equipment policy means a dynamic economy. It means a more rapid increase in the standard of living and in national well-being. It means a better competitive position in international trade. It means greater strength and security as a world power. The Institute has no hesitation, therefore, in bespeaking the attention of the disinterested reader."[1]

[1] George Terborgh, *Dynamic Equipment Policy,* McGraw–Hill Publishing Co., Inc. (1949), p. vi.

The work of MAPI in the field of investment analysis will undoubtedly continue in the future. Even while introducing the new MAPI system in 1958, George Terborgh re-emphasized the continuous inquiry should be made into this field of investment analysis when he said:

> "It is still true in general that the analysis and appraisal of investment projects is the most backward area of management."[2]

APPLICATION OF MAPI

Introduction to the MAPI System

All businesses that utilize mechanical equipment to manufacture a saleable product face the following well-known fact: As time goes on, equipment wears out or becomes obsolete and must be replaced.

A problem that arises as a consequence of this fact, is to time the replacement so as to be most profitable to the business. If the old machine is retired too soon, some of its valuable service life will be thrown away. If the old machine is held too long, money will be lost because it is standing in the place of a more profitable replacement. (In this article the term "investment" is restricted to mean the money put into new equipment projects which replace existing production facilities.)

There may be several investment opportunities existing at any given time but not enough capital available to invest in all of them. For example, there may be $50,000 of retained earnings set aside for equipment renewal this year. For this same year, there may be $80,000 worth of new equipment requisitions from the production department. Of this $80,000 equipment requisition, which projects can be undertaken and which cannot?

The investment analysis must provide a way of accurately determining which proposals will be the most profitable, so that the limited capital will be applied to these. This goal of the investment analysis was concisely expressed by Terborgh when he said:

> "This main object of business investment analysis is to help management place the capital funds of the company where they will do the most good. Stated otherwise, it is to rank investment proposals in the order of priority or urgency."[3]

The MAPI system is one of several analytic systems in use today which attempt to accomplish this goal. Two other systems, which are used most frequently in industry, are the "payback" system and the "rate of return" system. We will not go into an evaluation of these other than to say that they are the systems MAPI called "industrial folklore".

The MAPI system is designed to yearly analyze projects and obtain their priority. The system measures the urgency of a new investment project relative to going on without it for one more year; specifically, it derives an after tax return on the net investment in the new project as compared to going on without the project for one more year.

The urgency of each project is found by posing two alternative courses of action: ". . . installing the present project now or installing the then-available project at the end of the year . . . ."[4] This one year testing is used for three principal reasons: (1) management is accustomed to working with this period of time, (2) most data is obtained in the form of annual figures, and (3) it provides an annual critical look at existing facilities to find more profitable replacements.

The MAPI system is essentially a mathematical model which contains a formalized allowance for the superiority of future new projects to the present one. This formalized allowance for the superiority of future projects is accomplished with the MAPI formula, which will not be explored here.

The MAPI formula is only a part of the MAPI system. The purpose of the formula is to minimize the error which arises from the long range forecasts an analyst is required to make when using the MAPI system. As described in the MAPI manual, the formula is ". . . an elaborate structure of assumptions and projections designed to serve in lieu of certain long range forecasts by the analyst."[5]

The charts yield in a short time what might otherwise take hours to compute. Thus it is the MAPI charts, rather than the MAPI formula, which must be understood in order to use the MAPI system.

Although a thorough understanding of the theory of the MAPI system is not essential to the practical application of the system, the theory should be studied and understood if the system is to be used extensively for investment analysis. The MAPI system incorporates many assumptions which without clear understanding, could lead to erroneous results.

Part II of Business Investment Analysis by George Terborgh is suggested reading for a thorough understanding of the MAPI theory.

While the practical solution of the MAPI system can be obtained without a thorough knowledge of the theory, it is, by MAPI's own words, ". . . impossible to get satisfactory results without a careful scrutiny of the instructions."[6]

The MAPI system is addressed to two questions: "The first of these is the current annual (next year) operating advantage from the project. By how much will it improve the operating results of the business? The second question is the investment merit of the project in the light of the answer to the first question. Given the estimated improvement in operating results, what is the indicated rate of return on the project investment?"[7]

Following this format, the procedures of this system's investment analysis is broken down into two stages: The first stage is to gather data and determine the operational benefits of the project. This is the most difficult part of the analysis and usually requires more than 90 per cent of the total time needed to complete the analysis. The second stage is to calculate the rate of return. This is done quickly with the MAPI system once the operational benefits have been found. The first stage is very similar for all analytic systems, including MAPI. In this respect MAPI is like all the other systems. It is in the second stage that the MAPI formula comes into play thus making the MAPI system different from the others.

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[2] George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute (1958), p. 4.

[3] Ibid., p. 39.

[4] Ibid., p. 59.

[5] Ibid., p. 58.

[6] Ibid., p. 81.

[7] Ibid.

PROJECT NO. SHEET 1

SUMMARY OF ANALYSIS

(See Accompanying Work Sheet for Detail)

I. REQUIRED INVESTMENT

1	INSTALLED COST OF PROJECT	$	1
2	DISPOSAL VALUE OF ASSETS TO BE RETIRED BY PROJECT	$	2
3	CAPITAL ADDITIONS REQUIRED IN ABENCE OF PROJECT	$	3
4	INVESTMENT RELEASED OR AVOIDED BY PROJECT (2+3)	$	4
5	NET INVESTMENT REQUIRED (1−4)	$	5

II. NEXT-YEAR ADVANTAGE FROM PROJECT

A. OPERATING ADVANTAGE

(Use First Year of Project Operation)*

6	ASSUMED OPERATING RATE OF PROJECT (Hours Per Year)			6
	EFFECT OF PROJECT ON REVENUE	Increase	Decrease	
7	FROM CHANGE IN QUALITY OF PRODUCTS	$	$	7
8	FROM CHANGE IN VOLUME OF OUTPUT			8
9	TOTAL	$	A$ B	9
	EFFECT OF PROJECT ON OPERATING COSTS			
10	DIRECT LABOR	$	$	10
11	INDIRECT LABOR			11
12	FRINGE BENEFITS			12
13	MAINTENANCE			13
14	TOOLING			14
15	SUPPLIES			15
16	SCRAP AND REWORK			16
17	DOWN TIME			17
18	POWER			18
19	FLOOR SPACE			19
20	PROPERTY TAXES AND INSURANCE			20
21	SUBCONTRACTING			21
22	INVENTORY			22
23	SAFETY			23
24	FLEXIBILITY			24
25	OTHER			25
26	TOTAL	$	A$ B	26

27	NET INCREASE IN REVENUE (9A−9B)	$	27
28	NET DECREASE IN OPERATING COST (26B−26A)	$	28
29	NEXT-YEAR OPERATING ADVANTAGE (27 28)	$	29

B. NON-OPERATING ADVANTAGE

(Use Only If There Is an Entry in Line 4)

30	NEXT-YEAR CAPITAL CONSUMPTION AVOIDED BY PROJECT:		30
	A DECLINE OF DISPOSAL VALUE DURING THE YEAR	$	A
	B NEXT-YEAR ALLOCATION OF CAPITAL ADDITIONS	$	B
	TOTAL	$	

C. TOTAL ADVANTAGE

31	TOTAL NEXT-YEAR ADVANTAGE FROM PROJECT (29+30)	$	31

* For projects with a significant break-in period, use performance after break-in.

Figure 1.—The MAPI Form. (George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute. 1958. p. 103–4.)

The data necessary to use the MAPI system should be obtained from all sources available to the analyst. In general, this work is made easier if one has available a continuing inventory of investment opportunities, capital budgeting data which sets limits and plans, and accurate operational cost and revenue records.

Because of the diversity of the work involved in getting data for different projects in different companies, one must try to develop ones own detailed work sheets which produce the data going into the MAPI form. The two work sheets which make up the MAPI form are then merely a summary or cap sheets of the many detailed work sheets producing the data. The MAPI form serves as a checklist of factors to be considered in the analysis. The complete MAPI form is shown in Figure 1.

Determining the Next Year Operating Advantage

After the date for the analysis has been gathered, the next year operating advantage is ready to be found. This is done in the MAPI form or sheet 1, Section II, lines 6 to 29.

What is wanted in calcuating the operating advantage in Section II is a complete coverage of a costs and savings differences resulting from the project.

Included in the revenue effects of the project should be the effect of sales expansion or revenue increases as a result of the project. This effect is often not included because of the concentration on the cost reductions of the project.

In analyzing the effect of the new project on the costs of the business (lines 10 to 26) it is important to include the indirect as well as the direct effects on the costs. The analyst must be careful in evaluating the indirect effects to make sure that if he is assuming the new project frees some other existing facilities that they will not now be idle, but that they actually have another use.

Because of the variabilities of the new projects, the list of items in the operating advantage portion of the form (lines 6 to 26) must not be considered the last word. The list merely serves as a foundation upon which to add all pertinent costs and revenue differences from the project. Remember, this section is an attempt to get ". . . a good estimate of the total impact of the project on the operations of the business."[8]

Upon arriving at the answer to line 29, you will have completed stage 1 and have the next year operating advantage from the project.

Determining the Rate of Return

Up to this point the MAPI system has not appreciably differed from other investment analysis systems. We are now ready to start stage two of the analysis: calculation of the rate of return. From here on the MAPI system is unique in its approach to investment analysis. The remaining instructions deal with completing the rest of the MAPI form and how to use the MAPI charts.

We shall first examine (in order) the rest of the items which make up the MAPI form.

Installed cost of project. Includes the delivered cost of the new facility plus installation expenses. Also included where applicable, are costs incurred for converting or moving any existing equipment (already owned) to be assigned to the new project.

2. Disposal value of assets to be retired by project. The estimated net amount released through the disposal of the retired facility is shown. There may be cash release through a sale either as second hand equipment or as scrap.

3. Capital additions required in absence of project. This includes costs of rebuilding or renovating existing facilities which will be necessary if the new project is not undertaken. Costs of down time during this rebuilding should also be included if substantial. This is an investment avoided by the project.

5. Net investment required. This value is usually positive. If it is negative, there will be more money released through the disposals than the acquisitions. This would be a very desirable situation and would indicate a high degree of urgency.

6. Decline of disposal value during the year. This is the pre-tax estimation of how much less you will be able to get from the disposal value (2) if one waits until next year.

7. Next-year allocation of capital additions. The capital additions to existing facilities (3) will usually prolong the service life of the facility. To get the next year allocations of this, divide the capital additions of 3 by the number of years it is estimated they will add to the service life.

8. Total next year advantage after income tax. Deduct the income tax from the amount shown as the next year advantage from the project. For example, if the next year advantage from the project is $2,-000 and the applicable tax rate is 50 per cent, the value shown here is $1,000.

9. Amount available for return on investment. Because of the income tax effects this value is the amount available for return on investment after tax. This is the dollar amount of the next year gain from the project as compared with going on without it for the year.

10. MAPI Urgency Rating. This is ". . . the after-tax return that will be made next year on the net investment (given the data, estimates, stipulations, and projections of the analysis) as compared with going on without the project for the year. It is a measure of the current urgency of the project. By the same token, it is the factor for ranking the project with others in order of urgency."[10]

The above checklist (while not covering every variability of all possible projects) is meant to be an extensive list to cover a wide range of types of equipment investment projects. Thus, on any one project analysis, it is very likely that there will not be a value to fill in for every item listed. This will be illustrated in the sample program which follows. Estimates of values should be entered for the items only if relevant to the particular analysis.

We can now turn our attention to the final step in using the MAPI form—the MAPI charts. MAPI Chart No. 1 is shown in figure 2. MAPI Chart No.'s 2 and 3 are similar in appearance and method of use. Note that there are

[8] Ibid., p. 101.

[9] Ibid., p. 158.

[10] Ibid., p. 109.

III. COMPUTATION OF MAPI URGENCY RATING

32 TOTAL NEXT- YEAR ADVANTAGE AFTER INCOME TAX (31 – TAX) $______

33 MAPI CHART ALLOWANCE FOR PROJECT (Total of Column F, Below) $______ *

(Enter Depreciable Assets Only)

Item or Group	Installed Cost of Item or Group A	Estimated Service Life (Years) B	Estimated Terminal Salvage (Percent of Cost) C	MAPI Chart Number D	Chart Percentage E	Chart Percentage × Cost (E × A) F
	$					$
					TOTAL	$

34 AMOUNT AVAILABLE FOR RETURN ON INVESTMENT (32 – 33) $______

34 **MAPI URGENCY RATING** (34 ÷ 5) . 100 %______

* Since the chart allowance does not cover future capital additions to project assets, add an annual proration of such additions, if any, to the figure in Line 33.

two families of curves. The heavy lines are for sum of the year's digits or double rate declining balance depreciation methods, and the light lines are for straight line depreciation. Note also that the insert of the chart contains the sequence of steps for its use. These are easy to follow since all the information needed is supplied by the MAPI form. Therefore, no further explanation of the sequence should be necessary.

Since, as mentioned earlier, the charts are dependent on the formula, the eight stipulations required by the formula will be stated:

"1. The projection pattern
2. The estimated service life
3. The estimated terminal salvage, if any (as a percentage of the cost of the asset)
4. The assumed income tax rate
5. The depreciation method used for tax purposes
6. The debt ratio (ratio of debt to total investment)
7. The interest rate on borrowed capital
8. The after-tax return on equity capital"[11]

Of the eight stipulations listed above, the first five must be selected by the analyst and are different for each project. The last three are prescribed by MAPI and are the same for all projects.

The last three stipulations are used in making up the charts and are not specified by the analyst. They must, however, be known and kept in mind when using the charts. This is to avoid blind acceptance of assumptions which might not be applicable to the particular case. The three stipulations are:

1. The debt ratio (ratio of debt to total investment) is 25 per cent.
2. The interest rate on borrowed capital is 3 per cent.
3. The after-tax return on equity capital is 10 per cent.

These three stipulations are intended to be an average or mid-range value representative of the capitalization rates for business incomes. The assumptions do make possible a reasonable figure for the capitalization rate, and the result of the investment formula is not very sensitive to them. This means that in practice, reasonable differences from the assumed rates and debt ratio have a small effect on the results of the formula.

[11] Ibid., p. 114.

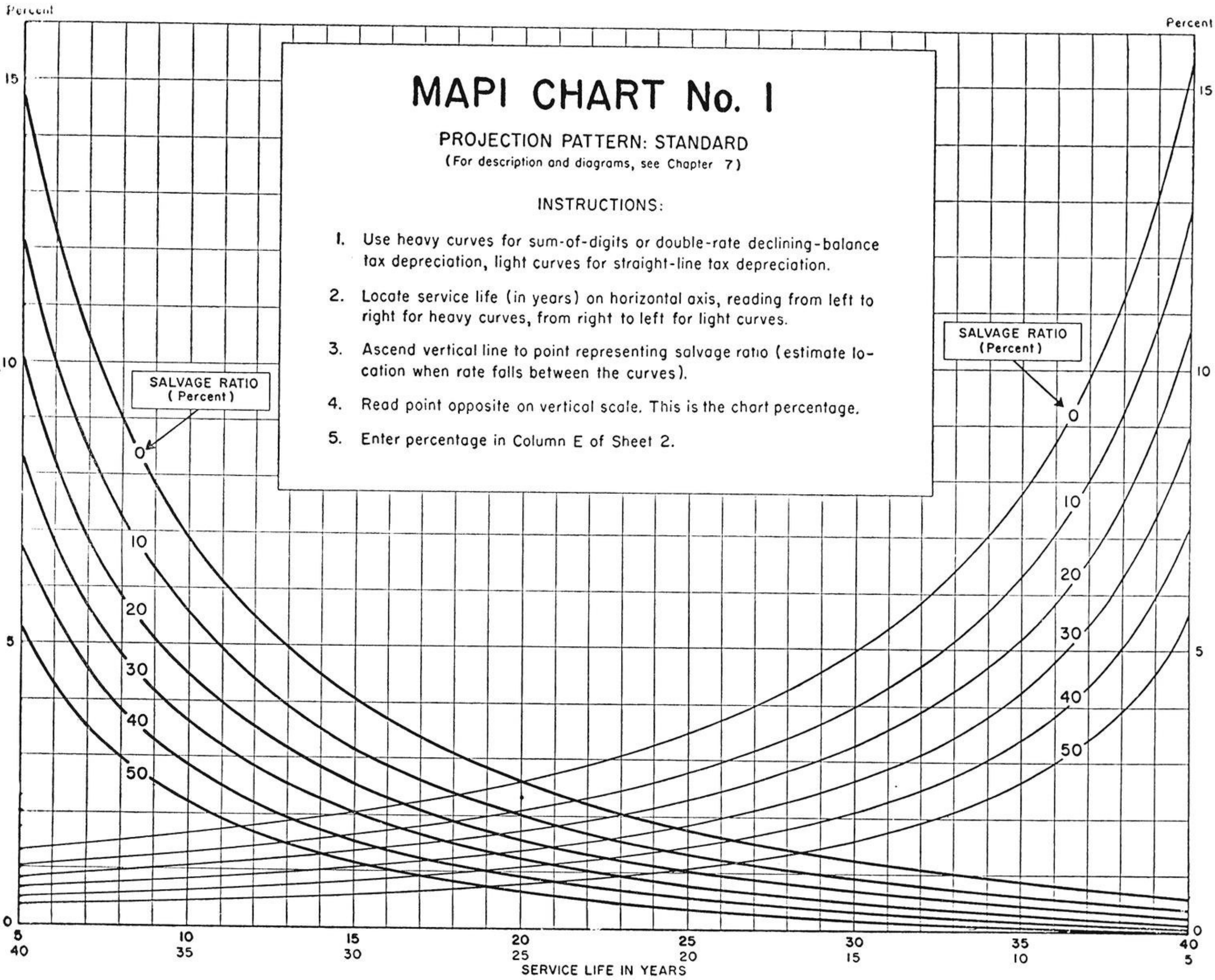

Figure 2.—MAPI Chart No. 1. (George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute, 1958, p. 121.)

There are still five stipulations left to the analyst. They are important inputs to the MAPI analysis and should be specified according to the conditions of each particular project. Here is how these stipulations are found and applied to the form:

1. *The projection pattern.* The decline in earning power of an asset is due to the combined accumulation of obsolescence and deterioration. The analyst estimates the pattern this decline in earning is going to follow. If the earnings decrease at a constant rate throughout the service life, the analyst uses Chart No. 1. If the decline in earnings is slow at first but speeds up with time, the analyst chooses Chart No. 2. If the decline is rapid at first but slows up with time, he chooses Chart No. 3. The chart number that the analyst has chosen is entered in the MAPI form on sheet 2, column D of the table.

2. *The estimated service life.* This is the period of time you plan to get useful production out of the facility. Note this is usually much shorter than its physical life. The charts are set up for any service life between 5 and 40 years. In estimating the service life, try to use an exact year figure. Don't shorten the estimated life to allow for obsolescence or a "safety factor" because to do so will inject error. The service life of the old equipment probably is not the same as that of the new, so to blindly use this figure would also cause error. The estimated service life is entered in column B of the table on sheet 2.

3. *The estimated terminal salvage.* This value is arrived at by estimating what you will be able to get for the facility after its service life is over. This may be either what it can be sold for as scrap or what can be gotten from a purchaser who plans further use for the facility. The value for terminal salvage is entered as a percentage of the initial cost of the item. For example, if a piece of equipment costs \$10,000 new and after its service life it can be resold for \$1,000, the value to be entered would be

$$\frac{\$\ 1000}{\$10000} \times 100\% = 10\%.$$

The charts are set up for any terminal salvage ratio between 0 and 50%. This range was chosen because it is very rare that a replacement analysis would be made on an asset which had a salvage value greater than 50 per cent. The terminal salvage value is entered in column C of the table on sheet 2.

4. The assumed income-tax rate. "It is our experience that most corporations assume a future income-tax rate of 50 per cent in making investment analyses."[12] Because of this finding by MAPI, the charts are calibrated to a 50 per cent tax rate. However, "tax adjustment factors" have been provided to permit the analyst to use any applicable tax rate between 0 and 100%. (These adjustment factors will be discussed later).

5. The tax depreciation method. The charts are designed for the following three tax depreciation methods: straight line, sum of the year's digits, and double rate declining balance. It is suggested that if you don't use one of these methods to depreciate the project, take the chart method that most nearly resembles it.

As mentioned in (4) above, the charts are calibrated for a 50 per cent tax rate. There is a table of adjustment factors for each chart which enables the analyst to use the three charts for any tax rate. Figure 4 shows the tax adjustment factors for MAPI Chart No. 1.

MAPI defines the adjustment factor as follows: "This factor is the correction (expressed as a percentage of the cost of the asset) for a none-point deviation of the assumed tax rate from the 50 per cent rate to which the chart is calibrated."[13]

The procedure to determine the correct chart is as follows: Follow the chart instructions in the insert until you have completed step 4 and have obtained the chart percentage. Thus far you have assumed a 50 per cent tax rate. Now turning to the Tax Adjustment Factors Table, find the factor which applies to the estimated service life, type of tax depreciation, and terminal salvage value for your particular project. Multiply this factor times the number of points your tax rate deviates from 50 per cent (30 per cent or 70 per cent would both deviate from 50 per cent by 20 points). The product of this multiplication is than added to or subtracted from the chart percentage reading which was determined above by step 4. If the deviation is positive (tax rate greater than 50 per cent) subtract the correction from the chart percentage; if the deviation is negative (tax rate less than 50 per cent)

[12] Ibid., p. 118.

[13] Ibid., p. 126.

TAX ADJUSTMENT FACTORS FOR MAPI CHART NO. 1

(Multiply the appropriate factor by the number of points by which the assumed tax rate deviates from 50 percent. Subtract the product from the reading if the deviation is positive, add if it is negative.)

Service Life (Years)	Tax Depreciation: Sum-of-Digits or Double-Rate Declining-Balance Terminal Salvage Ratio (Percent)						Tax Depreciation: Straight-Line Terminal Salvage Ratio (Percent)					
	0	10	20	30	40	50	0	10	20	30	40	50
5	.3394	.2840	.2412	.2026	.1678	.1360	.3234	.2696	.2284	.1914	.1582	.1280
6	.2960	.2445	.2057	.1738	.1442	.1181	.2788	.2318	.1945	.1608	.1348	.1095
7	.2560	.2138	.1810	.1522	.1264	.1026	.2386	.1980	.1670	.1400	.1158	.0938
8	.2275	.1928	.1603	.1372	.1124	.0920	.2116	.1740	.1497	.1255	.1027	.0823
9	.2063	.1732	.1458	.1240	.1022	.0837	.1883	.1546	.1330	.1115	.0918	.0735
10	.1878	.1570	.1334	.1128	.0942	.0768	.1694	.1404	.1186	.0998	.0830	.0676
11	.1732	.1455	.1235	.1050	.0877	.0718	.1542	.1280	.1086	.0897	.0760	.0623
12	.1605	.1352	.1145	.0975	.0818	.0670	.1416	.1175	.0998	.0825	.0700	.0578
13	.1491	.1263	.1068	.0912	.0767	.0631	.1307	.1085	.0920	.0770	.0652	.0538
14	.1398	.1180	.1004	.0856	.0722	.0597	.1215	.1006	.0853	.0718	.0608	.0502
15	.1312	.1106	.0946	.0806	.0680	.0564	.1128	.0940	.0798	.0678	.0570	.0472
16	.1242	.1048	.0895	.0767	.0646	.0538	.1060	.0884	.0747	.0639	.0536	.0443
17	.1175	.0998	.0854	.0732	.0616	.0514	.0996	.0830	.0706	.0601	.0508	.0420
18	.1110	.0950	.0815	.0698	.0589	.0492	.0938	.0784	.0668	.0568	.0482	.0400
19	.1061	.0906	.0778	.0668	.0564	.0472	.0882	.0742	.0633	.0538	.0459	.0382
20	.1014	.0864	.0746	.0640	.0546	.0455	.0834	.0704	.0602	.0516	.0438	.0366
21	.0969	.0828	.0719	.0614	.0523	.0440	.0792	.0670	.0574	.0495	.0419	.0350
22	.0927	.0794	.0693	.0591	.0505	.0426	.0754	.0640	.0550	.0475	.0403	.0336
23	.0892	.0763	.0668	.0572	.0490	.0413	.0720	.0612	.0529	.0456	.0388	.0323
24	.0863	.0735	.0645	.0555	.0476	.0400	.0690	.0586	.0506	.0438	.0374	.0311
25	.0836	.0718	.0624	.0540	.0462	.0388	.0664	.0562	.0486	.0420	.0360	.0304
30	.0712	.0607	.0537	.0468	.0404	.0344	.0550	.0472	.0407	.0358	.0308	.0262
35	.0622	.0544	.0478	.0420	.0364	.0312	.0468	.0404	.0354	.0312	.0272	.0234
40	.0550	.0490	.0421	.0375	.0330	.0287	.0408	.0358	.0309	.0278	.0245	.0214

Figure 3.—The Tax Adjustment Factors for MAPI Chart No. 1 (George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute. 1958. p. 120.)

AUTOMATIC SCREW MACHINE

"This is a simple case of the replacement of a machine with a newer updated model. It will be noted that the savings result from reductions in unit hours, spoilage, maintenance, and down time.

The Project

A complete overhaul is required for a 39-year-old screw machine. The equipment analyst recommends the purchase of a newly designed automatic screw machine with a vertical slide and feeding arrangement as a better alternative. The installed cost of the project will be $16,705. The purchase of the equipment will avoid an investment of $4,220 in a complete overhaul of the present equipment, which is prorated over 10 years. In addition, it is estimated that the disposal value of the present equipment is $300.

Analysis of Operating Advantage

Greater speeds can be made on the new equipment and jobs can be tooled up to take advantage of these new speeds. Based on a check of 11 jobs, the analyst estimates an average gain of 21 percent. Figured on an 80-hour week, this will result in a direct labor saving of 840 hours a year at $2.50 an hour, or $2,100. Savings in fringe benefits will be $336. In addition, the following costs are expected to decrease:

Scrap and rework	$ 600
Maintenance	1,055
Down time	525

The proposed equipment is capable of greater output than the machine it is replacing. At this time, however, work is not available for the new equipment beyond the 3,300 hours indicated as the operating rate. Nevertheless a value of $400 is assigned to the greater flexibility in shop operations made possible by the additional capacity. Property taxes and insurance will increase by $170.

Stipulations

Project operating rate	3,300 hours
Projection pattern	Variant B
Service life	18
Terminal salvage ratio	5 percent
Tax depreciation method	Sum-of-digits
Tax rate	50 percent

Figure 4.—Sample Problem. (George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute. 1958. p. 158–60.)

add the correction to the chart percentage in column E of sheet 2.

One last word on the tax adjustment correction. If the project's tax rate falls within the range of 45 to 55 per cent, the adjustment can be ignored with little error.

The instructions for the application of the MAPI system have now been completed. A sample problem will be presented to demonstrate how the entire MAPI form is used to solve an investment problem. The problem concerns the replacement of a screw machine. This is the same problem we examined earlier to find the next-year operating advantage. Now we will look at the whole problem and use the MAPI system to obtain the MAPI urgency rating.

In *Business Investment Policy* the author of the MAPI system, George Terborgh, makes the following statement:

"Analytical systems and formulas, whatever their merits, can never be more than an aid to judgement. This is true of our own as of any other.

"What we claim for the MAPI system, essentially, is this. It is rationally contrived to carry out a clearly stated purpose: the ranking projects in the order of urgency. It rests on simplifying assumptions that are also clearly stated. It can be used therefore with full knowledge not only of what is aimed at, but of what is assumed as to the future. Knowing what is assumed, you can interpret and qualify the results accordingly. You can proceed deliberately, and with your eyes open, from a recognized point of departure. We submit that this is better, on any count, than floundering around in the dark."[14]

[14] Ibid., p. 210.

PROJECT NO. 2 SHEET 1

SUMMARY OF ANALYSES

(See Accompanying Work Sheets For Detail)

I. REQUIRED INVESTMENT

1	INSTALLED COST OF PROJECT	$ 16,705	1
2	DISPOSAL VALUE OF ASSETS TO BE RETIRED BY PROJECT	$ 300	2
3	CAPITAL ADDITIONS REQUIRED IN ABSENCE OF PROJECT	$ 4,220	3
4	INVESTMENT RELEASED OR AVOIDED BY PROJECT (2+3)	$ 4,520	4
5	NET INVESTMENT REQUIRED (1−4)	$ 12,185	5

II. NEXT-YEAR ADVANTAGE FROM PROJECT

A. OPERATING ADVANTAGE

(Use First Year of Project Operation)*

		Increase	Decrease	
6	ASSUMED OPERATING RATE OF PROJECT (Hours Per Year)		3,300	6
	EFFECT OF PROJECT ON REVENUE			
7	FROM CHANGE IN QUALITY OF PRODUCTS	$	$	7
8	FROM CHANGE IN VOLUME OF OUTPUT			8
9	TOTAL	$ A	$ B	9
	EFFECT OF PROJECT ON OPERATING COSTS			
10	DIRECT LABOR	$	$ 2,100	10
11	INDIRECT LABOR			11
12	FRINGE BENEFITS		336	12
13	MAINTENANCE		1,055	13
14	TOOLING			14
15	SUPPLIES			15
16	SCRAP AND REWORK		600	16
17	DOWN TIME		525	17
18	POWER			18
19	FLOOR SPACE			19
20	PROPERTY TAXES AND INSURANCE	170		20
21	SUBCONTRACTING			21
22	INVENTORY			22
23	SAFETY			23
24	FLEXIBILITY		400	24
25	OTHER			25
26	TOTAL	$ 170	$ 5,016 B	26

27	NET INCREASE IN REVENUE (9A−9B)	$	27
28	NET DECREASE IN OPERATING COST (28B−26A)	$ 4,846	28
29	NEXT-YEAR OPERATING ADVANTAGE (27+28)	$ 4,846	29

B. NON-OPERATING ADVANTAGE

(Use Only If There Is an Entry in Line 4)

30	NEXT-YEAR CAPITAL CONSUMPTION AVOIDED BY PROJECT:		30
	A DECLINE OF DISPOSAL VALUE DURING THE YEAR	$	A
	B NEXT-YEAR ALLOCATION OF CAPITAL ADDITIONS	$ 422	B
	TOTAL	$ 422	

C. TOTAL ADVANTAGE

31	TOTAL NEXT-YEAR ADVANTAGE FROM PROJECT (29+30)	$ 5,268	31

* For project with a significant break-in period, use performance after break-in.
George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute (1958) p. 159.

III. COMPUTATION OF MAPI URGENCY RATING

32 TOTAL NEXT-YEAR ADVANTAGE AFTER INCOME TAX (31 − TAX) $ 2,634

33 MAPI CHART ALLOWANCE FOR PROJECT (Total of Column F, Below) $ 785 *

(Enter Depreciable Assets Only)

Item or Group	Installed Cost of Item or Group A	Estimated Service Life (Years) B	Estimated Terminal Salvage (Percent of Cost) C	MAPI Chart Number D	Chart Percentage E	Chart Percentage × Cost (E × A) F
Automatic Screw Machine	$ 16,705	18	5	3	4.7	$ 785
					TOTAL	$ 785

34 AMOUNT AVAILABLE FOR RETURN ON INVESTMENT (32 − 33) $ 1,849

35 **MAPI URGENCY RATING** (34 ÷ 5) . 100 % 15

* Since the chart allowance does not cover future capital additions to project assets, add an annual proration of such additions, if any, to the figure in Line 33.

George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute (1958), p. 160.

What Terborgh wants to point out is that the MAPI system is a better system than the traditional "payback" and "rate of return" systems. And actually, a study of the theory behind the MAPI system indicates that it does eliminate many of the false assumptions and axioms upon which the traditional systems are based. However, not all engineering economists feel that the MAPI system is a very spectacular improvement of the traditional systems.

There are some engineering economists who feel this claimed "sudden burst of light,, from the MAPI system is unwarranted. In a critical discussion of the system H. O. Davidson said:

"We doubt that many will be persuaded to seek salvation through the MAPI system, except perhaps some who may believe that formulas are more important than analysts in generating investment priority rankings."[15]

The MAPI system is essentially a mathematical model which contains a formalized allowance for the superiority of future new projects to the present one. This formalized allowance is accomplished with the MAPI formula. Terborgh says the following on the subject of the MAPI formula:

"A formula finds its principle usefulness where the present, or initial benefits of a project can be estimated, but where it is impractical, because of the time required or for other reasons, to develop the numerous future estimates required for a non-formula solution of the problem. As noted, this condition obtain most frequently with minor projects."[16]

This is sort of a limiting statement which describes the types of projects the system is best suited to analyze. The system is best applied to minor projects such as machine replacements, (for example, the screw machine replacement) rather than major projects such as con-

(Continued on page 40)

[15] H. O. Davidson.

[16] George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute (1958), p. 13.

Critical Path Techniques

By RICHARD H. SEVERN

Richard Severn, a junior in Civil Engineering, is from Madison, Wis. Dick is a member of Triangle Fraternity for which he was a National Convention Delegate.

IN RECENT years, companies have found that to attempt any kind of engineering project without some form of work schedule is extremely expensive and time-consuming. Many types of scheduling were therefore developed, and of these the Critical Path technique has become the most widely used. The Critical Path form of scheduling considers the following: (1) jobs necessary to complete the project, (2) duration of single jobs, (3) sequence of jobs, (4) effect of deliveries, and (5) those jobs which control the length of the project. All this is accomplished with a simple, easy-to-read, easy-to-work-with chart.

None of the mathematical theory behind the Critical Path system will be covered in this article. It should be noted, however, that every Critical Path schedule does have a mathematical solution, but these become important only in cases involving lengthly and intricate applications of the method. It is safe to assume that most engineers will never become involved in a case of this type.

REASONS FOR USING THE CRITICAL PATH

Control Over the Project

Control over any engineering project is essential today because of the increased competition in this field. The degree of control over a job may mean the difference between a profit or loss, but control is often hard to achieve today because of the complexity of activities on most jobs. An example of this complexity is the case of a certain Canadian chemical company. At the time of a plant overhaul, the employees were due to have their yearly physical checkup. *One* welder was away from the job for 5 hours for this, and as a result, the entire plant had to be shut down for an extra day.[1] Such a situation might have been avoided if the plant engineer had known that this person's job was critical. Since job control is a complex problem requiring a comprehensive knowledge of each project and a means of determining the inter-relationships between these projects, any method of scheduling which simplifies the problem of control is therefore a great asset to an engineer.

Job Reminders

To an engineer who is supervising a complex job, a simple reminder of what is happening at any given moment and what is to happen next may be of extreme importance. If he should overlook one small thing, the job may be delayed. But more important is the need for coordination; overall knowledge of the project at one stage will enable the engineer to coordinate the jobs better. He will know where to place his men each day and will be able to keep track of progress. Without a reminder, an engineer is likely to forget simple items which may seriously delay the job. The Critical Path method gives us this day-to-day job reminder.

Money Controls

Many jobs are initially scheduled to meet a certain budget, and later it is found advantageous to increase financial support of the project. In the case of plant shutdowns, perhaps a small increase in expenditures will get the plant back into operation weeks sooner. Here we would like to know where to increase our spending. It is obvious that not all jobs should or can be rushed; you cannot cure concrete appreciably faster, but you might be able to speed up the cut and fill work in constructing a road bed. The Critical Path method will show us how to speed up a job economically.

Effect of Deliveries

Another problem facing a project engineer is delivery of materials. Since it may not be of great importance to job progress if deliveries are late, and since suppliers often go to great and unnecessary expense to meet delivery dates in fear of losing their contract, it would be advantageous to have an alternate date of delivery for a supplier who can not meet the original date. Of course, if this late delivery would delay the job, the delivery could not be delayed. The Critical Path method will take into consideration the effects of late deliveries and from it we can make sound decisions on delivery matters.

However the Critical Path method will tell us more than just when the job will start and end. It will give the inter-relationship between jobs, day-to-day control over men and machines, control over the spending of extra money to speed up the job, and also some control on the delivery dates of materials. It will be shown later in the report that the Critical Path

[1] Martino, "How Critical Path Scheduling Works," p. 40.

method does all this without being difficult to use. First, however, there are a number of definitions important to Critical Path scheduling with which one should be familiar.

DEFINITIONS

Planning

Planning is the act of stating what activities must occur in a project, and in what order these activities must take place. Since knowledge of all the activities is necessary, much experience in the type of job to be scheduled is necessary.

Scheduling

Scheduling is the establishing of the project timetables with consideration to plans and costs. It entails deciding when, after the start of work, a particular activity should start and end. Here again, experience on jobs of the type planned is needed.

Nodes

Nodes are job endings and beginnings on the Critical Path diagram. They are usually represented by a numbered circle, with the higher numbered nodes only reachable from the lower numbered ones. Any number of activities may lead to or away from a node. See Fig. 1.

Activities

Activities are tasks which must be done to complete the project, and may be anything from setting "grade stakes" to the delivery of materials. They are represented by arrowed lines between nodes, and are named on the chart by the actual task name in abbreviated form. (Example, procure structural steel to "proc. str. stl.") They are also given a time interval equal to the estimated work time needed for the task. Notice should be given to the types of activities encountered.

Concurrent activities are two or more distinct activities which start at one node and end together at another. See Fig. 2.

Aggregated Activities are a series of activities which may be considered as one small project of their own. See Fig. 3.

Composite Activities are those which only may be started upon completion of a percentage of another activity.

Dummy Activities are a special type; they do not represent any specific task, but are placed in the chart only for clarity. They are given no name or time interval, and are usually represented by a dashed line. See Fig. 4.

Start Conditions

The start of many activities will be dependent upon weather, materials, plans, the authorization of funds, or any combination of these. Because of this dependency, extra time must be allowed for the project either in the original time estimate for the activity or in the project float time.

Float Time

Float time is a means of allowing for unforeseeable delays in the progress of a job. The time is not added to individual activities on the chart, but is added on at the end of the scheduled calendar time.

Lead Time

A means of putting a project on the calendar, lead time starts at the zero date and ends at the start of the project.

Critical Path Diagram

The diagram, a basic working tool of the Critical Path method, is a graphical representation of the plan of operation adopted for accomplishing the project.

The Critical Path

The Critical Path is the *longest* time path through the diagram, and can take any job flow route through the diagram.

CREATING THE CRITICAL PATH DIAGRAM

In the creation of the Critical Path diagram, there will be a few sections which at present will be beyond the ability of most student engineers. These sections deal with

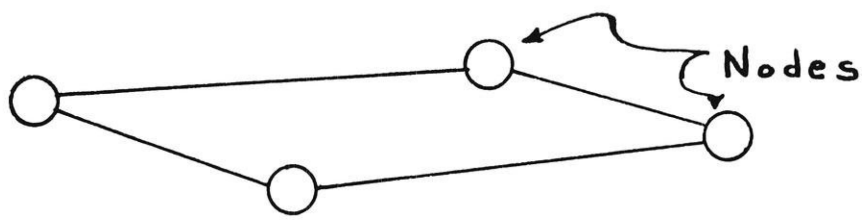

Figure 1.—Example of Nodes.

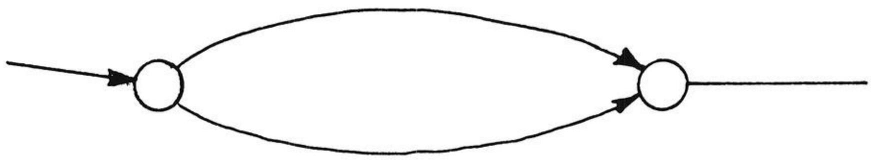

Figure 2.—Example of Concurrent Activities.

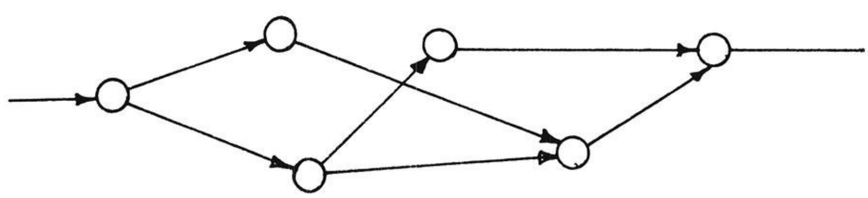

Figure 3.—Example of an Aggregated Activity Group.

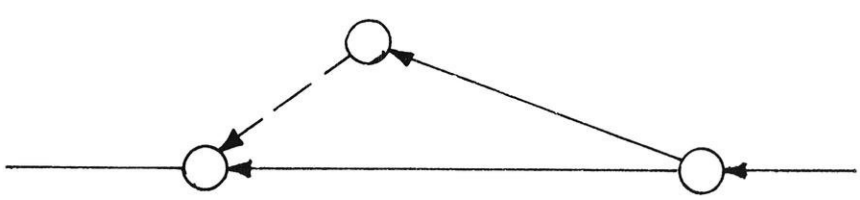

Figure 4.—Example of a Dummy Activity.

the decisions which require experience in the field to which the Critical Path is to be applied. The finished diagram will only be as good as the individual activity selection and time allotments, and a poorly constructed diagram will be of little use as a schedule. The degree of trust one may place in an entire finished schedule will be the degree of trust one may place in the least trusted estimate, plus or minus the degree of float time allowed; therefore a high degree of workmanship is required to create a workable diagram.

Selecting the Activities

Selecting the activities for the diagram is the first important step in its construction. The degree of control is dependent upon the degree of separation of the project into individual activities. Dividing the job too finely, however, will lead to a more complicated diagram than is necessary; the actual work activities should be divided into what one would consider a unit job. Dividing finer than this will lead to many unnecessary aggregated activity groups in the schedule.

Included as activities must be all restraints upon the project. Such as inspections, tests, and procurement of materials. Examples of typical activity selections are given in Fig. 5.

1 *Activity Number*	*2* *Activity Description*	*3* *Activity Time Allowance*
0 1	Assembly Crew (Lead Time)	96
0 4	Line Availability	150
1 2	Measure and Sketch	12
2 3	Material List	8
3 5	Erect Scaffold	12
3 6	Procure Pipe	200
3 7	Procure Valves	225
4 5	Deactivate Line	8
5 6	Remove Old Pipe	35
6 8	Prefabricat New Pipe	40
7 10	Place Valves	8
8 9	Place New Pipe	32
9 10	Weld Pipe	8
10 11	Connect Valves	8
10 12	Insulate	24
11 12	Pressure Test	6
12 13	Remove Scaffold	4
13 14	Clean Site	4

Figure 5.—Activity, Sequence, and Time Worksheet. Courtesy of *Canadian Chemical Processing*.

Activity Time Allotments

Time estimates are based upon experience and conditions. Experience in the type of work to be scheduled will give a better estimate of time for each job and will lead to a more usuable schedule. However, if experience is lacking, an allowance for this may be made in the selection of float time, a safety valve for the system. If you feel you cannot trust your time estimates, then you may allow for this by increasing the float time. Conditions which will exist at the time of a job such as weather, site, money, available labor, etc. should be allowed for in the activity time. More time must be allowed for construction of outdoor projects in the winter and spring. Adverse conditions are sometimes allowed for in the float time, but it is more practical to allow for the foreseeable things right in the activities' time.

Lead time is the time from the day of making the diagram to the day of the start of the project; so it is easily chosen. Float time, however, is selected last and is dependent upon your methods of making the other time choices; thus if you aren't sure of the other times, you should make your float time larger. Average time would be 1 to 3 working days per month for good time estimates, depending upon the season. See Fig. 5. for an example of lead time.

Sequence of Activities

Planting the activities for the diagram in the proper sequence is generally an exercise in logic. To do it, one must know what preceedes and follows a given activity, and what can be carried on simultaneously with it; knowing this, you will be able to number your activities in a node system. The first number refers to the node at which the activity begins and the last number is the node at which it ends. An example of typical node code numberings may be found in column 1 of Fig. 5.

Making the Diagram

Having compiled the activities, their times, we have done the most difficult tasks in the preparation of the diagram. It is now ready to construct. Using the code, we start at the O–X numbers and construct lines to the X numbered codes, and from these nodes to the X–Y nodes; in this way we work through the activities to the finish. Fig. 6. is a step-by-step example of this method of construction. One simple rule to follow, which will aid in making and reading the chart, is that each node be reached only from a lower numbered node.

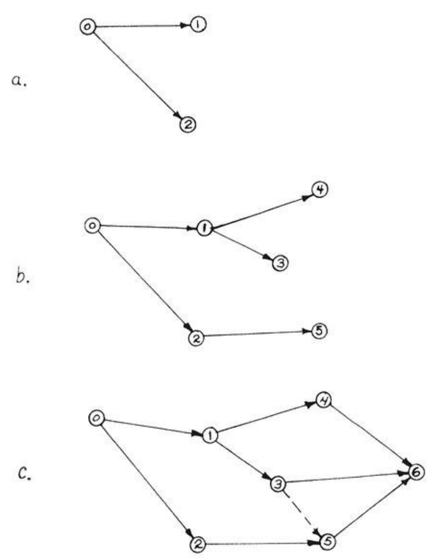

Figure 6.—The Step by Step Method of Constructing the Critical Path Diagram.

Once the basic network is laid out, the activities may be named above the lines and their times placed below; all of this to be done on the final diagram sheet. Note should be made here that one other form of placing the time on the diagram is by a horizontal or vertical scale. This method, however, requires more time in preparation of the diagram, and is not as easy to work with. The diagram should be recopied neatly and revised as needed. Neatness is required for ease of use and should not be overlooked. Two examples of Critical Path diagrams are Fig. 7. and Fig. 8. Fig. 7. is a first draft drawn from the worksheet, Fig. 5. Fig. 8. is a finished diagram, ready for use, except for calendar dates.

Selecting the Critical Path

Now that the diagram is complete, we are ready to find the Critical Path. To do this we add up the total time for various paths through the diagram, the longest one (or ones being the Critical Path

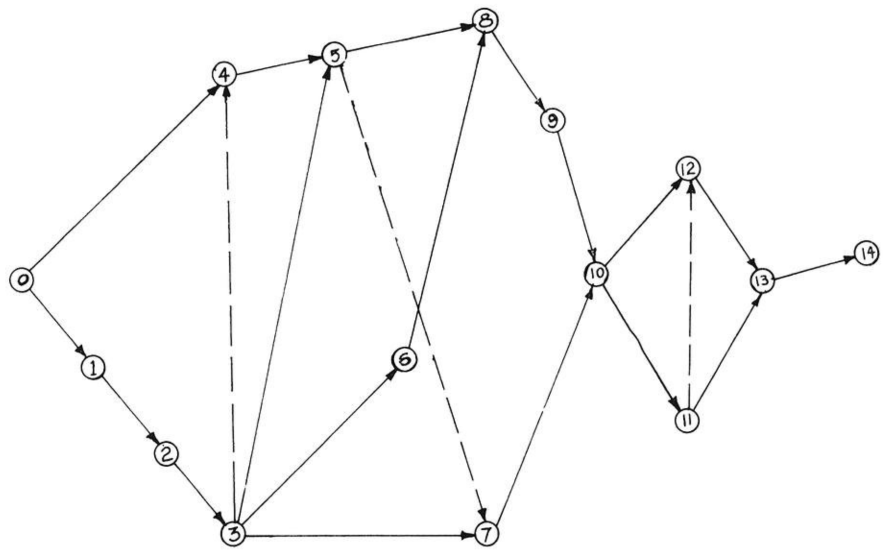

Figure 7.—Rough Draft Critical Path Diagram-Drawn From the Worksheet.

for the diagram of which there may be more than one. Another method for very long diagrams is summing the time between obvious break points. In Fig. 8., node number 9 would be a good point to divide the diagram. There may then be more than one Critical Path through any section.

The Critical Path, once chosen, should then be made to stand out in some way, either by a colored or dashed line, thus completing the Critical Path diagram. To schedule the project on the calendar, start at the current day, add on the lead time, the time for the projects on the Critical Path, and the float time, thus giving the probable day of completing the project. To get the probable day for completing any activity, add up the time on the Critical Path, the activity, and the lead time. If the activity is not on the Critical Path, add the time to the activity on the longest path. These dates should then be noted on the diagram.

Note: Time on the diagram is generaly only actual work time. On the calendar, then, an allowance must be made for this.

APPLYING THE SCHEDULE

With the diagram completed and projected on to a calendar schedule, we are ready to use it. Although it is an aid in making decisions, that is all it is; care must be taken not to use the diagram as the immediate answer to any problem. Decisions based on the schedule must therefore be weighed, with reliance placed on such decisions in accordance with the validity of the diagram.

Allocation of Finances

As a guide to the allocation of available finance, the schedule is excellent. It is not often that one would want to spend extra time or money on an activity which is rushed still would not speed up the job. Because of this, we are able to see that if the job is to be expedited, the extra effort must go into activities which are on the Critical Path, otherwise the extra effort will not have an effect upon the length of the project. The exception is the path which will become "critical" if the Critical Path is reduced. If more than one Critical Path exists, then to speed up the project we must speed up the activities on all of these paths. You may only shorten a Critical Path until another path becomes critical;

(Continued on page 40)

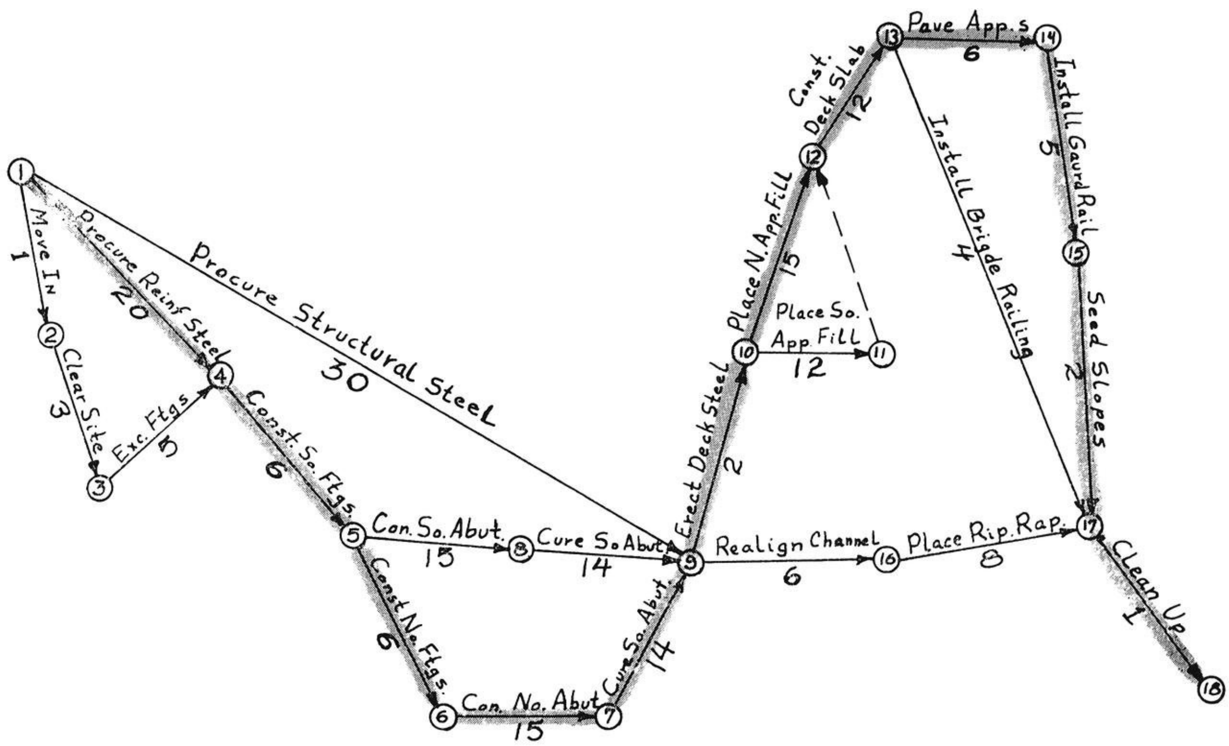

Figure 8.—Final Draft Critical Path Diagram.


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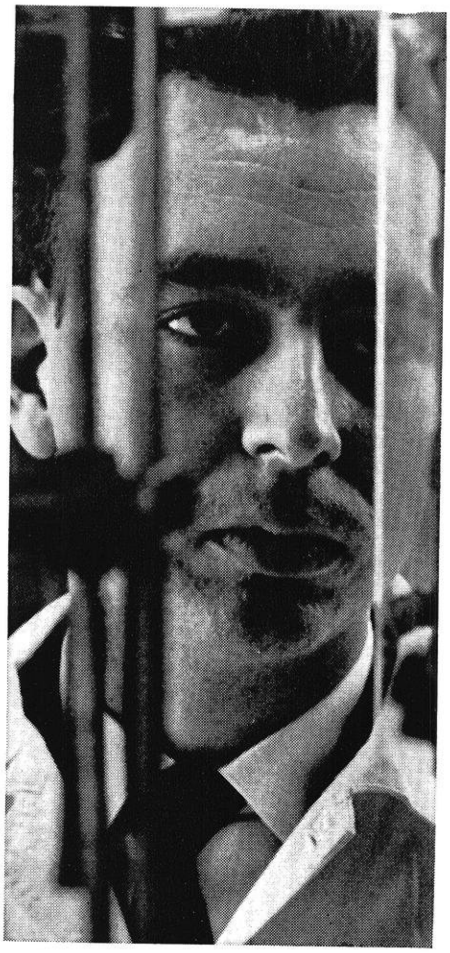

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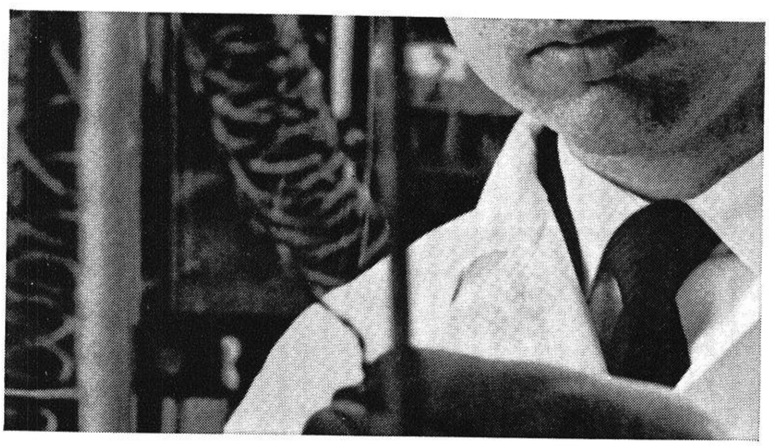

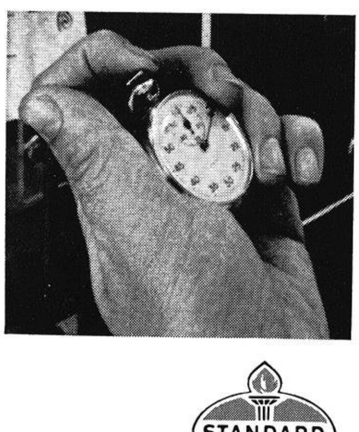

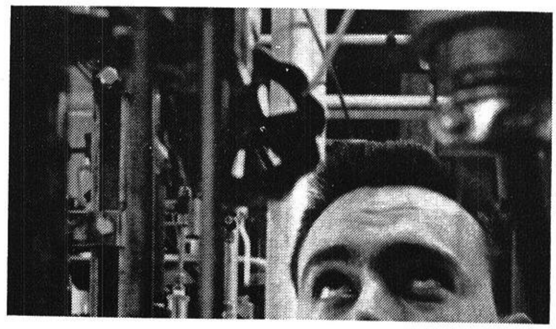

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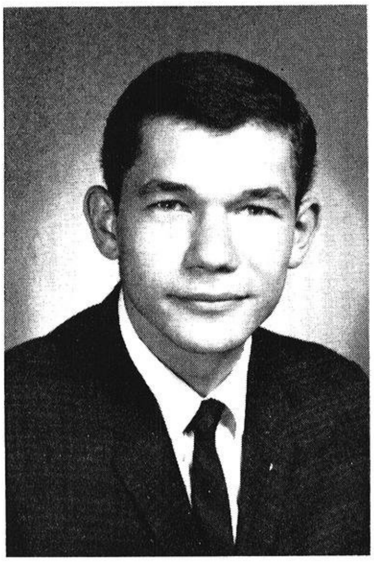
DEPENDABLE ENGINES

The Digital Computer In Industrial Problem Solution

By MICHAEL A. UNGER I.E.'64



Mike's home town is Milwaukee and he is a senior in Mechanical Engineering. Some of his activities include Triangle Fraternity, ASME, and SAE.

THIS article is directed to those interested in the potential of the electronic digital computer as an aid to decision making in industry. The word "computer" is fascinating. It brings to mind visions of a thinking machine capable of completely controlling a huge corporation, keeping track of every movement of parts and men, calculating costs and payrolls, and making decisions absolutely void of error. If man's scientific effort of the last twenty years could be summed up in a word, it would be "computer". In reality, however, the computer of today is limited to certain areas of industrial application.

Initially, this article will put the computer in its proper perspective in today's industry, indicating its history, operation and use in the three main areas: Operations Research, Production Process and Equipment Control, and Integrated Data Processing. Subsequently, it will focus on the computer in its most extensively used capacity, that of problem solution, studying the approach and methods uniquely suited to computers. Finally, it considers the future uses of the computer in achieving the ultimate the automatic industry. It deals with the problems, road of achievement to this goal, and the ideal.

Background for this report, in addition to the sources listed in the bibliography, was gathered in at least four courses at the University of Wisconsin in which computer applications or theory was covered. These were: Operations Research, Quality Control and Industrial Statistics, Computer Programming, and Machine Design.

THE COMPUTER IN INDUSTRY

In our economy, a product is useful only when it becomes profitable. Thus, the producer is charged with finding as many uses for his equipment as is possible to insure a profit. In this section, we will focus primarily on the applications of the computer in industry. In addition, we will briefly cover its history, operation, and effect upon management.

History and Growth

The computer is a postwar development that evolved during the general application of the scientific method to industry. One cannot say definitely whether the computer came about to satisfy management's need or whether the computer was instrumental in allowing science to enter the management function. Most probably, the two occurred as a result of a special economic consideration; high priced labor. Essentially, the computer is a substitute for labor, relieving man of the drudgery of computation and inventory control. The computer's forte is this substitution at a lower cost in the long run.

Sperry Rand and IBM were the pioneers in development along with UCLA who devised applications. In th 1950's heavy obsolescence was realized due to general improvement of the system using transistors, tape inputs and outputs, and improved circuitry.

Today, however, the computer stands primarily perfected except for minor improvements or new attachments. Attention is now turning to application and the ultimate result of the completely automated factory. The United States Steel Corporation, for example, has a 98% automated rolling mill able to operate competitively. This is but one segment of their whole operation but, certainly, complete automation will become a reality in the not to distant future. Executives will have, at their fingertips, probable effects of major decisions that have been stimulated on the computer.

Digital Computer Operation

As stated previously, we will limit ourselves to the general purpose electronic digital computer. This system, able to perform arithmetic operations of: addition, subtraction, multiplication, division, and square root, is also capable of logic through number comparison, determining whether a number is larger, smaller, or equal to another number. Operations are performed by the manipulation and transmission of electrical charges or magnetic marks.

The computer has five components: input, output, storage, control, and arithmetic.

Input and output stages receive and transmit data and commands on punched cards, magnetic tape (the fastest), or perforated paper tape. The memory system, capable of storing huge amounts of data using capacitors or similar electronic devices, keeps track of input, reference, intermediate or instructional data. The arithmetic unit, comprised of amplifiers, performs calculations in as little as 1/100,000 of a second. Control is affected by directly the other elements, according to the input instructions, to print, recall from memory, do arithmetic, or compare.

The overall picture we get of the computer is both large information handling ability and a high computational speed. These two features form the basis of its application in industry.

Areas of Industrial Application

Digital computers are used in three main industrial fields: Operations Research, Production Control and Integrated Data Processing. Table I shows the applications within these areas.

TABLE 1—COMPUTER APPLICATION AREAS

Operations Research—Simulation, Competitive Strategies, Dynamic Programming, and Linear Programmaing.

Production Control—Inventory Control, Replacement, Allocation, Production Scheduling, and Sequencing.

Integrated Data Processing—Payroll, Accounting, Production Records, and Cost Data.

Distinguishing these areas by function, Production Control and Integrated Data Processing accomplish various functions of a corporation while Operations Research handles its problems.

Operations Research involves the use of scientific analytical methods to solve business management's problems. These invariably take the form of alternative courses of action in a situation. The applications cited in Table I are, strictly speaking, methods. However, some authors feel that, since these particular methods can only be applied to certain characteristic problems in this area, the words method and application are synonymous. Supporting this view, we shall postpone our explanation.

Production Control deals with the predictable cost control of the functions necessary for production. Inventory cost, expressed as an equation where:

1. Timing of production runs,
2. Changing the run size,
3. Sales promotions,

are factors expressed in terms of cost, is minimized by differentiating the equation and setting it equal to zero. In Replacement, where remedial action to replace existing capital equipment is determined, the same technique is used. Production Scheduling, Allocation and Sequencing solutions are a bit different in that, instead of a single equation, a matrix exists and can be solved using the Linear Programing technique. The matrix appears due to the alternate paths available in scheduling operations to be performed. Allocation and Sequencing are special areas of Production Scheduling; the former concerns problems resulting from the occurrence of a number of destinations, the latter deals with the order or sequence in which jobs are to be done.

Integrated Data Processing tries to combine information from all departments into one high-speed system so that, ultimately, the effects of one department are immediately reflected in all other departments concerned. Because of this overall interest, a sharp distinction between Production Control and Integrated Data Processing cannot be drawn on the basis of application. We can, however, effect a distinction depending upon computer methods, since the method applied in Integrated Data Processing is the reaction-type, not the solution-type found in Production Control. Putting in data corresponding to an effect of some sort, the machine, depending upon the input, causes particular reactions to occur.

The method can be illustrated by the word "if". For example, we put in the effect that John Smith worked 40 hours in a week. Particular reactions occur depending upon the "if" of Table II.

TABLE II—COMPUTER STEPS IN SOLUTION

1. IF he has worked these 40 hours in less than 8-hour lengths.
2. IF he is entitled to certain benefits.
3. IF certain deductions are to be taken.
4. IF he has a certain rate.

Taking our example one step further, we see that, in the event that John Smith has worked 10 hours a day, production should be rescheduled to a more acceptable level to eliminate overtime cost.

The Effect of the Computer in Industry is overwhelming. For the first time, an abundance of accurate, up-to-the-minute data is available. Previously, it was not represented because of its massiveness, not to mention its computational difficulties. In addition, management is relieved of the drudgery of day-to-day operation decisions.

This machine, however, is not the miracle some think. It has limitations. It cannot replace the human brain in formulating and defining problems and procedures. Incapable of originality, it can only do as ordered. It can accomplish a lot, though, and fast, incredibly fast. This is the computer's forte; here we intend to exploit it fully.

THE COMPUTER IN PROBLEM SOLUTION

Only certain types of questions requiring a digestion or consideration of large amounts of data or needing extensive computation are suitable to computer solution. In addition, those problems must be subject to mathematical description. Problems such as repairs and major machine adjustments still depend on man for their solution. In this section, we shall first explore

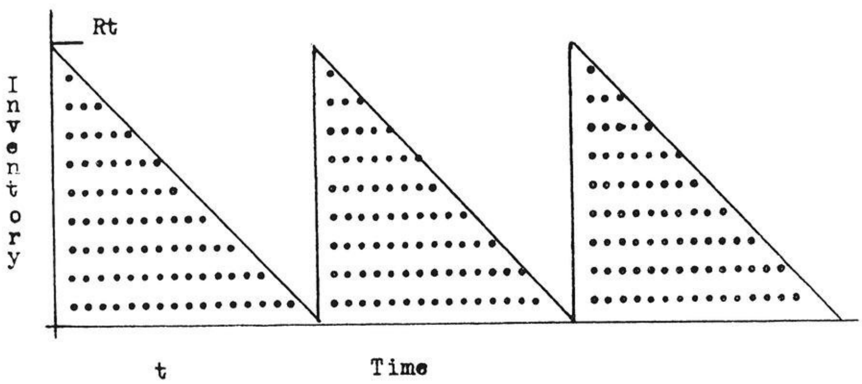


Figure 2.—Variation of Inventory with Time. Demand is known and constant.

the approach common to all computer problems: the scientific method. We shall outline the steps involved in the development of the mathematical model. Last, we will cover statistical analysis, sketching the reasons for its use and tracing the methods used in computer solutions.

The Scientific Research Approach

This attack consists of seven steps given in Table III.

TABLE III—THE SCIENTIFIC METHOD

1. Define the real problem.
2. Collect data on the factors affecting the results.
3. Analyze the data and other information about the problem.
4. Establish a realistic criterion for measurement of the results.
5. Develop a model representative of the system.
6. Test the model on sample problems to insure representation.
7. Integrate the new method into company operations.

Interest in it here lies in its application to the problems of management, bringing them under the realm of scientific analysis and solution. The approach will be studied by considering the development of the model.

Models, used to define, analyze and solve these questions depend primarily on the operator's skill and knowledge. He must construct his model such that the variables can be manipulated to accurately predict the effects and interrelationships between these factors. Since these variables are, to a degree, an abstraction of a real-life situation or process, the model-builder must be sure of true representation. He follows a procedure similar to that of the scientific method and described in Table IV below.

TABLE IV—METHOD OF MODEL DEVELOPMENT

1. Define the system under study.
2. Define a Measure of Effectiveness, E, for the system.
3. Construct a model where E is expressed as a function of variables.
4. Identify the controllable variables, X_i, and the uncontrollable variables, Y_j, forming the equation, $E = f(X_i, Y_j)$,
5. Solve by maximizing or minimizing the equation.

We see immediately the importance of the differential calculus. Its use will be shown in the following example.

Consider the problem of inventory control. We define the system as one in which the demand for a certain product is known to be R units per unit time. Production time is assumed negligible and the producer wants to minimize inventory costs, the measure of effectiveness. Figure 2 illustrates the situation.

If a production run is made at intervals of t, an amount, Rt, must be produced. The shaded area then represents:

$$\int_0^t I dt$$

and equals:

$$\tfrac{1}{2}Rt^2$$

hence, the cost of holding inventory per production run is:

$$\tfrac{1}{2}C_1Rt^2$$

where C_1 is the cost of holding one unit of inventory for one unit of time. The cost of holding inventory per unit time is then:

$$\tfrac{1}{2}C_1Rt^2/t$$

Defining the setup cost per production run as C_2, and the average setup cost as C_2/t, we can say the average total cost per time, E, is:

$$E = \tfrac{1}{2}C_1Rt + C_2/t$$

Differentiating and setting the derivative equal to zero yields:

$$t = (2C_2/C_1R)^{1/2}$$

Therefore, the optimum production run, Rt, is:

$$Rt = q = (2C_2R/C_1)^{1/2}$$

The above situation, greatly simplified, is unlikely to occur in reality. We shall now consider an alternative situation where the total demand, D, is specified for a long period of time, T, and runs of fixed quantity, q, or D/q runs per total time, T, are made, as shown in Figure 3.

Holding cost for T is:

$$\tfrac{1}{2}C_1q(t_1 + t_2 + t_3 + \ldots + t_n) = \tfrac{1}{2}C_1qT$$

and setup cost is:

$$C_2D/q$$

finally, the total cost, E, is:

$$E = \tfrac{1}{2}C_1qT + C_2D/q$$

again, differentiating and setting the differential equal to zero yields:

$$q = (2C_2(D/T)/C_1)^{1/2}$$

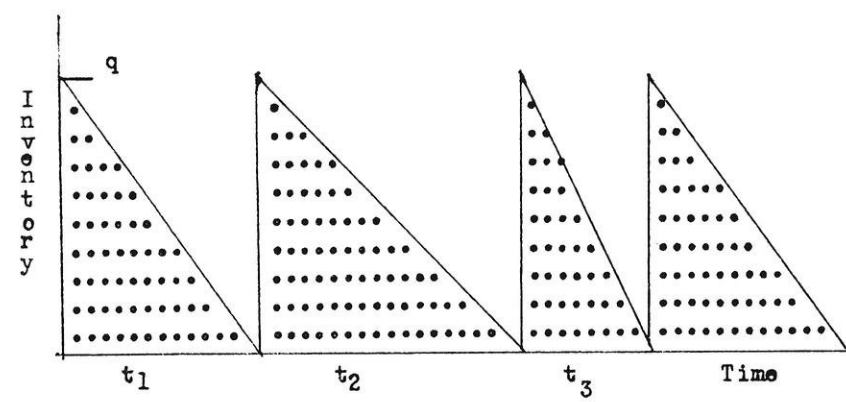


Figure 3.—Variation of Inventory with Time. Run size and number of runs fixed.

Hence, we get a different answer dependent upon the assumptions made. Variations are limitless and the decision we face is how elaborately to define each variable. This is usualy decided on the closeness with which we wish the model to approximate the real situation. In the previous example, it may be of little consequence to assume negligible production time. There may be implicit assumptions such as not allowing for future to fulfill the delivery schedule. Thus, the development of the model is the most difficult step in the solution of computer problems due to the inability to recognize the complete relationship of variables. As an aid to overcoming this difficulty, the theory of probability is employed so, in absence of a clearly defined relationship, a most probable one could be found.

Statistical Analysis and Probability

Statistical Analysis recognizes the reality of situations in which variability is the rule rather than the exception. For example, we say that our best estimate of the demand for a product is from 102 to 130 pieces per day, 95% of the time, with 116 pieces as the most likely demand. Because of variability, measurements and controls need to be based on probability concepts to be most effective. The importance of these concepts is due to the inherent variance of industry.

The use of statistics and probability can best be explained by means of the techniques used. We shall discuss four main methods, namely:

1. Sampling Theory
2. Simulation Theory
3. Simplex Method
4. Game Theory

Sampling Theory is a guide to sample selection that is representative of the whole, or universe. The theory assumes that each member of the universe has an equal chance of being picked for the sample. With this assumption, inferences concerning the universe can be made, using two statistics of the sample, its mean and variance. The mean, X, is the measure of central tendency described, for a set of X items, each having a value, N_i, as:

$$X = \Sigma N_i / X$$

The variance is a measure of the variability of the sample and is defined as:

$$V(X) = \Sigma (N_i - X)^2 / (X - 1)$$

or the sum of the squares of the differences between individuals in the sample and the sample mean, all divided by one less than the total number in the sample. If the sample size is over 30, it makes no difference if one uses X − 1 or X in the divisor.

The purpose, mentioned above, is to draw conclusions about the universe from the sample. For example, we may want to know whether a product is within specification and, instead of measuring the entire output, we take a small sample, measure it, and infer from the sample whether the whole universe is acceptable.

The computer is used to calculate, in addition to making calculations determining the quality of the output, the mean and variance of the sample. If the sample is large or if output is checked often, this represents a considerable savings in time and effort.

Simulation Theory is a special type of sampling used whenever it is impossible or too expensive to take a sample from the actual universe. It involves the replacement of the actual universe by its theoretical counterpart from which subsequent samples are taken.

For example, say a bus company schedules buses every 15 minutes and wants to know the average waiting time of a person along the route in addition to the average number of empty seats at any given stop. Here, we find, perhaps by asking bus drivers on the route, the average number of people boarding the bus at each stop and some measure of the variability of this mean. We then turn to the computer and generate a "history" based on assumptions concerning the distributions of bus and passenger arrivals. On a per bus basis, we can find the average waiting time of passengers and the number of empty seats on the bus. Table V shows the steps taken by the computer in solving this problem.

This "history" provides us, in addition to the average waiting time, with an almost absolute assurance that this is a true average based on years of data. Because of the computer's speed, years of data can be calculated in a matter of minutes. Note that we can also change bus schedules, a controlled variable, without the cost involved in the actual rescheduling.

TABLE V—AN EXAMPLE OF COMPUTER SOLUTION USING SIMULATION

1. Start with an empty bus.
2. Stop at the first stop to pick up passengers.
3. Pick, at random, the number of passengers that should be waiting for this bus (they have been arriving for the last 15 minutes).
4. Store the number and the length of time each waited in your memory.
5. Load the passengers into the bus and go to the next stop.
6. Store the number of empty seats in your memory.
7. Repeat 3–6 until the end of the route.
8. Repeat 1–7 for a specified period of time (say, 2 years).
9. Recall all the people who waited.

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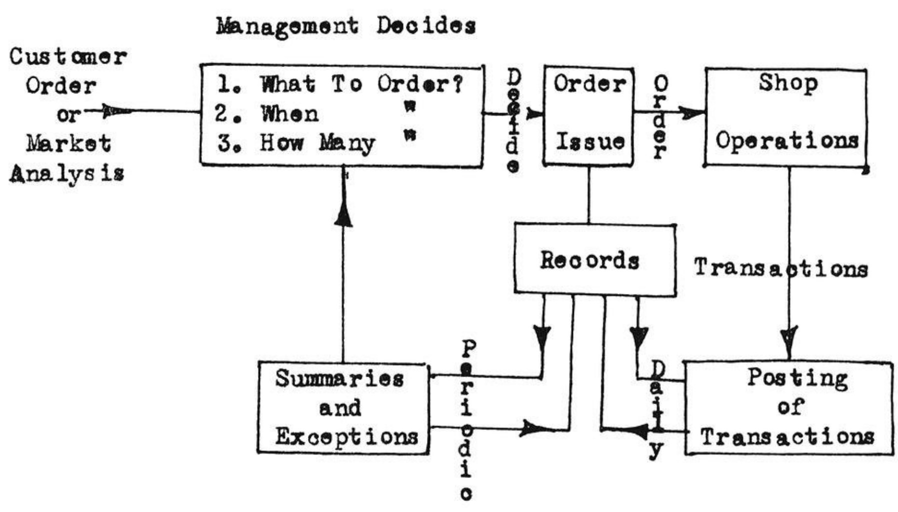

Information flow in the automatic factory.


AEB

ENGINE EARS

Wisconsin Chapter Hosts 20th Annual A.S.C.E. Mid-Western Conference

Members of the American Society of Civil Engineers from eight mid-western colleges and universities will gather at the University of Wisconsin, Madison on April 23–25 for the 20th Annual Mid-Western Conference. Those student chapters participating are from Iowa State College, Michigan College of Mining and Technology, North Dakota State College, South Dakota State College, University of Iowa, University of Minnesota, University of North Dakota and the University of Wisconsin.

Each year since 1944 the members have made a significant gain in fostering desirable relations among the student chapters as well as among the student bodies of their respective schools. The conference's prime objective is to further the knowledge of the standards and ethics of the engineering profession. It is around this nucleus that the program at Wisconsin has been constructed.

Headlining the conference this year is a panel discussion on "What Is Expected of the Graduate Engineer?" Representatives of various aspects of engineering will present their views on the subject. Representing government will be E. P. Fortson, Jr. Chief of Hydraulics Division, Waterways Experimental Station. Speaking for the contractors will be W. A. Klinger. Thomas M. Niles will represent the consulting engineers. Representing industry will be John Gammel of Allis Chalmers.

Several tours have been planned to acquaint visitors with the University's engineering facilities. Included will be the nationally known Forest Products Laboratory and the University Reactor Laboratory. To insure that one does not forget that he is still in civil engineering, inspection of materials testing as well as electronic and high-precision surveying equipment will also be shown.

Members may participate individually by entering the student paper contest. Each paper submitted is to be written on a technical or professional civil engineering subject. First prize is $20.00 and a one year subscription to A.S.C.E. journals of all technical divisions.

While the conference is sure to provide a technical atmosphere, the calendar of events does include an adequate amount of social events and banquets —a necessity for today's technical man.

Officers and advisors for this conference, to which recognition is surely due are: Dwight Zeck, President; Edgar Doss, Vice President; Jerry Bizjak, Secretary; Rod Nilles, Treasurer; and advisors, Professor E. C. Wagner, Richard Dopp and Dennis McMillan.

MISS MARCH

KATHY FRANCOUR

Kathy is a freshman majoring in English and Spanish. Her home town is La Crosse, and one of her favorite pastimes is swimming.

The Saturday morning when she posed for these pictures, at the Triangle Fraternity House, this brown haired, green eyed beauty captured the interest of every engineer who had managed to roll out of the sack before 10:30 a.m.

TOWARD YOUR B. S. DEGREE

Dedicated to the principle that in order to be a good Engineer a person must know a little bit about everything. In this section expect to find anything ranging from the history of Zoroastrianism to how to select a wedding ring.

WHAT'S THE DIFFERENCE BETWEEN MEN AND WOMEN?

"La difference" between men and women is greater than you may think: women are more easily hypnotized than men—and more apt to suffer migraines. Men's vocal cords are longer and thicker, but girl babies speak earlier and more clearly than boy babies. And science has proved that women's tear ducts are twice as active as those of men!

THE difference between men and women is even greater than you may think.

By examining any one of the body's approximately 30 trillion cells, a scientist can tell if it belongs to a man or a woman.

A man's brain is slightly heavier than a woman's, and the average red-blooded American male has 10% more red blood cells than his feminine counterpart. A woman's heart beats eight to ten time more per minute than that of her current heart-throb; if both live average life spans, she'll tick off some 300,000,000 more heartbeats than he will!

"Straight from the shoulder" is a male attitude. A man's arms do hang that way; in women, there's a definite bend at the elbow so that the lower arm extends outward at an angle. Similarly, a man's thighs and legs are in a straight line while a woman, by comparison, seems knock-kneed; her legs bend inward at the knee.

Relative to a man, a woman has a longer head, but a shorter neck;

shorter limbs, but a longer trunk; a seated woman is relatively taller than a seated man. Her thumb is comparatively shorter, her index finger longer, and her wrist swivels with more ease—explaining why women excel at delicate manual work.

Though a man's vocal cords are longer and thicker than a woman's, she apparently gets in not only the last word, but the first one, too. Girl babies tend to speak a little earlier than boys, and to utter more comprehensible words. Studying children in the same social brackets, psychologists found that little girls use longer sentences than little boys! Speech therapists say that stuttering is two to ten times as common in males as in females.

Here's an interesting fact to remember next time you get involved in an argument with your sweetheart or spouse; each sex tends to hear its own voice better! A woman's hearing is keener than a man's in higher frequency ranges, while man's ears pick up low notes more readily.

It may also be useful to recall the experiment made by two eye specialists who fastened narrow strips of filter paper to the lower eyelids of 231 men and women. The dampness of the paper after five minutes revealed the individual's capacity for tears. Guess what? The female tear ducts proved almost twice as active as those of the men!

Color blindness affects one man in every 25, but only one woman in 250. Even as tiny babies, females are apparently more color-conscious; in tests made on infants aged five and a half months to 24 months, more girls than boys grabbed for the brightly colored discs in preference to the gray ones.

So far, there's no conclusive evidence as to which sex has the keener sense of smell. Both sexes enjoy fragrance of the right type: according to researchers men use a surprising $44 million worth of scented after-shave lotion each year.

Differences in male-female psychology showed up interestingly on a multiple-choice word-association test administered to a test group by psychologists Lewis M. Terman and Catherine Cox Miles. It was found that the word "closet" reminded most male subjects of "door," most women of "clothes." "Charm tended to make women think of "beauty" and men of "snake!" When the word "home" was mentioned, women thought "happy," men more prosaically of "house."

Which sex is really smarter?" In general intelligence, men and women seem about equal, according to those who have studied results of modern IQ tests. However, more men than women to be found at either intellectual extreme. More males fall into the "feeble-minded" category. But in a survey of exceptionally gifted children (IQ's of 132 and over) psychologist Terman found about 120 boys for every 100 girls that met the minimum requirement.

Women, according to Dr. Justus J. Schifferes in the Family Medical Encyclopedia, are more easily hyp-

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The MAPI System

(Continued from page 19)

struction of a new plant or other extensive expansion. Because of the huge investment involved, major projects warrant detailed studies and call for another analytic system.

In looking further at the MAPI system as compared to other investment analysis systems, a word can be said about the "intangibles" of the MAPI system. "Intangibles" is a relative term. Things that Terborgh calls intangibles are called this because in his system they can't be calculated. However, in another system some of them can be calculated and therefore are not intangibles to that system.

A final word of evaluation concerns the way MAPI and other systems differ in approaching the uncertainty aspects of investment analysis. To overcome the uncertainty of the future, MAPI makes simplifying assumptions, some of which can lead to erroneous results from the analysis. MAPI does not say what to do if given a problem ". . . with as estimated next year plant operation rate in the form of a probability distribution."[17] There are new systems which utilize computers and do not have as many simplifying assumptions as MAPI.

In short, it would appear from this brief evaluation that the MAPI system does give a more accurate analysis for equipment investment problems than can be accomplished by traditional methods. However, each system has some merits in particular situations and should not be forgotten completely in favor of the MAPI system. What is needed in an investment analysis is not a formula specialist, but a professional who can select and use the proper system or technique to solve the problem.

Because of the inadequacies of traditional replacement analysis systems, the MAPI system was formulated. The MAPI system is designed to yearly analyze investment projects and obtain their ranking or priority. The system applies a one year test, which derives an after tax rate of return on the net investment of the project, as compared to going on without the project for one more year.

The MAPI system attacks an equipment replacement problem in two stages: (1) determining the next-year operating advantage from the project, and (2) determining the rate of return from the investment. It is in the second stage that MAPI is unique in its approach to investment analysis.

The MAPI Urgency Rating is the result of the analysis. "It is a measure of the current urgency of the project. By the same token, it is the factor for ranking the project with others in order of urgency."[18]

Many of the false assumptions upon which the traditional systems are based have been eliminated in the MAPI system. However, MAPI has still included many assumptions of its own in its system, and it is necessary to have a good understanding of these before using the MAPI system extensively for investment analysis.

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[17] H. O. Davidson.

[18] George Terborgh, *Business Investment Policy*, Machinery and Allied Products Institute (1958), p. 109.

Critical Path Technic

(Continued from page 23)

as the longest overall path through the system will still control the length of the project. Because of this, it will be easy to decide where to spend any extra funds, where to send the extra truck, or the extra men.

Adjustment of the Schedule

No plans are ever so definite that no one will want to change them; therefore the schedule may have to be adjusted from time to time. Such adjustments may be because of a speed-up in progress, or a more realistic picture of the conditions. For changes in conditions not accounted for in float time, all that is required is a change of time on the diagram. If the change is too extensive, then perhaps a new data sheet will have to be made and, from this, a new diagram. If the change disturbs the Critical Path, causing it to shift to a new position, the diagram should be changed, or redrawn if necessary, to show the new Critical Path. One should note here that it is unnecessary to change the schedule to account for minor discrepancies in time estimating, as these should be allowed for in float time.

Sample Problems and Their Solutions

The late delivery is always a problem on any construction job. It may or may not delay the work of men, and the decision of what to do if a delivery threatens to be late is often a hard one to make; the Critical Path diagram, however, can be applied here with little effort. In Fig. 9., activities 1–4 and 1–9, are deliveries, one on the Critical Path, the other on a "slack path." If both deliveries were about to be delayed by three days, but could be delivered on time at some added expense, would it be worthwhile to have them delivered on time? For 1–4 the expense would be justified since it is on the Critical Path and will delay the project. Delivery 1–9, however, is not on the Critcal Path, and will not become critical until the 56th day of the project. Therefore it is unnecessary even to think about speeding this delivery as it would have no effect on the project outcome. It is unwise to use float time to make up a difference of three days, especially so early in a project. Keeping a whole crew idle for three days will no doubt be much more expensive than rushing the delivery.

Often a company would like to find the most workable plan with the available cost, time, and resources for the project. Various plans may be tested by diagramming them and analyzing the Critical Path of each. One may clearly be the best, or perhaps parts of each will combine to form the most workable. Du Pont de Nemours reports that by diagramming various plans they were able to spot a method of action that would complete a plant overhaul two months early, with only a 1% increase in costs.

The advantages of the Critical Path method should by now be apparent. It gives the user a high degree of control on his project and does so without being complicated. By permitting the user to see the inter-relationships between activities, it enables him to pinpoint conditions critical to job completion and shows where extra funds should be spent, should an emergency arise. Plans may even be checked against each other in deciding on the best one, again made

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Critical Path Technic

(*Continued from page 40*)

possible by the Critical Path method.

The Critical Path method is also very easy to work with in that schedule adjustments are easily made, requiring little work other than a few additions of numbers. Du Pont de Nemours reports that their experience show that a 40% change in plans will require only a 10% change in the schedule. It would require a 100% change in any conventional plan.

The Critical Path also leads to economy. The plan in general leads to a more economical allocation of the available resources. In plant shutdowns, the shutdown time is generally much less if the Critical Path is used than it would be without such a plan. Du Pont again reports favorable experience in this line, indicating that the method can save an estimated $500,000 for a large company every year, just in maintenance shutdowns.

The Critical Path system is more widely adaptable than just plant maintenance, being usable on any project which involves the completion of an inter-related series of activities. Some of the uses found for it right now are: (1) construction and maintenance, (2) retooling programs, (3) low-volume production scheduling, (4) budget planning, (5) new product launchings, (6) assembly and testing of electronic systems, and (7) even missile countdown procedures. There are an infinite variety of jobs to which the method can be applied, and for this reason most engineers will find it advantageous to know how to use it.

The Digital Computer

(*Continued from page 31*)

10. Add those who waited.
11. Add the waiting times of the passengers.
12. Find the average by division of 11 by 10.
13. Recall the empty spaces.
14. Find how many times the bus was full.
15. Find the average number of empty seats.
16. If buses are full many times (say, a certain percent), schedule buses (X — 1) minutes apart and repeat 1–15.
17. Find the optimum schedule.

The Simplex Method and Game Theory are used to solve problems in Linear Programming and Competetive Strategies. Both involve a large amount of tedious work to solve a set of m linear equations using matrix algebra. As is prevalent in matrix algebra, solution methods employ algorithms (methods presented without proofs) and, for this reason, are not presented here both because of length and inability trace these methods using logic. Suffice it to say that, by programming these procedures on the computer, an enormous amount of time and effort can be eliminated.

The computer cannot save us the work of setting up the model but it can solve the effectiveness equation with each combination of the elements in the matrix. Remembering these solutions, it then compares each to determine the maximum or minimum, which ever is called for. Please note that the computer is used only in relief of the mechanics of the problem. It cannot formulate the matrix or the effectiveness equation.

THE COMPUTER IN THE FUTURE

The future promises the extended use of the computer in the automation of the entire factory, even relieving middle management of the task of decision-making. This eruption of the status quo presents tremendous problems in the cost, knowledge and psychological areas. In this section, we will attempt to deal wtih these problems, offering a solution. Subsequently, we will present the automated factory, giving the flow of information through the plant.

Problems in Achievement

The three areas of difficulty, mentioned above, are effects directly attributable to the introduction of the computer into industry. Managements, today, are vying with each other for the privilege of competing in this high cost race of automation.

The Cost of Computing is borne by many areas in industry but chiefly by research, engineering and production profits. Today, it isn't a major problem, even though computers are far from profitable, because industry can afford the cost, hoping for a high return on its investments. In the future, however, as business becomes more competitive, the problem of cost will loom large. The main challenge, here, is to keep the change orderly and cooperate with other companies as techniques advance to prevent the collapse of competitors.

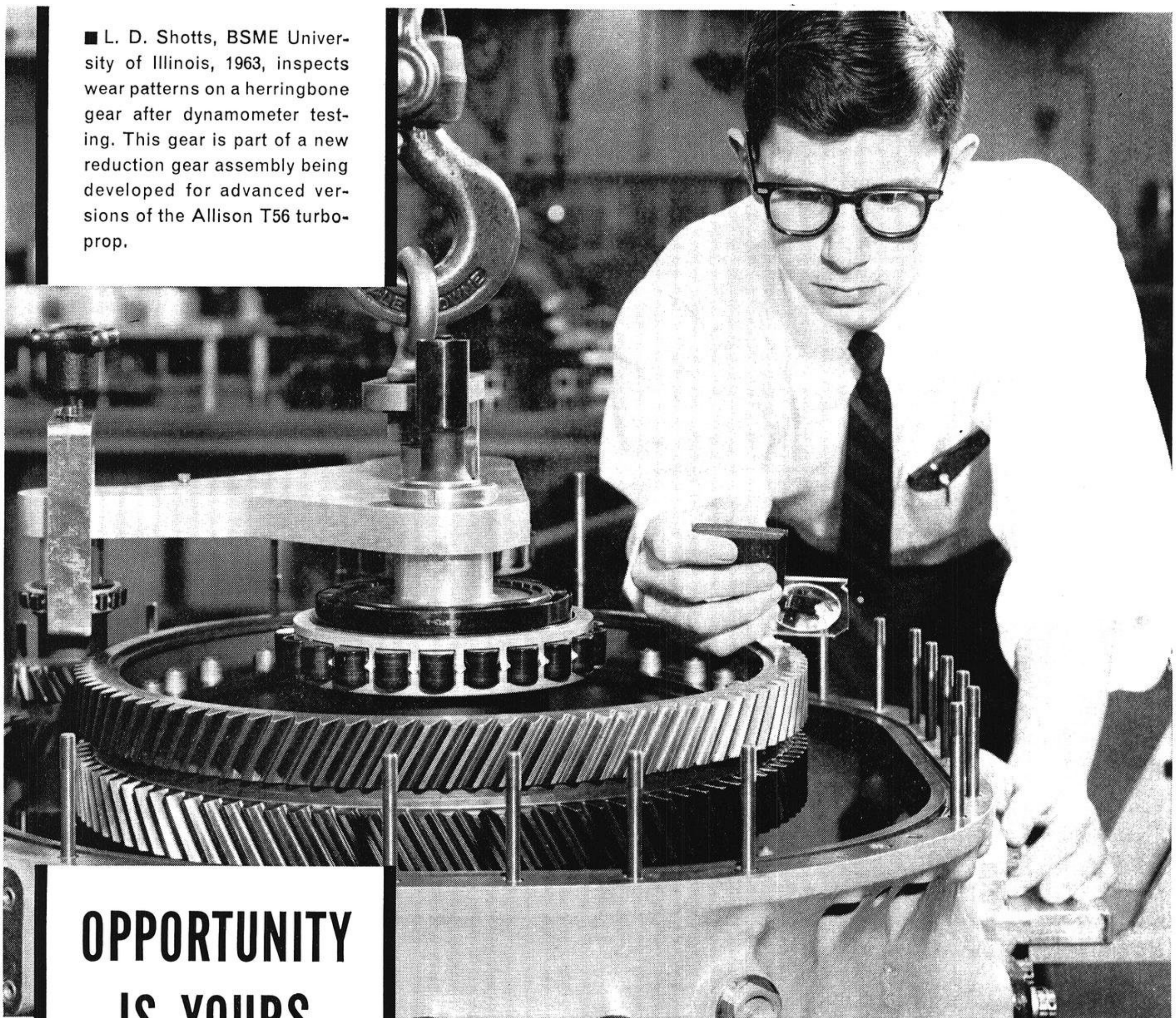
Psychological Problems, today, are evidenced with misgivings concerning future job security. The major problem seems to be one of employment, since automation may reduce factory labor by as much as 75%. Quantitative questions such as: "What will tomorrow's worker do?" and "Where will he be displaced—if at all?" are not as important as the qualitative question of: Will the worker feel that he is making a positive contribution to the product if future jobs consist only of button pushing?" The success of this revolution will depend heaviest on management's solutions in this area.

Knowledge and the Engineer are the keys to success, just as management needs to become more scientific orientated, so too, does the engineer need to become more people orientated. Engineers, chiefly, will be responsible for the harmonious meshing of the computer into the gears of industry with a minimum of disruption of profits and labor. The future engineer will have to be aware of all the factors involved in the automation revolution to be able to supervise the relocation and retraining of personnel to maintainance and other operations. He will have to overcome the resistance to change and consolidate the diversity of attitudes. He will accomplish this feat through education both of himself and others.

The Automated Factory

This ultimate goal is, in effect, one machine completely automated. It will process information regarding customer orders, inventories, production control, and payroll data. The system, shown below, is unique because it leaves to management the descretion of starting with broad overall objectives completely apart from an existing mechanical system or at a

(*Continued on page 47*)



■ L. D. Shotts, BSME University of Illinois, 1963, inspects wear patterns on a herringbone gear after dynamometer testing. This gear is part of a new reduction gear assembly being developed for advanced versions of the Allison T56 turboprop.

OPPORTUNITY IS YOURS AT ALLISON

■ For L. D. Shotts, the move from the University of Illinois was a natural. L. D. had learned of the work Allison is doing in advanced turbine engine development. Particularly, he was impressed with Allison's assignment to develop the T78 regenerative turboprop engine.

The T78—selected by the Navy for anti-submarine aircraft—utilizes turbine exhaust heat to raise the temperature of compressor discharge air, resulting in increased fuel economy for extended long-range and on station aircraft capability.

Air-cooled turbine blades, another Allison achievement, mark a significant advance in turbine engine state of the art. And, the workhorse of turboprops, the Allison T56, continues to set new standards as our engineers find additional means of improving performance and reliability.

In addition to leadership in the turboprop area, Allison also is making great strides in the development of nuclear energy conversion projects, including a compact, mobile nuclear reactor and an energy depot concept which will permit manufacturing of fuel "on the spot" for military field units.

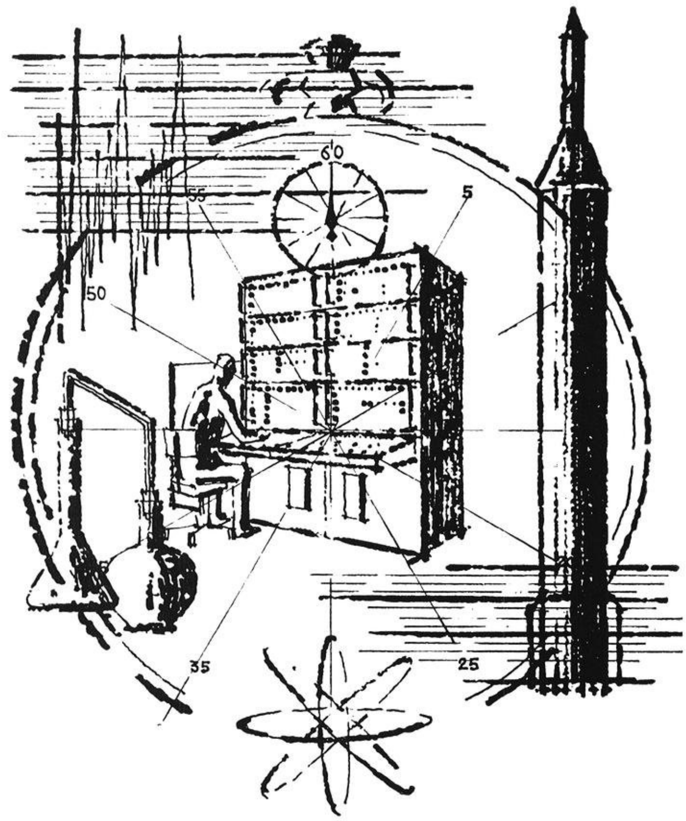
Well-qualified, young engineers will find unlimited opportunities in the long-range, diversified energy conversion programs at Allison. Talk to our representative when he visits your campus. Let him tell you what it's like in the creative environment at Allison where Energy Conversion Is Our Business.

An equal opportunity employer

Allison

THE ENERGY CONVERSION DIVISION OF GENERAL MOTORS, INDIANAPOLIS, INDIANA

GM GENERAL MOTORS



SCIENCE HIGHLIGHTS

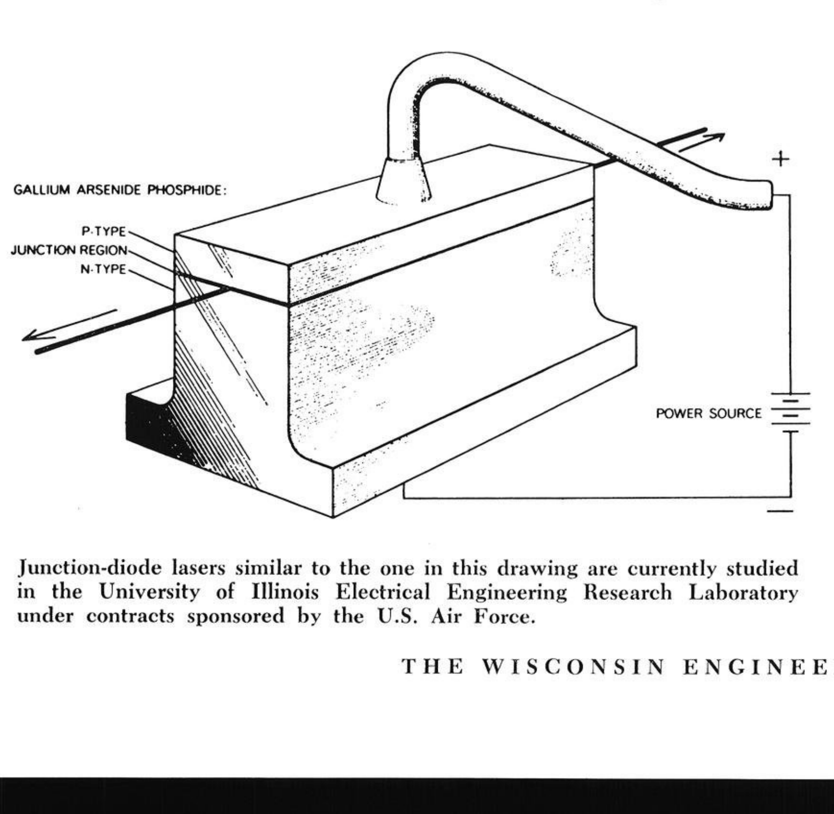
By Robert Rosenberg, ME'65

A SEMICONDUCTOR LASER

One of the strange things about the laser is that more money and more man-hours are being poured into research on the device itself than on its proposed applications. Not since the rapid development of the transistor has so much scientific and engineering interest been turned to such a specialized research area.

Only three years ago the first working laser was developed by engineers at Hughes Aircraft Company. In the "early" lasers the specialized coherent light was created when an electron made a transition between two sharply defined energy levels. Coherency means that all the waves making up the light are in step with each other—crest to crest and trough to trough. For the first two years, most lasers utilized ruby crystals or noble gases as the principal feature of their make-up. However, in the fall of 1962 a new type of laser, a semiconductor P-N junction laser, was introduced. In this laser the light results from electron transitions between the edges of broad energy bands. These "junctions" are pumped by feeding electrons into one side of the junction and holes into the opposite side by direct application of an electric current. This differs from the older ruby crystal and gas lasers in that the direct application of electric current makes the use of flash lamps or gas discharges unnecessary to stimulate the production of coherent light.

At the University of Illinois a team of researchers, is presently engaged in the study of these new semiconductor lasers. Professor Holonyak has been a pioneer worker in junction laser technology, having developed the first junction-diode laser to operate in the *visible* region of the spectrum. Presently extending his experimental program on these lasers in the Electrical Engineering Research Laboratory, Dr. Holonyak has a working model which is so tiny that hundreds of them can be put in a thimble. Measuring 1/100″ long, 1/50″ wide, and 1/200″ high, this tiny speck has the ability to achieve *any* wavelength between 8400 and 6400 angstrom units. In



Junction-diode lasers similar to the one in this drawing are currently studied in the University of Illinois Electrical Engineering Research Laboratory under contracts sponsored by the U.S. Air Force.

addition, the laser developed by Holonyak is remarkably efficient, compared to ruby or gas lasers, in converting electrical energy into light, and it requires relatively little accessory equipment to put it into operation. The current in this miniature laser can run up and down at kilomegacycle rates. This means that the laser is thus more versatile than previous lasers because it has a much higher speed.

Dr. Holonyak and his group at the University of Illinois are presently concentrating on improving the design of the junction-diode laser. Their emphasis, like the emphasis of most researchers in this rapidly expanding field, is mainly on attempting to understand this device better. Applications ranging from the use of lasers for an improved TV communications network to its use as an advanced tool for human surgery have been proposed by researchers in the field, but few of the devices have actually been put to use. Most laser researchers, like Dr. Holonyak, feel that possible applications for lasers are potentially vast; therefore they feel no constraint about concentrating on design improvements befor turning their attention to specific applications.

UNIVERSAL TESTING MACHINES DETERMINES THE 'WHY' OF PRODUCT FAILURE

A servo-controlled testing machine to determine not only when a product fails but *why* it fails, is now available from MB Electronics.

Product failure is just one of the investigations that can be run on the Model TM6 Universal Testing Machine. The machine can assist research, development or production engineers in studying the behavior of practically any material including metals, plastics, elastomers, ceramics, cloth and paper. It can test for tension or compression at uniform strain or load rates, bending, creep, creep-relaxation, recovery, fatigue cycling, hysteresis or any test requiring the application of a precisely known and controlled force or deflection.

The heart of the TM6 is the servo-controlled hydraulic loading system, with a closed-looop (feedback) control system to operate the high-response servo valve. Electronic commands can be linear, in steps, oscillatory or complex functions of time. The same command may be made to control either a load or an extension in length simply by selecting which sensing device (load cell, gage length extensometer or loading ram position) is used as the feedback signal.

In operation, the movable table exerts loading forces while the adjustable crosshead is used only to resist the force and to hold interchangeable load cells of capacities from grams to tons. Tension or compression loading is obtained simply by controlling the table lownward or upward from the initial non-load position. Tension, compression or fluctuating loading for fatigue or hysteresis testing is possible at rates up to 1000 cycles per minute.

Because the control console is entirely separate from the test bed, remote operation is possible for testing of dangerous materials.

The Digital Computer

(Continued from page 42)

certain level, focusing on specific bottleneck situations.

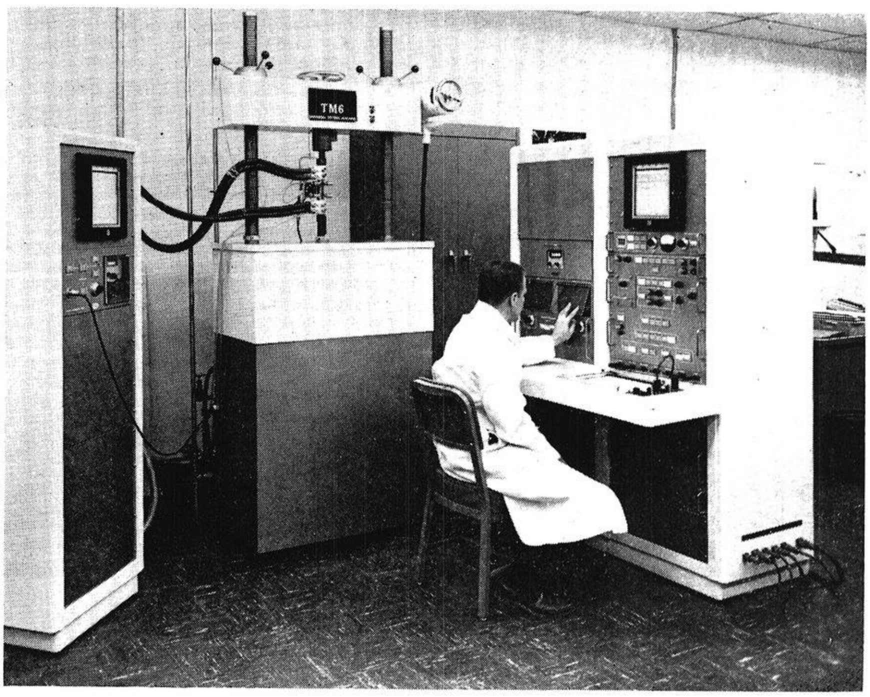
This description is by no means a utopia for man. If anything, as with the industrial revolution, more responsibility will be placed on his shoulders. Just as the industrial revolution relieved man's muscles, so the automation revolution will free his mind and new uses will be found for this thing called man.

Toward Your B.S. Degree

(Continued from page 39)

notized than men. They are somewhat more apt to suffer from migraine headaches: a typical migrain victim, according to Dr. Schifferes, is a little woman with fine hair, a smooth complexion—and perfectionist tendencies! Woman are sick about 20% more often than men, yet at any age, the female death rate is at least 25% lower than the male's!

Is it *ever* a man's world? Yes—few people realize that 105 boys are born for every 100 girls.



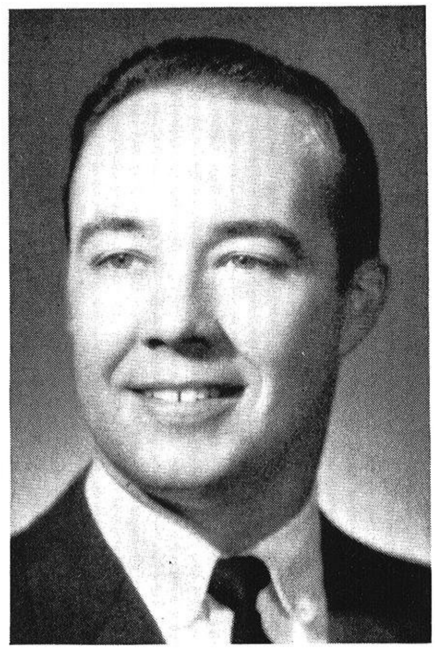
One of the first installations of the TM6 Universal Testing Machine is at a laboratory devoted to development of missiles. Here, materials and parts for missiles are tested for their ability to withstand the simulated effects of space flight. The test bed is in the center. At the right is the electronic control console. At the left is the power source and controller for tests conducted under high temperatures.

B-52. 8-engine jet bomber with range of over 9000 miles. Backbone of the Strategic Air Command.

THESE GRADUATES THRIVE ON CREATIVE CHALLENGES...THEY'RE

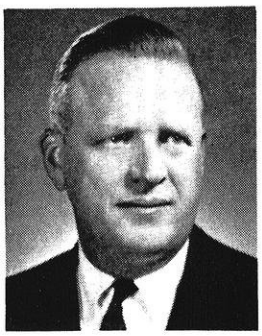
PROJECT MANAGEMENT
V. H. Simson
Iowa State University—BSEE—1948

MANUFACTURING ENGINEERING
R. A. Busby
University of Michigan—BSME—1952



DEVELOPMENT ENGINEERING
R. P. Potter
University of Illinois—BSME—1959

There's an exciting challenge ahead for you



K. M. Nelson, Manager—Industrial Control Sales, discusses the functioning of Cutler-Hammer's automation teams, and how creative graduates contribute to pioneering developments.

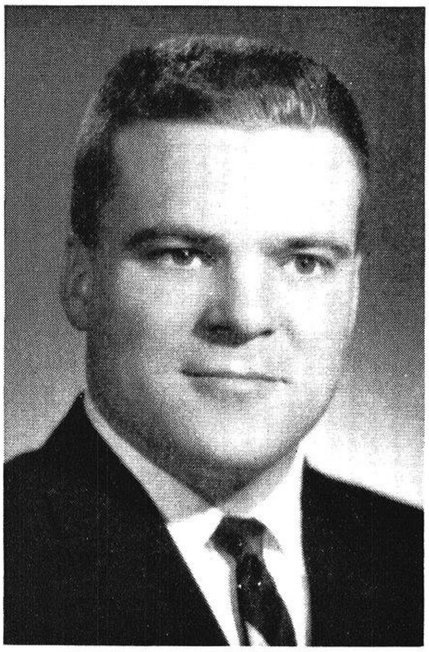
For over sixty years Cutler-Hammer has been a key contributor in planning automatic systems—now called automation.

To meet the pressing challenge of rapidly expanding industrial automation, we have formed a number of automation project teams. These teams combine the technical and manufacturing talents of versatile, seasoned specialists and young, creative-minded engineering and business administration graduates.

Their primary job: to make sure that a customer's automation investment pays an adequate return.

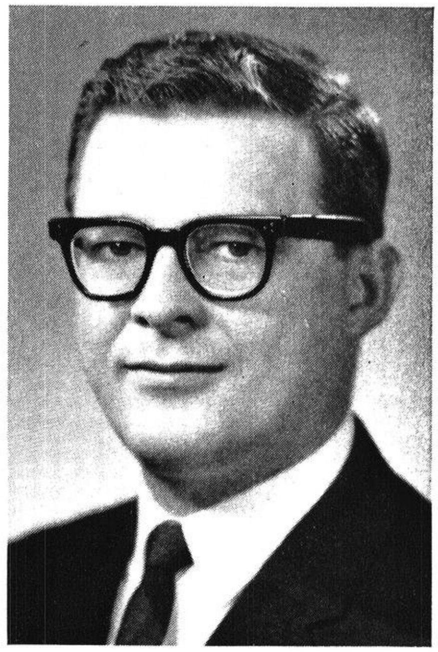
How do they meet this challenge? By working with customer engineers and consultants to isolate cost problems in manufacturing and warehousing operations. Then, by applying their individual disciplines and creative ingenuity to build common-

AUTOMATION PROBLEM SOLVERS



CONTROL ENGINEERING
B. O. Rae
University of Wisconsin—BSEE—1957

SALES ENGINEERING
J. B. Hewitt
University of Colorado—BSME—1957



ANALYTICAL ACCOUNTING
D. R. King
University of Wisconsin—BBA—1957

too, on a Cutler-Hammer automation team

sense automation proposals that can be justified economically.

Automation teams work together in a modern 500,000 square foot plant specifically designed to house every activity involved in the evolution of a system . . . in a creative climate that is conducive to imaginative planning and development.

This approach has paid off! Though industry has barely scratched the surface of the automation potential, our credentials already are quite impressive. Jobs such as the U.S. Post Office mail handling systems in 14 major cities; a pallet handling system for a mail-order firm; data accumulation systems for large steel producers; a number of automobile body-line systems; bundle-handling systems for 30 major newspaper mail rooms; and a package-handling system for a prominent publisher are just a few examples of our automation planning skill at work.

What are the advantages to the young, creative-minded graduate? Short range, it's an exceptional opportunity for the man who responds to the challenge of finding new solutions to tough manufacturing problems. Long range, being a key member of a Cutler-Hammer automation team is an excellent way to get the diversified experience so essential to steady career development and future advancement.

Want to know more? Write today to T. B. Jochem, Cutler-Hammer, Milwaukee, Wisconsin for complete information. And, plan to meet with our representative when he visits your campus.

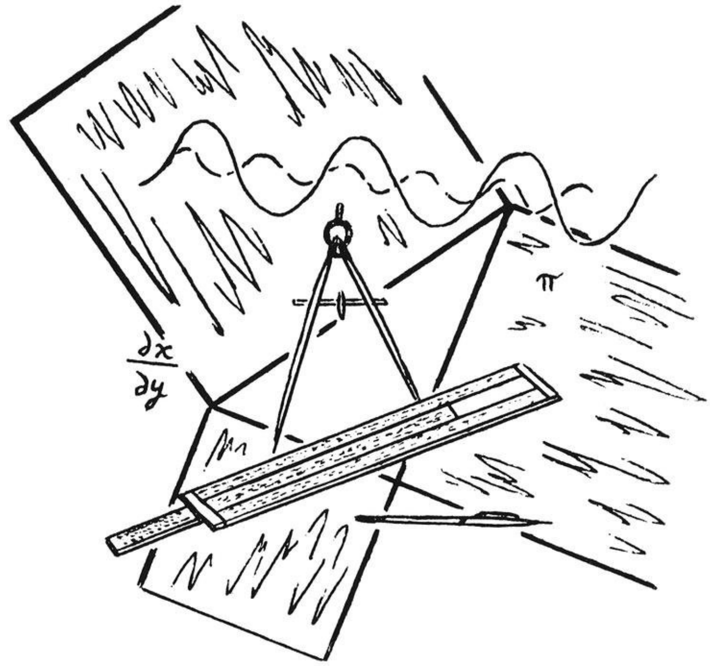
CUTLER-HAMMER
AN EQUAL OPPORTUNITY EMPLOYER

WHAT'S NEW? ASK...

CUTLER-HAMMER

Cutler-Hammer Inc., Milwaukee, Wisconsin • Divisions: AIL; Mullenbach; Thayer Scale • Subsidiaries: Uni-Bus., Inc.: Cutler-Hammer International, C. A. Associates: Cutler-Hammer Canada, Ltd.; Cutler-Hammer, Mexicana, S. A.

THE MENTAL MAZE



By Clifton Fonstad, Jr., EE'65

THIS month we are proud to announce that history's first Maze Master has been selected. Not only that, but the second one will soon be chosen and you have an excellent chance to be the third. If you know of a way to spend five dollars you'll want to check the "answers" section to get full details on our contest, awards, and cash.

Now, let's get started on the first puzzle—the first turn in this month's Mental Maze.

1. The latest report from Tioga Tech this month is that the students have been studying so hard that there has been a rash of diseases. In one class of 100 people, 85 percent had colds, 79 percent had the flu, and 63 percent had mono. Can you figure out the least number in the class who must have all three?

2. Here's a relatively simple proof that 2 = 1. Many such proofs make the error of dividing by zero. Here, use is made of the fact that if you have two quantities multiplying the same thing on either side of an equality, the two quantities are equal.

FOR EXAMPLE:

$$3 \cdot X = 3 \cdot 4$$

implies X = 4. The forth step uses this theorm. Now for the proof:

Say $a = b$
Multiply $a^2 = ab$
Subtract $a^2 - b^2 = ab - b^2$
Factor $(a + b)(a - b) = b(a - b)$
Theorm $a + b = b$
Substitute $a + a = a = 2a$
$1 = 2$

We didn't divide by zero and thus everything is ok.

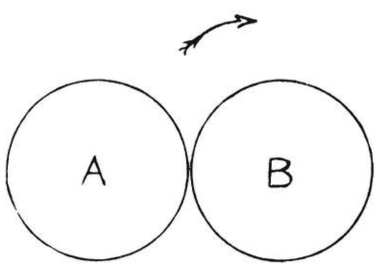
3. Manipulating and playing with numbers can be fascinating. As an elementary beginning, try this next problem:

Using five 2's and any operational signs you want make seven.

2 2 2 2 2 = 7

We know two solutions. Can you find them? More?

4. Look at the drawing of the two non-slip gears below.



If B remains stationary as A goes around it once, how many revolutions does A make?

5. Now, look at this logic puzzle. Four men, one known to have committed a crime, made the following statements to the police:

Archie: Dave did it.
Dave: Tony did it.
Gus: I didn't do it.
Tony: Dave lied.

If only one statement is true, who is guilty?

If only one statement is false, who is guilty?

6. This problem can be stated simply, but the solution may give you some trouble. The problem is to select four weights of varying sizes that will allow you to weigh all integral amounts from one to forty pounds on a scale balance. Can you do it?

ANSWERS:

The February answers are:

1. B
2. 3 boys, 4 girls
3. Use a lens and burn the thread.
4. There's no dirt in a hole.
5. 13 karts

This month's collection of puzzles represents the third in our series of "Mental Maze" contests. To win five dollars and the coveted title of Maze Master all you need do is be the first person to send the correct answers to Clifton Fonstad, Jr., % Wisconsin Engineer, 333 Mechanical Engineering Building, U. of W., Madison, Wisconsin.

Now we can't hold back any longer. The first Maze Master is Mark M. Hanneman of 10 South Orchard Street, Madison, Wisconsin 53715. Mark is a junior M.E. (with five dollars in his pocket).

Define Your Career Objectives!

■ An interview with W. Scott Hill, Manager—Engineering Recruiting, General Electric Co.

W. Scott Hill

Q. Mr. Hill, when is the best time to begin making decisions on my career objectives?

A. When you selected a technical discipline, you made one of your important career decisions. This defined the general area in which you will probably begin your professional work, whether in a job or through further study at the graduate level.

Q. Can you suggest some factors that might influence my career choice?

A. By the time you have reached your senior year in college, you know certain things about yourself that are going to be important. If you have a strong technical orientation and like problem solving, there are many good engineering career choices in all functions of industry: design and development; manufacturing and technical marketing. If you enjoy exploring theoretical concepts, perhaps research—on one of the many levels to be found in industry—is a career choice to consider. And don't think any one area offers a great deal more opportunity for your talent than another. They all need top creative engineering skill and the ability to deal successfully with people.

Q. After I've evaluated my own abilities, how do I judge realistically what I can do with them?

A. I'm sure you're already getting all the information you can on career fields related to your discipline. Don't overlook your family, friends and acquaintances, especially recent graduates, as sources of information. Have you made full use of your faculty and placement office for advice? Information is available in the technical journals and society publications. Read them to see what firms are contributing to advancement in your field, and how. Review the files in your placement office for company literature. This can tell you a great deal about openings and programs, career areas and company organization.

Q. Can you suggest what criteria I can apply in relating this information to my own career prospects?

A. In appraising opportunities, apply criteria important to you. Is location important? What level of income would you like to attain? What is the scope of opportunity of the firm you'll select? Should you trade off starting salary against long-term potential? These are things you must decide for yourself.

Q. Can companies like General Electric assure me of a correct career choice?

A. It costs industry a great deal of money to hire a young engineer and start him on a career path. So, very selfishly, we'll be doing everything possible to be sure at the beginning that the choice is right for you. But a bad mistake can cost you even more in lost time and income. General Electric's concept of Personalized Career Planning is to recognize that your decisions will be largely determined by your individual abilities, inclinations, and ambitions. This Company's unusual diversity offers you great flexibility in deciding where you want to start, how you want to start and what you want to accomplish. You will be encouraged to develop to the fullest extent of your capability—to achieve your career objectives, or revise them as your abilities are more fully revealed to you. Make sure you set your goals realistically. But be sure you don't set your sights too low.

FOR MORE INFORMATION on G.E.'s concept of Personalized Career Planning, and for material that will help you define your opportunity at General Electric, write Mr. Hill at this address: General Electric Co., Section 699-10, Schenectady, N. Y. 12305.

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