file

General Electric News

Friday, March 6, 1959

Production

Friday, March 6, 1959 GENERAL ELE

A 306 ANALOG COMPUTER was donated last week by the Computer Department to the University of Arizona at Tucson. Grouped around the machine at the time of presentation last Friday were L to R: Bob Wooley, mgr.-business and scientific subsection of eng.; Dr. Richard Harvill, the University's president; Dr. Wayne Wymore, director of the University's numerical analysis lab; Dr. Thomas Martin, dean of the college of engineering, and Elza Kuhlman, special projects engineer of our eng. section. General Manager Clair Lasher said the gift was presented "in keeping with our desire to assist educational institutions with their undergraduate and graduate engineering programs." The machine, which can be plugged in any 115-volt AC outlet, can be used conveniently to solve practical laboratory problems in areas of interest to the University's business administration people as well as a mathematical tool for solving various other problems. These solutions can be produced in a tiny fraction of the time required by conventional methods, with answers accurate to within three per cent.

file
Production

March 4, 1959

Professor William Spafford
Rensselaer Polytechnic Institute
Management Engineering Department
Troy, New York

Dear Professor Spafford:

I heard from Dean Bouton recently that you were the recipient of a General Electric 306 ("Productron") computer. I certainly feel that this was a fine gesture on the part of the Computer Department and I am sure that the machine will be useful in your work.

I thought you might be interested in the fact that the organization of which I am a part -- Production Control Service (a section of Manufacturing Services) -- was instrumental in determining the specifications of the machine, in having it manufactured and in promoting its internal sale. Mr. H. F. Dickie, Manager - Production Control Service, had the original idea that such a machine would prove useful. Mr. T. F. Kavanagh, an electrical engineer from Manhattan College, and I worked on the requirements and specifications. We consulted with the General Engineering Laboratory in the actual design of the machine and the construction of a prototype. We then prepared a one-day program to introduce the machine's capabilities to interested Company people. I have attached a copy of the speeches that were given during that one-day presentation (attachment 1).

After this, Mr. Kavanagh and another member of our organization, Mr. A. J. Rowe, toured the Company discussing applications of this machine with various departments. As a result of this work, the Computer Department felt it worthwhile to manufacture an initial batch of ten computers.

One of the most interesting applications of the machine is in the Appliance Motor Department in DeKalb, Illinois. I have enclosed a brief write-up discussing their use of this machine (attachment 2, 3).

I should be very interested in hearing about any new applications that you find for the machine, since we would still like to find greater use for it both within the Company and outside.

Give my best regards to Rose.

Very truly yours,

Burton Grad, Technical Counselor
PRODUCTION CONTROL SERVICE
Room 2409 - ext. 3530

BG/pd

enc. (3)

"The Productron Analog Computer" prepared by Industrial Computer Section of Electronics Division
PROduction CONtrol Information Letter, Volume 3, No. 1, March 27, 1957
"Load Capacity Analysis at Appliance Motor Department, DeKalk, Illinois by A. J. Rowe, 1/16/57

PRO & CON features

Supplement #12 March 27, 1957

PRODUCTRON: ANALOG COMPUTER FOR FACTORY LOAD ANALYSIS

T. F. Kavanagh
Specialist - Production Control
Production Control Service

THE CONTENTS:

THE IMPORTANCE OF SCHEDULING

Having observed the manufacturing activities of General Electric operating departments for several years, Art Vinson, Vice President, Manufacturing Services, has noticed on several occasions that there was a high correlation between success in business and success in scheduling. Conversely, it was his finding that departments in difficulty almost invariably had poor scheduling systems, characterized by inadequate personnel and questionable techniques. Sound scheduling practices are prerequisite to the proper utilization of men, machines and materials in an integrated manufacturing program. Consider for a moment two production schedules for the same plant; the first results in something akin to chaos; customer deliveries are missed; overtime in one area is matched by idle time in others; extra costs erode profits. The other schedule meets customer promises without undue extra cost and results in profit. What is the difference between these two manufacturing plans? The men, machines and materials were the same, but the timing was different. Bottlenecks developed because the effect of product mix was not adequately analyzed. Time, the all-important fourth dimension of the manufacturing plan, was not given adequate consideration.

In the past, long manufacturing cycles characterized industry; scheduling was not considered too critical. Currently, however, every trend in our economy militates against a casual approach to production scheduling. In recent years, the capital requirements of business have risen sharply, and as we enter the age of automation, we can only speculate on the financial requirements of the future. We can, however, be certain that a good return on investment will necessitate increased utilization of equipment. The advent of the guaranteed annual wage promises further penalties for poor scheduling; as a result, labor costs will no longer vary directly with the level of output. Perhaps the most important factor spotlighting scheduling is beating competition. The highly competitive post-war years have brought requirements for shorter, more reliable deliveries. These demands of King Customer must be met to remain a significant force in business. This requires more accurate knowledge of the effects of scheduling decisions on manufacturing facilities – when the actual commitments are made. Accurate production scheduling is no longer a glint in the industrial engineer's eye; it is now a recognized competitive tool.

PRODUCTION SCHEDULING

Production Scheduling may be defined broadly as planning the use of your facilities – men, machines, and materials, to obtain maximum long-range profit. It is the what, when, where and how many of the products to be produced in a set of time periods. Often it is expressed as a quantity of products to be "shipped out the back door" per day or week. It may specify the weekly production rate for the entire plant or be a simple list of parts to be completed by the end of the day. Regardless of its shape or form, it is designed to answer the universal manufacturing question of executives, foremen, or machine operators, "What are we going to make next?"

In one proposed solution the scheduling problem is divided into three closely related components:

- The Master Schedule which specifies the quantity and type of products which are to be shipped during a series of time periods;
- The Materials Schedule which sets forth the quantity of components and raw stocks to be purchased to support the master schedule; and
- The Manufacturing Schedule which states the plan of work for each manufacturing section, specifying the quantity of parts to be manufactured and the time sequence in which the operations are to be performed.

While these components are closely interwoven, each has its own specific problems. Materials Scheduling faces the difficulty of analyzing and evaluating market conditions. Manufacturing Scheduling is complicated by lot-size and job-sequencing, which have a direct bearing on product cost. Despite these detailed problems, it is Master Scheduling that determines the over-all success or failure of the manufacturing plan.

THE MASTER SCHEDULE

Optimum utilization of men and machines cannot be accomplished without adequate means for determining in advance the effects of scheduling decisions on factory capabilities. Hence, the true function of the Master Schedule is to evaluate the feasibility and desirability of proposed scheduling plans. The decisions made are critical, for once the Master Schedule is set, subsequent materials procurement and manufacturing schedules are tied directly to it. The proper master scheduling decisions required to meet customer demands as well as insure profit can be substantially removed from the realm of intuition by utilizing load-capacity analysis techniques. To perform a load-capacity analysis, we must know first our factory capacity; second, understand the unit load-impact of each product on factory capacity and finally, we must have a proposed schedule of product requirements.

CAPACITY

Capacity is the planned availability of manufacturing facilities in forthcoming time periods. It can be developed analytically by examining the basic machine time available and compensating for such factors as operator efficiency, absenteeism, machine break-down, set-up time, vacations, etc. This somewhat academic approach results in a "theoretical factory capacity." From a practical, realistic standpoint, capacity should be a measured phenomenon. Despite the somewhat unpredictable behavior of each factor reducing capacity mentioned above, the aggregate effect is remarkably constant. Thus, the best possible way to learn the factories' capabilities under various operating conditions is by observation and historical analysis of performance.

UNIT LOAD IMPACTS

Unit load impact is the machine time and labor required by each type of product at each significant work-station in each time period. Generally, the load impacts can be summed readily from standard time data for the various parts and assemblies, bearing in mind the obvious precaution that load and capacity should be expressed on the same basis. Typically, at this stage in the scheduling operation, it is possible to ignore individual components. Similarly set-up costs often are averaged as one of many factors reducing capacity. For example, a product (all parts) is said to have "X" hours of lathe work in certain time periods, hence the term "unit load impact."

LOAD-CAPACITY ANALYSIS

Next, comes the laborious aspect of the problem: performing a LOAD-CAPACITY ANALYSIS. To analyze the effect of a set of production requirements on each work-station, it is necessary to multiply the quantity of each product scheduled by its unit load impact at each of the work-stations. All the individual load impacts for each work-station must then be added together to determine the total load on that workstation. Naturally, as the number of products to be analyzed and the number of work-stations increase, this problem rapidly becomes preposterous in size. From the outset care must be exercised to make certain the problem remains within manageable proportions. All elements of load-capacity analysis must be reviewed to determine their relative importance in the over-all solution. An analysis of various product departments in General Electric indicated that a substantial contribution could be made in being able to evaluate the load impact of 50 products or model families at 25 work-stations.

MORE LIMITING ITEMS

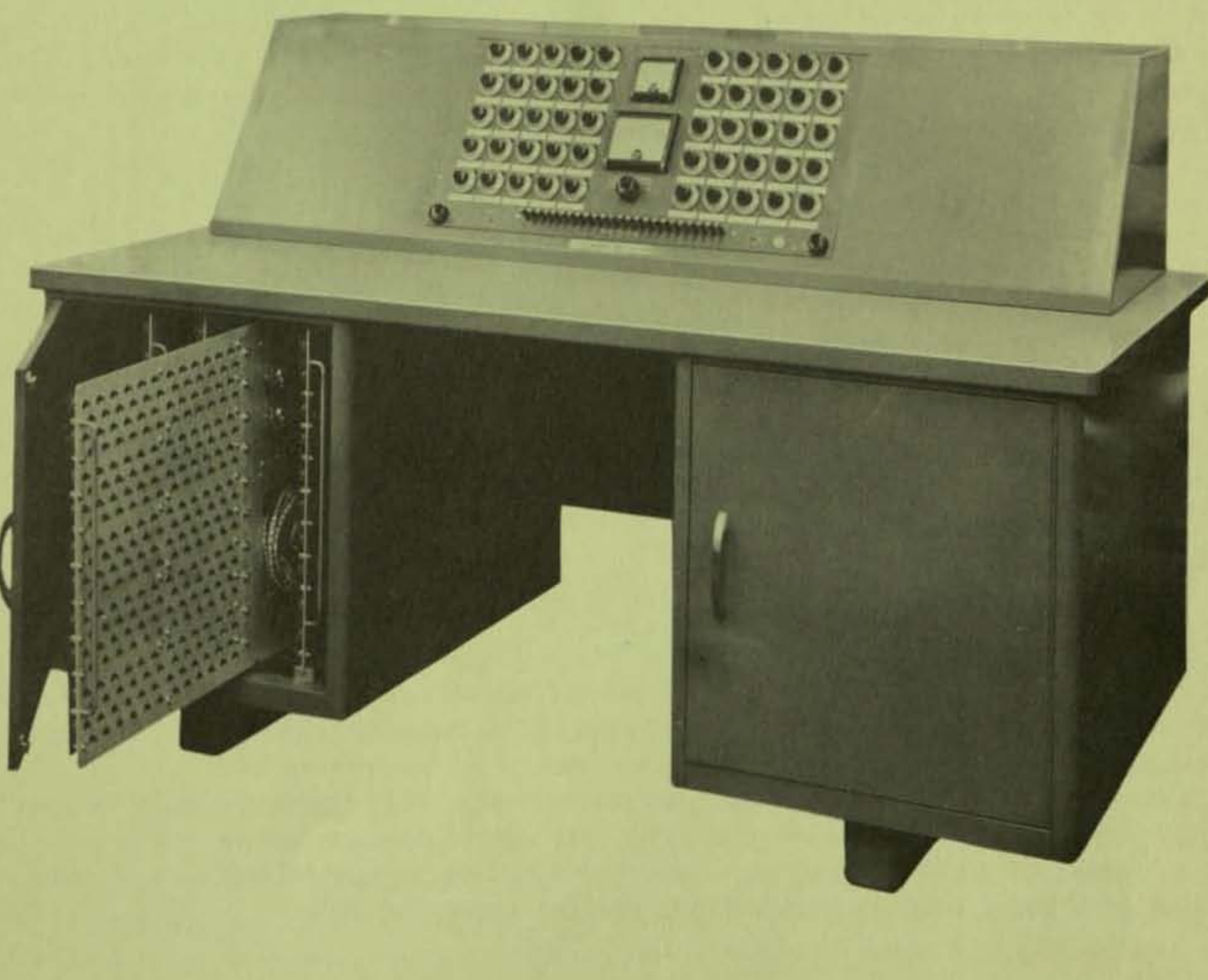
To this point discussion has centered around the technical aspects of the Load-Capacity Analysis problem. To completely understand the framework which pointed toward a new answer, a small special purpose computer called PRODUCTRON, two additional factors must be understood. First, General Electric's decentralization has created a multiplicity of operating departments, completely independent, wholly responsible, but of necessity somewhat small operating units. Many have been decentralized geographically, as well as organizationally. The second factor is timeliness. To achieve maximum effectiveness, load-capacity analyses must be performed quickly because customers are waiting on a commitment; the answer must be forthcoming from the factory – and fast. It was a combination of these two over-riding considerations which made those working on this problem feel from the beginning that something new was needed. Large scale digital computers, although ideally suited to solve the problem, were prohibitive in cost. Manual techniques applied to the fifty product, twenty-five work-station problem, proved not only lengthy but also of questionable accuracy. While punched card techniques were very applicable, they were somewhat time consuming, and few production control groups in General Electric could afford their own equipment. Often it was a case of "waiting one's turn" to get on the machines. This meant work would be done on the second shift; a day would pass before there would be an answer. The opportunity to suggest more profitable alternatives had passed by. Hence, something new and different seemed in order to . . . handle 50 products . . . 25 work-stations . . . cost less than \$15,000 . . . read out the answers in less than 5 minutes. The solution was PRODUCTRON.

PRODUCTRON – WHAT IS IT?

Now at last what is PRODUCTRON? First, PRODUCTRON is no "cure-all" general purpose computer; it is a small special purpose analog computer whose function is to handle load-capacity analysis problems. The computer is wholly contained within a desk-size console and is designed so that the only installation work required is to place the power cord into an ordinary 115V wall socket. Conspicuous by their absence are costly air-conditioning units, separate power supplies, and a host of other elaborate, complicated accessories normally associated with computers. This is significant for two reasons. Quite obviously, such accessories cost a substantial amount of money. Being able to do without them was essential to remain within the \$15,000 target, a figure which reflected the limited budgets of smaller businesses. It is also important, for it illustrates concretely the simplicity in PRODUCTRON's design. The complicated electronic and mechanical equipment which has almost become synonymous with the word "computer" just does not exist in PRODUCTRON. It utilizes fundamental principles of electricity which have been tried and proven many times over; to be more specific, Chm's Law.

WHAT ARE ITS COMPONENTS?

Let's look more closely at this desk-size computer (see Fig. 1). Answers, read in total load by work-station, are displayed on a meter directly in front of the operator. This instrument may be calibrated to read whatever load units a particular business would find significant - dollars, hours, barrels, pounds, etc. For uniformity and understanding, most firms work in hours. On either side of the load indicator on the PRODUCTRON console is a series of direct-reading, ten-turn potentiometers on which the production requirements are entered. The quantities for any or all of the products can be changed by merely turning these "pots" to the new product quantities for which a load-capacity analysis is required.



The unit load impacts for each product on each of the work-stations are recorded on small variable resistors. Since these quantities are not usually subject to change throughout any given series of load-capacity analyses, they have been stored on printed circuit panels in the left-hand side of the desk-type console. PRODUCTRON has 1,250 such tiny resistors, which is analogous to saying it has a 1,250-word memory. Values are set on these resistors to $\pm$ 0.5% accuracy through use of a bridge circuit, thus preserving internal accuracy while still using low-cost components. An independent $\pm$ 0.5% self-regulating power supply provides all reference electrical power requirements. This emphasis on precision components is necessary because PRODUCTRON is voltage analog – that is, it arrives at an answer by translating the elements of the problem internally into differences of electrical potential.

HOW DOES IT WORK?

To make the computer indicate total load for any given work-station, the operator depresses one of the 24 buttons which are stretched out on the console. Each push button represents one of the factory work-stations which the machine has been set-up to analyze. Once depressed, the required circuits automatically energize the load indicator to instantaneously display the total load on that particular work-station. The load on the balance of the work-stations is obtained by successive depressions of the remaining selectors.

Presented with a new set of production requirements to be evaluated, all that has to be done, assuming for the moment that there are no changes required to bring the unit load impact table up to date, would be to:

- turn on the machine
- set the production requirements on the dials across the top of the console
- check voltages
- depress work-station selector
- read load indicator

If you wish to make a complete analysis of all 25 work-stations, you would start by pushing down the first work-station selector, read the load indicator, and record the load for the first work-station. Then, depressing the second button start cycling until all stations have been recorded. The total time to read out twenty-five work-stations is less than two minutes.

A SAMPLE PROBLEM

To make things easy, let's reach into the future for a typical, but surely hypothetical, product. Let's consider the ENERSTAT – the successor to the modern-day thermostat, which will integrate the total energy requirements of the home, office, or factory of tomorrow and control their individual atomic power plants. The factory required to build ENERSTATS will have four major manufacturing areas – lathes, mills, punch press and die casting. Conveniently, the aggregate effect of absenteeism, set-up, idle-time, machine-breakdown, etc. is a constant 25%.

CAPACITY

WORK-ST'NS	NO. OF MACH.	NO. OF HRS.	LOAD FACTOR	CAPACITY (Hours)
Lathes	16	40	.75	480
Mills	10	40	.75	300
Punch Press	8	40	.75	240
Die Cast	7	80	.75	420

There are several models of ENERSTATS and analysis shows that they have the following impacts on plant facilities:

UNIT LOAD IMPACT TABLE (Hours)

Models:	A	B	C	D
Work-stations				
Lathes	.410	.510	.750	.880
Mills	.240	.310	.450	.570
Punch Press	.190	.240	.350	.370
Die Cast	.450	.550	.150	.170

To determine the total effect of a set of production requirements on the lathes, for example, it would be necessary to multiply the number of Model A's schedules by their unit load impact, add the product of Model B times its unit load impact and so on, until the total lathe load is accumulated, for example:

QUANTITY

Model	A	B	C	D
QUANTITY:	425	325	100	50

The lathe load would be:

$$(425 \times .410) + (325 \times .510) + (100 \times .750) + (50 \times .880) = 460$$

Similarly the load on the mills would be:

$$(425 \times .240) + (325 \times .310) + (100 \times .450) + (50 \times .570) = 275$$

212 hours of punch press work is needed while die casting requires 394 hours. By comparing these numbers with the figures given in the capacity table, it is seen that this is a feasible and a relatively balanced load. Should an overload condition exist, several alternatives may be examined, depending on whether the condition is long or short range; for example, work overtime, add personnel, expand facilities, etc.

Although rarely discussed, conditions of underload can be quite significant; unused facilities cost money. Similarly, the total cost of factory lay-offs is sometimes more costly than absorbing excess inventory charges.

Hand calculation of the product mix yielding optimum machine utilization is an arduous task, yet the knowledge is extremely valuable in master scheduling. Using PRODUCTRON the calculation reduces itself to a simple matter of dial turning and meter reading. In this little four-product, four-work-station example, certain facts become obvious. Models C and B are heaviest contributors to the lathe load, while models A and B are noticeably heavy in die casting. However, it is not intuitively obvious that a feasible schedule cannot be written which utilizes all mill or punch press capacity. This is important, for analysis shows that output can be increased as much as 20% by adding capacity in either the lathe section or die casting section. This information is the kind of data that rules of thumb, or experience will never supply on a 50-product, 25 work-station problem. In addition to the standard load-capacity problems described it is also possible to handle other constraints making PRODUCTRON a poor man's linear programming computer. A typical example is the multiple machine assignment problem in which both man-hours and machine-hours for the same station must be analyzed. All these applications emphasize the importance of retrial - one of the most outstanding features of this device.

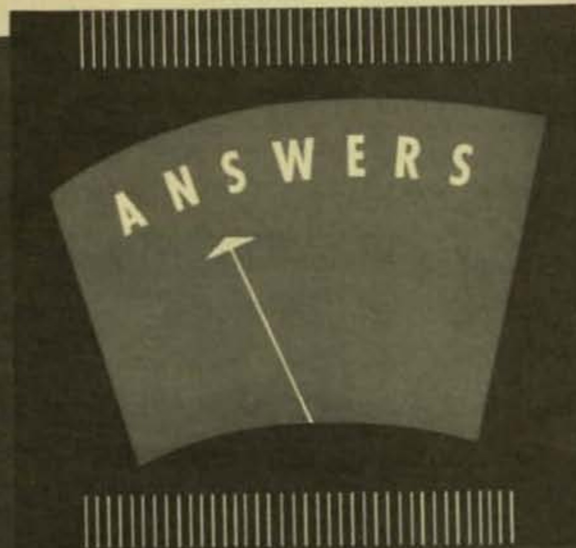
TYPICAL APPLICATIONS

Having observed briefly how the computer tackles the load-capacity analysis problem and discussed its specific area of application, let's summarize by reviewing some of the typical tasks that PRODUCTRON might be assigned. The computer is designed to help that person: production manager, sales manager, superintendent, who controls future commitments of factory capacity to make better decisions, and hence answer such questions as:

- Do we have ample capacity to handle this program?
- What stations are underloaded or overloaded?
- What products would best balance manufacturing operations, considering present committed load?
- What product mix will provide optimum machine utilization?
- What effect will proposed process changes have on present facilities?
- What effect will Make or Buy decisions have on work-station loads?
- What are plant maximum product restrictions?
- What adjustments are necessary to bring production requirements within capacity?

At present, several PRODUCTRONS are being manufactured for installation in General Electric. As of October 1, 1956, PRODUCTRON became available to industry. Further information may be obtained by writing General Electric Co., Industrial Computer Department, Marketing Section, Phoenix, Arizona.

DIAL your answers . . .



TO:

Production Schedule Analyses
Budget Syntheses
Materials Explosions
Operating Reports
and Other Business Problems

with the PRODUCTRON

ANALOG COMPUTER

GENERAL ELECTRIC

NEW PRODUCTRON

. . . An analog computer for solving business problems.

PRODUCTRON is the General Electric's complete analog computer for solving many important and time consuming office and factory business problems.

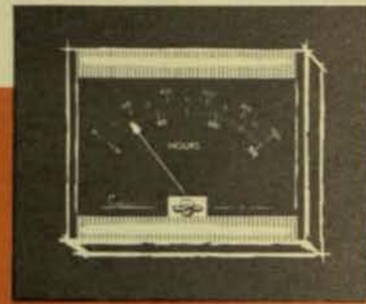
This computer is simple in design, easy to operate and contains only proved components.

The size of an average office desk, it plugs into 115 v AC power and uses less current than a TV set. No accessory equipment is required, nor is a special dust-proof, air conditioned room necessary. Normal maintenance and service costs are negligible.

The clean, simple lines of the PRODUCTRON blend with the furnishings in any office, and its rugged strength make it equally suitable on the factory floor.

After the unit has been calibrated, a trained operator can solve typical problems in about two minutes. Answers are accurate to within 3%.

- Input — Dials — Variable quantities to three significant figures are set on vernier-type dials.



- Output Instrument — Answers are read out on one of two 50-division scales.

- The PRODUCTRON'S desk size, clean lines, and rugged strength make it equally at home in office or factory.

With PRODUCTRON dial answers to such problems as:

• PRODUCTION SCHEDULE ANALYSES

- Work Station Load Impacts

  PRODUCTRON reveals the production bottle necks in time to take corrective action by indicating in a matter of minutes the load impact of up to 50 different products as they affect 24 work stations.

- Optimum Machine Utilization

  PRODUCTRON indicates the best way to utilize production facilities by analyzing the effects of variations of product mix.

- Maximum Production Limitations

  PRODUCTRON determines in advance the limitations of the manufacturing facilities for a particular schedule.

- Evaluation of Process Changes

  PRODUCTRON reveals the effects of a new design or method which changes the amount of time or number of work stations required for production.

• BUDGET SYNTHESES

PRODUCTRON quickly evaluates the effects of varying production quantities on costs, profits, floor space requirements, contributed value per sq. ft., etc.

• MATERIAL EXPLOSION

PRODUCTRON indicates what to order and what to produce to meet a given production schedule and the correct inventory to be maintained.

• OPERATING REPORTS

PRODUCTRON analyzes the effects of varying sales volumes and costs on profits.

• OTHER BUSINESS PROBLEMS

PRODUCTRON can be used to solve any problem which can be expressed in a first order linear equation.

SCOPE OF SPECIFICATIONS

The full intent of all specifications will be met in the construction of the equipment described. The General Electric Company, however, reserves the right to make any departure from the specifications for reasons of improved design.

The General Electric PRODUCTRON brings offices and factories:

SPEED — about 2 minutes for the average problem.

ACCURACY —less than 3% error.

ECONOMY — low initial cost
Low maintenance costs
No Extras (air conditioning, dust proofing, etc.)
Uses standard 115 v AC
Long life

EASY OPERATION — Set dials, push buttons, read answers. Operator can be trained in one day.

S P E C I F I C A T I O N S

PRODUCTRON is an analog computer for solving first-order linear equations. It performs multiplications and summations within a 50 x 24 Matrix. The Matrix may be expanded by the insertion of additional panels if desired.

Desk —
constructions, steel cabinet, textolite top.
size — 63" wide, 30" deep, 49" high to (top of operating board)
30" high to (top of desk)

AC input — 117 V ± 5 V, 300 — 500 watts

Output Indicating Instrument — Two special scales, one calibrated for 3,000 units, the other for 10,000.
Each scale has 50 marked divisions.

Accuracy — within 3%

Operating Conditions —
Temperature — 60F to 107F
Humidity — to 90%

Advanced engineering designs and manufacturing methods such as transistors, printed board circuits and dip soldering are used in PRODUCTRON wherever possible to reduce costs and improve reliability.

For full information or demonstration of a portable model contact:

Industrial Computer Section
Industrial Electronics Division
General Electric Company
Electronics Park
Syracuse, New York

PRODUCTRON ANALOG COMPUTER

for analyzing factory and business problems

"Set dials, Push buttons, Read answers"

- Easy Operation
- Economical
- Accurate
- Desk size
- No "extras"

For full information, contact

INDUSTRIAL COMPUTER SECTION
INDUSTRIAL ELECTRONIC DIVISION

GENERAL ELECTRIC

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In Canada, Canadian General Electric Company, Ltd., Toronto, Ont. Outside the U.S.A. and Canada, contact International General Electric Company, Electronics Sales, 150 East 42nd Street, New York 17, N. Y.

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Grad

DIAL YOUR ANSWERS . . .

TO

production schedule analyses
budget syntheses
materials explosions
operating reports and other business problems

WITH general electric's new 306 ANALOG COMPUTER

GENERAL ELECTRIC

COMPUTER DEPARTMENT

THE

306...

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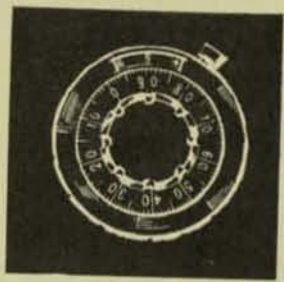
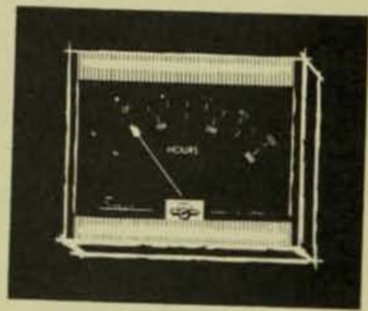
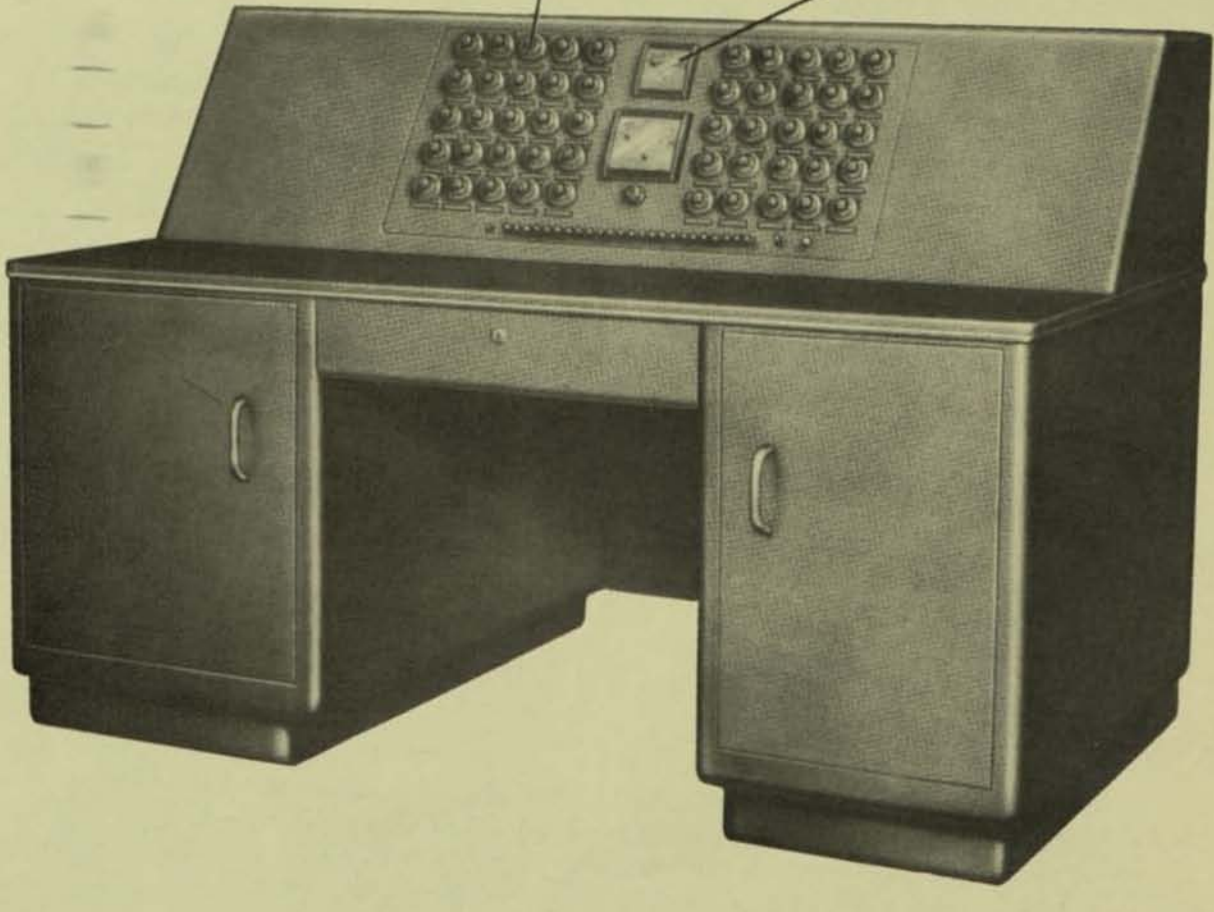
After the unit has been calibrated, a trained operator can solve typical problems in about two minutes. Answers are accurate to within 3% of full scale.

Output Instrument -- Answers are read out on one of two scales.

Input -- Dials -- Variable quantities to three significant figures are set on vernier-type dials.







WITH THE 306 YOU CAN DIAL ANSWERS TO SUCH PROBLEMS AS:

* PRODUCTION SCHEDULE ANALYSES

    * Work Station Load Impacts
      306 reveals the production bottlenecks in time to take corrective action by indicating in a matter of minutes the load impact of up to 50 different products as they affect 24 work stations.

    * Optimum Machine Utilization
      306 indicates the best way to utilize production facilities by analyzing the effects of variations of product mix.

    * Maximum Production Limitations
      306 determines in advance the limitations of the manufacturing facilities for a particular schedule.

    * Evaluation of Process Changes
      306 reveals the effects of a new design or method which changes the amount of time or number of work stations required for production.

* BUDGET SYNTHESES
  306 quickly evaluates the effects of varying production quantities on costs, profits, floor space requirements, contributed value per sq. ft., etc.

* MATERIAL EXPLOSION
  306 indicates what to order and what to produce to meet a given production schedule and the correct inventory to be maintained.

* OPERATING REPORTS
  306 analyzes the effects of varying sales volumes and costs on profits.

* OTHER BUSINESS PROBLEMS
  306 can be used to solve any problem which can be expressed as a first order linear equation.

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Output Indicating Instrument - Two special scales, one calibrated for 300 units with 60 divisions, the other for 1,000, with 50 divisions.

Accuracy - 3% of full scale.
Operating Conditions -
Temperature - 60F to 107F
Humidity - to 90%

Advanced engineering designs and manufacturing methods such as printed board circuits and dip soldering are used in the 306 wherever possible to reduce costs and improve reliability.

INQUIRE TODAY -

For application and price details contact your nearest Computer Department sales engineer:

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1103 North Central Avenue
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ALpine 4-3171

R. W. Johnson
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Syracuse, New York
GRanite 6-4411, Ext. 5125

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951 Commercial Street
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YOrkshire 8-0061

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EXecutive 3-3600, Ext. 242

T. J. O'Rourke
3325 Wilshire Blvd.
Los Angeles, California
DUnkirk 1-3641

APPLICATION AND PROGRAMS

Production Schedule Analyses

Load-capacity Analyses

The 306 can be used to reveal production bottlenecks in time to take corrective action. It does this by indicating, in a matter of minutes, the load impact of the schedule as it affects the factory work stations.

Optimum Machine Utillization

The 306 can indicate the best way to utilize production facilities by analyzing the loading effects of variations of product mix.

Maximum Production Limitations

The 306 can determine in advance the limitations of the manufacturing facilities for a particular schedule.

Evaluation of Process Changes

The 306 can reveal the effects of a new design or method which changes the amount of time or the number of work stations required for production.

Material Explosions

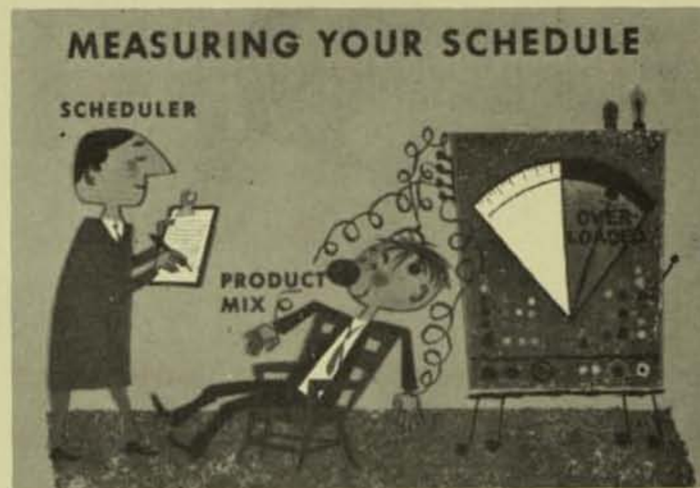
The 306 can indicate what to order and how much to order, or what to produce to meet a given production schedule and to maintain correct inventory.

Budget Syntheses

The 306 can quickly evaluate the effects of varying production quantities on such items as costs, profits, floor space requirements, and contributed value per square foot.

Operating Reports

The 306 can analyze the effects of varying sales volumes and costs on profits.



PRODUCTION SCHEDULE ANALYSES

The foundation of a sound manufacturing plan is sound production scheduling. Scheduling is the art of planning the use of the productive elements in order to obtain the greatest long-range profit.

As the era of automation arrives, improved manufacturing scheduling becomes necessary, since

1. Automation requires a higher fixed investment which, in turn, necessitates efficient utilization

2. Automated equipment is less flexible and therefore requires planned usage

3. Competition forces shorter and more reliable production

Load-capacity Analysis

Load-capacity analysis is the measurement of the feasibility of a scheduling plan. Good scheduling cannot be realized without adequate and accurate means of determining ahead of time the results of scheduling decisions. This measurement is the basis for planning the expenditure of money, of building inventory, and of promising delivery to customers. The three basic elements of a load-capacity analysis are:

1. Schedule - product demand

2. Load Impact - the loading that each product causes on each work station

3. Capacity - the planned availability of the productive elements.

Load-capacity analysis can be reduced to a straightforward mathematical problem. In order to synthesize the total load per work station for a given product schedule, the quantities of each product are multiplied by their respective loads on each work station and the resulting loads are then summed by work stations.

Thus,

The quantity of product 1 times its load at work station A

The quantity of product 2 times its load at work station A

The quantity of product 3 times its load at work station A

etc.

Total load at work station A

The quantity of product 1 times its load at work station B

The quantity of product 2 times its load at work station B

The quantity of product 3 times its load at work station B

etc.

Total load at work station B

The basic equation is

(A x B) + (C x D) + (E x F) + ... = the total load for each work station

Where A, C, E, etc., are quantities of products and B, D, F, etc., are their load impacts.

The load-capacity elements are somewhat flexible:

The product schedule can be for products, families of products (with similar loading characteristics), assemblies, components, or parts

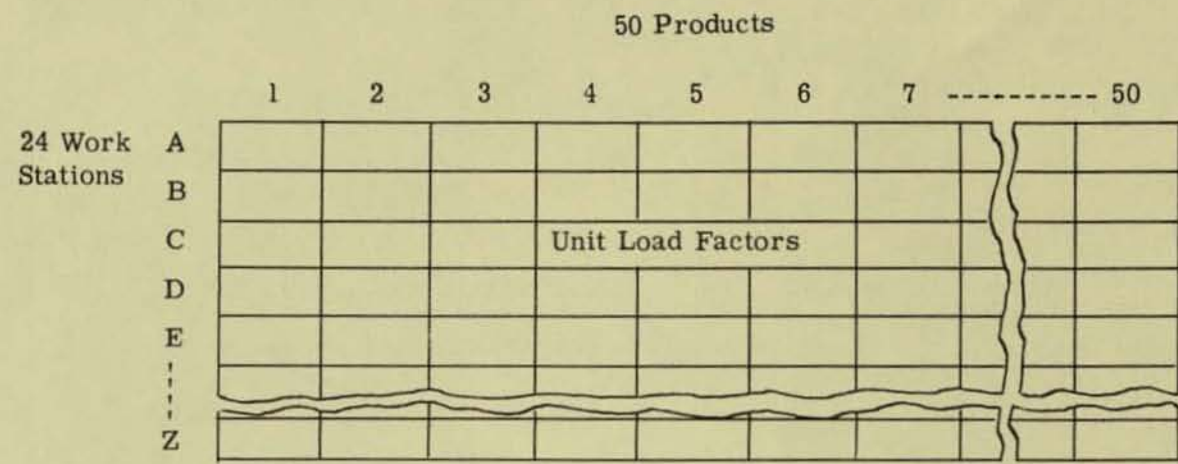
The load impact units of measure can be time, dollars, or quantities and are accurate to three significant figures

The work stations can be for shops, areas, stations, machines, or men

The time periods can be single or multiple

The operation can be job shop or flow shop.

UNIT LOAD IMPACT TABLE



The unit load impact (the loading that each product causes on each work station) information is inserted in the 1200 memory through the calibration procedure specified in the operating instructions.

The work-station capacity or productive machine hours is determined by the number of machines available, the hours to be worked per period, and the efficiency factor for each machine. For example

Lathe capacity = 16 lathes x 40 hours/week x 75 percent efficiency

= 480 lathe hours/week.

The variable product dials are then set to the scheduled quantities of each product, the respective work stations are selected, and the 306 computes the loading for each work station which is read out on the unit meter. The resulting information reveals the load-position of the facilities in relation to the proposed schedule. This information can be recorded on the suggested work sheet form (page 6).

A comparison of this load with capacity provides the information for decisions on overtime, changing the schedule, facilities expansion, subcontracting, etc.

LOAD WORK SHEET

Purpose ______
Section ______
Operator ______
Date ______

PRODUCTS

Product	1	2	3	4	5	26	27	28	29	30
Description										
Quantity										

	6	7	8	9	10	31	32	33	34	35

	11	12	13	14	15	36	37	38	39	40

	16	17	18	19	20	41	42	43	44	45

	21	22	23	24	25	46	47	48	49	50

STATIONS

Work Stations	A	B	C	D	E	F	G	H	I	J	K	L	M
Capacity													
Loading													
Over or Under													

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Optimum Production Facility Utilization

The 306 indicates the most efficient way to utilize the production facilities by analyzing the effects of variations of product mix. By trying different combinations of products through successive retrials, it is possible to maximize the load on the work stations.

The method for this solution is called iteration, which in effect is trial and error. For each successive trial (new product quantities) corrections are made for the errors observed in the preceding trials.

An abbreviated illustration of "Optimum Production Facility Utilization" is a small manufacturer producing four different products. His factory consists of four work stations such as lathes, mills, punch presses, and assembly. Let these products be designated 1, 2, 3, 4, and these work stations A, B, C, D. Previous time studies have given the load impact data in Table II. These data give the manufacturing time required by each product at each work station.

The work station capacity is determined by the same formulae as in "Load-Capacity Analysis."

The problem facing the production manager is to schedule the maximum number of each product to be manufactured each week in order to utilize these facilities to the most productive extent.

As a first approximation, assume that there are 100 each of four products. This quantity is dialed on the variable quantities dials and the computer will multiply these figures by their respective load impact data from Table II which has been placed in the memory. When the work station switches are depressed, the meter indicates a loading for work station A = 255, B = 152, C = 115, and D = 132 as shown in Table IV.

A quick comparison with capacity figures (Table I) shows that the first trial was low.

TABLE I

WORK STATION CAPACITY

Work Stations	Capacity (in hours)
A	480
B	300
C	240
D	420

TABLE II

UNIT LOAD IMPACT
(In Hours Per Unit)

Work Station	Products 1	2	3	4
A	.410	.510	.750	.880
B	.240	.310	.450	.520
C	.190	.240	.350	.370
D	.450	.550	.150	.170

For the second trial, assume 200 units of each product (Table III). At the second step it becomes evident that the loading for work station A has been exceeded. By comparing total loads, product quantities, and the unit impact tables, it is obvious that only a few additional products 3 and 4 can be manufactured since they use relatively more of the capacity of area A. However, there is D area available, so that products 1 and 2 can be increased to achieve balance of factory level.

This process is continued until, as in step 7, the optimum utilization (approximately 100% loading on each work station) is reached. It should be remembered that this example is for a small operation. Exactly the same procedure applies with up to 50 products at 24 work stations.

Thus the 306 provides the ability to optimize by checking various alternative schedules (product quantities) to compare with the original.

TABLE III

SCHEDULE OF PRODUCTS

	Products			
Trials	1	2	3	4
1	100	100	100	100
2	200	200	200	200
3	300	200	100	100
4	400	200	100	100
5	400	300	100	100
6	425	325	100	50
7	425	375	100	50

TABLE IV

FACTORY CAPACITY AND UTILIZATION

Work Station	A	B	C	D
Capacity-Hrs/Wk	480	300	240	420
Loading per Trial				
1	255	152	115	132
2	510	304	230	264
3	388	231	177	277
4	429	255	196	322
5	480	286	220	377
6	459	274	213	394
7	484	298	225	421
	101%	96%	94%	100%

Maximum Production Limitations

The 306 can determine in advance the limitations of the manufacturing facilities for a particular schedule.

In operations where a large schedule is required for marketing or business reasons, this computer examines the load on each station and indicates what and how much the work stations must be worked overtime or expanded, and whether subcontracting will be necessary.

The necessary schedule (product quantities) is dialed in, computer multiplied by their loads, totaled by each work station, and read out on the unit meter. These totals are then compared with the available capacity information for the time period involved. The limiting work stations are those where the loading exceeds the capacity and corrective action must be taken.

Evaluation of Process Changes

The 306 reveals the effect of a new design or method which changes the amount of time or number of work stations required for manufacture.

Important considerations in deciding on incorporating a new design or process change are cost, relative time, and whether new or additional equipment is required. All of these factors are related to the planned schedule.

Use of the 306 shows the comparison load effects of the current and contemplated designs or methods. Thus it enables intelligent decisions to be made.

MATERIAL EXPLOSIONS

With a product scope of a large number of products using common materials, the 306 computes the necessary material requirements for varying quantities of this range of products.

The variable quantities of all the products are multiplied by their respective material requirements (feet, pounds, volts, wire sizes, etc.) which are summarized for all the scheduled products. The totals are read on the unit meter.

In cases where the material supply is limited for a given period (i.e., shortages, long delivery cycles), a comparison can be made with the proposed schedule to determine the portion that can be produced, or by using iteration, the optimum production from this available material can be computed.

TABLE V

50 Products

		1	2	3	4	5	6 -----------	50
Materials	A							
	B							
	C	Amount of Material Required Per Product						
	D							
	⋮							
	Z							

TABLE VI

MATERIAL TOTALS

		Totals
Materials	A	
	B	
	C	
	D	
	⋮	
	Z	

BUDGET SYNTHESES

Another excellent use for the 306 is budget syntheses. Again the calculations follow in the same pattern as the load-capacity analysis calculations. Such elements as sales volume per unit, cost per unit, contributed value per square foot, finished stock area per unit of product, floor space per unit of product, box, pack and shipper product and any other constants which pertain to a given product are recorded in the memory. Then by dialing the production quantity requirements the meter will read the dollars of sales, the shipments at manufacturing cost, the total finished stock area required, the contributed value for the department and other pertinent information about the business for computation of the budget.

TABLE VII

MEMORY STANDARDS PER UNIT

	50 Products				
	1	2	3	4 ------------	50
Elements					
Cost of Sales					
Liquidation of:					
Std. Eng.					
Std. Mat.		Standards Per Unit			
Std. Labor					
Std. Overhead					
Gross Margin					
Comm. & Admin.					
Net Margin					
Etc.					

OPERATING REPORTS

A preliminary profit and loss on operating statement can be computed when factors such as margin, standard material, standard labor, standard overhead or burden, standard engineering, standard tool liquidations and other cost factors are put in the computing memory (Table VIII).

The quantity of the products sold when multiplied by the above factors in the memory will quickly compute the composite margin and the liquidations included in cost (Table VI). If summary figures of actual expenditures are secured from the accounting section, and compared with the budget over/under liquidations are then known for incorporation in the statement. Similarly, changes in inventory of material and labor can be computed for supplemental statement information.

The above elements may be expanded to include necessary and detailed information up to at least 24 categories where beneficial.

TABLE VIII

PRELIMINARY PROFIT & LOSS STATEMENT

	50 Products					Grand Total
	1	2	3	4 ---------	50	
Quantity of Products Sold						
Net Sales						
Cost of Sales						
Liquidation of:						
Std. Eng.	Totals of Product Qty.					
Std. Mat.	Times (x) Unit Factors					
Std. Labor						
Std. Overhead						
Gross Margin						
Comm. & Admin.						
Net Margin						
Etc.						

OPERATION

Requirements

The only requirements for the 306 are a source of 117-volt, 60-cycle power, an electrical ground connection, and the space allocation of an office desk.

Accessory Equipment

A calibration unit (Figure 1) is supplied for accurately setting up the memory of the 306.

No other accessory equipment is required for operating the 306.

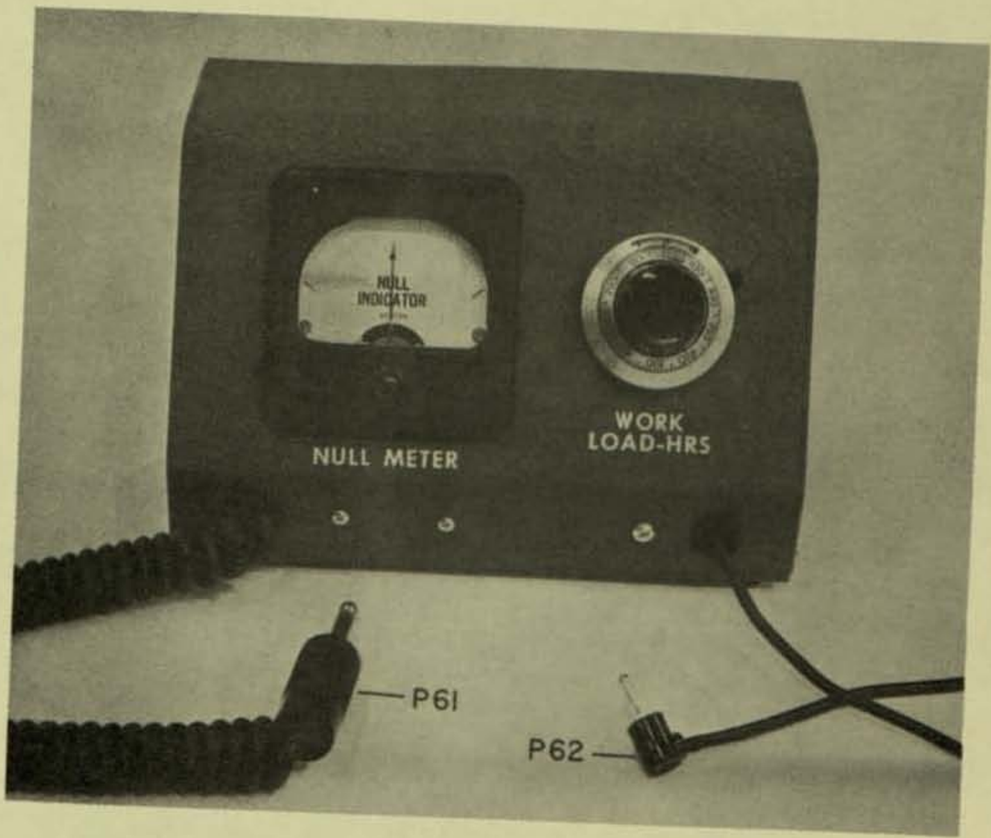


Figure 1. The Calibration Unit

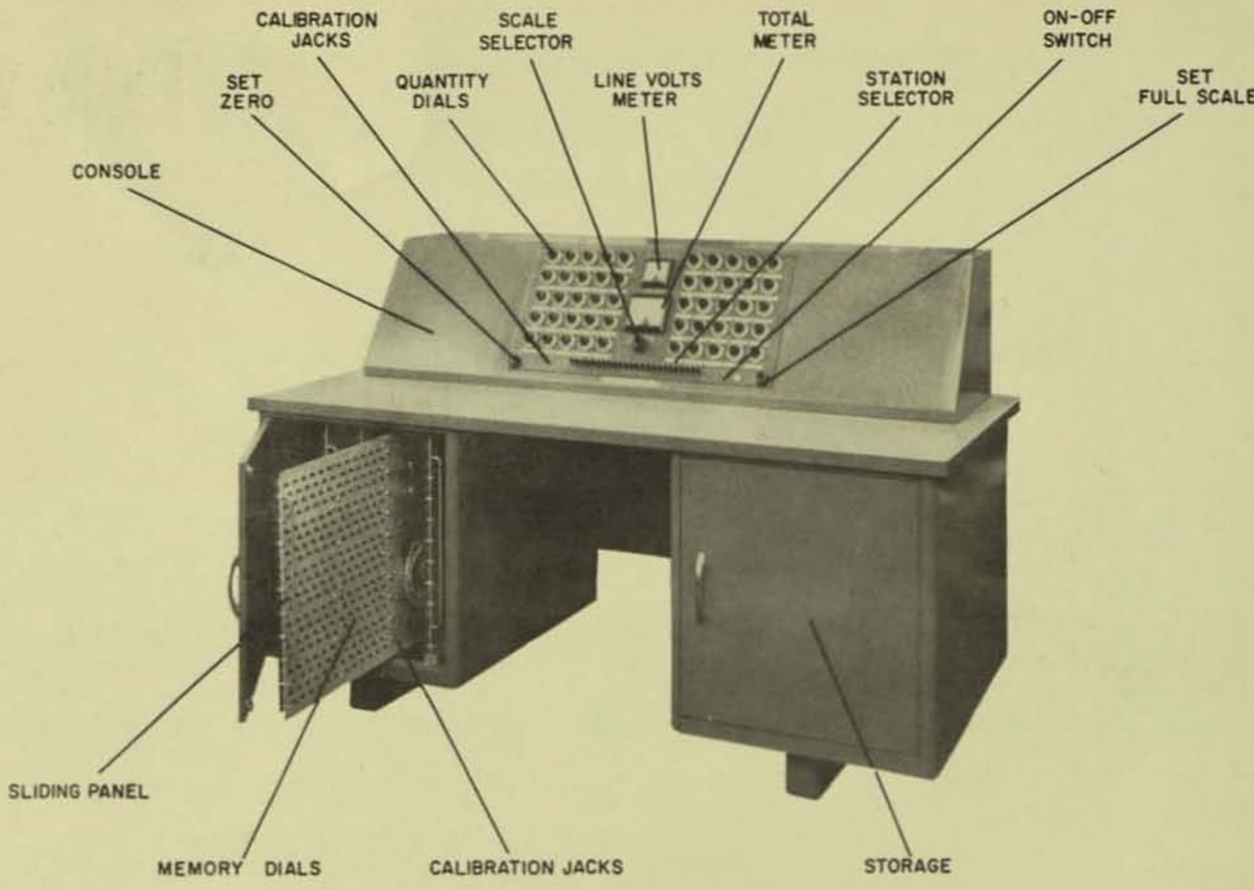


Figure 2. Front View of the 306

Controls

Figure 2 shows the controls that are used in operating the 306.

The QUANTITY dials for products 1 through 25 are located to the left of the TOTAL meter and to the right of the TOTAL meter for products 26 through 50.

The MEMORY dials for products 1 to 10 are located on sliding panel Z1; dials for products 11 to 20 are located on sliding panel Z2; 21 to 30 on panel Z3; 31 to 40 on panel Z4; 41 to 50 on panel Z5.

On each sliding panel are calibration jacks, J1 to J10, adjacent to sets of memory dials.

Calibration jack J1 on panel Z1 is used to calibrate memory dials A through Z for product 1; J2 on panel Z1 is used to calibrate memory dials A through Z for product 2; J1 on panel Z2 is used to calibrate memory dials A through Z for product 11; etc.

Figure 3. Calibration of Memory Dials

Sample Problems

1. Problem 1

   a. Set QUANTITY dials 1 through 6 to dial readings of 100.

   b. Place the calibration unit on the desk top. Slide memory panel Z1 out and plug P61 of the calibration unit into jack J1 and plug P61 into the CAL jack on the PRODUCTRON front panel.

   c. Set the dials on the calibration unit to 500 and adjust MEMORY pot "A" for Product 1 until the calibration unit null meter indicates a null.

   d. Remove P61 from J1 and insert it into J2 on panel Z1. Repeat step c with potentiometer "A" for Product 2. Continue the process for Products 2 through 6.

   e. Switch the SCALE SELECTOR successively from BLACK (x 10) to RED (c 10) to BLACK and RED. The TOTAL reading should read approximately 300 hours (on the BLACK and RED scales, the reading should be 300 hours, ±9 hours).

2. Problem 2

   a. Switch the SCALE SELECTOR to BLACK (x 10).

   b. Set QUANTITY dials 1 through 30 to 500.

   c. Repeat steps lc, ld, le for Products 1 through 30.

   d. The output instrument should read 7500 hours, $\pm$225 hours.

3. Problem 3 - Repeat the steps of Problem 2 successively for potentiometers B, then C, etc., through Z, checking each time that the proper meter readings are obtained on each scale.

4. Check Problem - The following problem set up is given to provide the operator with a check problem to use in determining the correctness of his procedure and/or the operating condition of the equipment.

The problem is to determine the load impact of five models of the same product on the same 10 factory work stations. Quantities involved are from 100 to 500 of each model, and the work content varies from 0.1 hour (six minutes) to 1 hour per unit at the various work stations.

The answers on the output instrument vary from 550 work station hours to 1900 work station hours as shown in Table IX.

TABLE IX

Model No.	Qty.	A	B	C	D	E	F	G	H	J	K	
1	100	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
2	200	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	Unit
3	300	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	Labor content
4	400	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	0.3	(hours)
5	500	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	0.3	0.4	
Total hours		550	700	850	1000	1150	1300	950	680	550	500	

To set up for solution of this problem, proceed as follows:

1. Set all QUANTITY dials to zero.
2. Set all MEMORY potentiometers to their full counterclockwise position.
3. Set SCALE SELECTOR switch to BLACK x 10.
4. Set all QUANTITY dials for Products 1 through 5 to 100 through 500, respectively.
5. Connect the calibration unit as described for "Sample Problem" lb and depress work station switch "A".
6. Set the dial on the calibration unit to 0.1 hour (full scale 1.0 hour), and adjust MEMORY potentiometer "A" for Product 1 for a null.
7. Remove P61 from J1 and insert in J2.
8. Set the dial on the calibration unit to 0.2 hour.
9. Adjust the MEMORY potentiometer "A" for Product 2 for a null.
10. Repeat steps 6, 7, and 8 for MEMORY potentiometer "A" for Products 3, 4 and 5.
11. Repeat steps 5 through 10 successively for stations B through K.
12. The TOTAL meter should read the total hours shown in Table IX.

Progress Is Our Most Important Product

GENERAL ELECTRIC

COMPUTER DEPARTMENT

PHOENIX, ARIZONA

CPB—16 (1-58, 600)

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PRODUCTRON

ANALOG COMPUTER

GENERAL ELECTRIC

operation and service

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

PRODUCTRON

ANALOG COMPUTER

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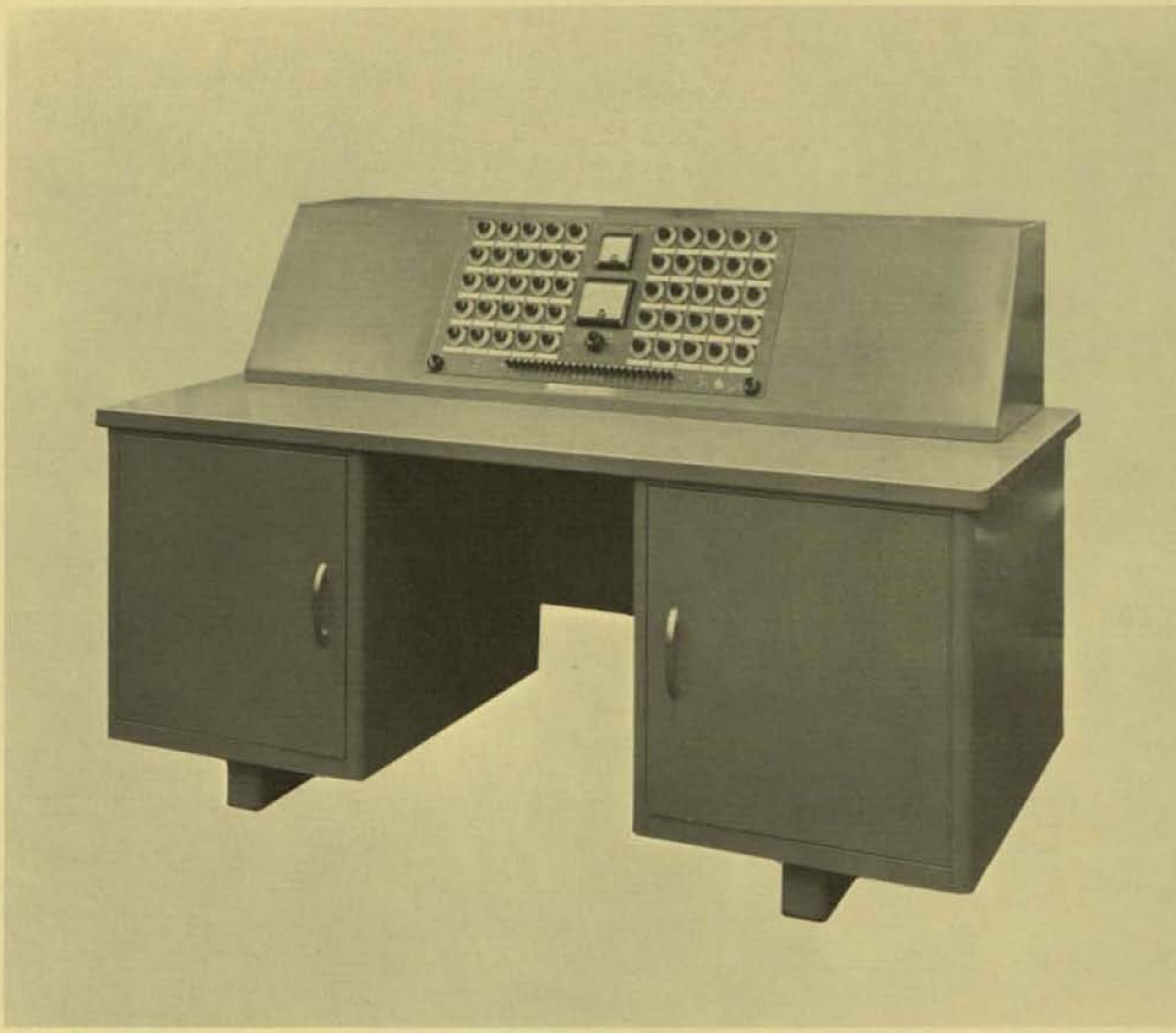
contents

Page

application and programs



application and programs

INTRODUCTION

The PRODUCTRON is a General Electric analog computer for solving instantaneously many important and time-consuming office and factory business problems.

The PRODUCTRON can solve those problems that can be expressed as first order linear equations. The PRODUCTRON has 50 variable quantity dials, 1200 memory knobs, and 24 selector positions. This versatility of design enables it to perform instantaneously a series of multiplications and summations within a 50 by 24 matrix or other matrices (such as 100 x 12, 25 x 48) whose product is 1200 or less. In addition, this basic matrix may be expanded by the insertion and usage of additional memory panels. While the PRODUCTRON was designed primarily for solving load-capacity analyses, it has proven equally capable of solving numerous other problems as discussed in the following paragraphs.

Production Schedule Analyses

Load-capacity Analyses

The PRODUCTRON can be used to reveal production bottlenecks in time to take corrective action. It does this by indicating, in a matter of minutes, the load impact of the schedule as it affects the factory work stations.

Optimum Machine Utillization

The PRODUCTRON can indicate the best way to utilize production facilities by analyzing the loading effects of variations of product mix.

Maximum Production Limitations

The PRODUCTRON can determine in advance the limitations of the manufacturing facilities for a particular schedule.

Evaluation of Process Changes

The PRODUCTRON can reveal the effects of a new design or method which changes the amount of time or the number of work stations required for production.

Material Explosions

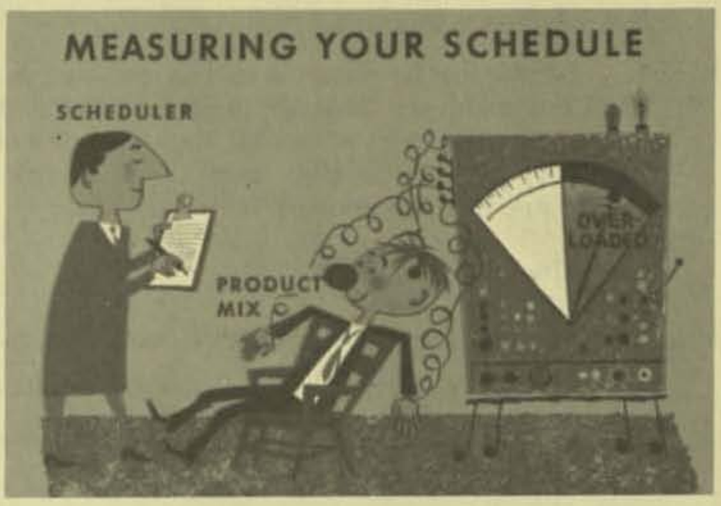
The PRODUCTRON can indicate what to order and how much to order, or what to produce to meet a given production schedule and to maintain correct inventory.

Budget Syntheses

The PRODUCTRON can quickly evaluate the effects of varying production quantities on such items as costs, profits, floor space requirements, and contributed value per square foot.

Operating Reports

The PRODUCTRON can analyze the effects of varying sales volumes and costs on profits.



PRODUCTION SCHEDULE ANALYSES

The foundation of a sound manufacturing plan is sound production scheduling. Scheduling is the art of planning the use of the productive elements in order to obtain the greatest long-range profit.

As the era of automation arrives, improved manufacturing scheduling becomes necessary, since

1. Automation requires a higher fixed investment which, in turn, necessitates efficient utilization

2. Automated equipment is less flexible and therefore requires planned usage

3. Competition forces shorter and more reliable production

Load-capacity Analysis

Load-capacity analysis is the measurement of the feasibility of a scheduling plan. Good scheduling cannot be realized without adequate and accurate means of determining ahead of time the results of scheduling decisions. This measurement is the basis for planning the expenditure of money, of building inventory, and of promising delivery to customers. The three basic elements of a load-capacity analysis are:

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2. Load Impact - the loading that each product causes on each work station

3. Capacity - the planned availability of the productive elements.

Load-capacity analysis can be reduced to a straightforward mathematical problem. In order to synthesize the total load per work station for a given product schedule, the quantities of each product are multiplied by their respective loads on each work station and the resulting loads are then summed by work stations.

Thus,

The quantity of product 1 times its load at work station A

The quantity of product 2 times its load at work station A

The quantity of product 3 times its load at work station A

etc.

Total load at work station A

The quantity of product 1 times its load at work station B

The quantity of product 2 times its load at work station B

The quantity of product 3 times its load at work station B

etc.

Total load at work station B

The basic equation is

$(A \times B) + (C \times D) + (E \times F) + \ldots\ldots =$ the total load for each work station

Where A, C, E, etc., are quantities of products and B, D, F, etc., are their load impacts.

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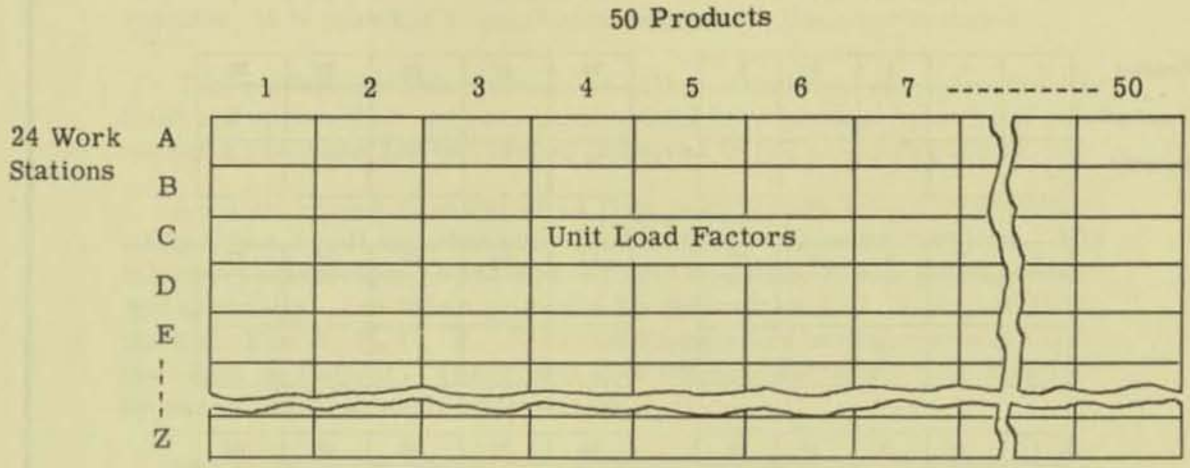

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A comparison of this load with capacity provides the information for decisions on overtime, changing the schedule, facilities expansion, subcontracting, etc.

PRODUCTRON LOAD WORK SHEET

Purpose ______
Section ______
Operator ______
Date ______

PRODUCTS

Product	1	2	3	4	5	26	27	28	29	30
Description										
Quantity										

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STATIONS

Work Stations	A	B	C	D	E	F	G	H	I	J	K	L	M
Capacity													
Loading													
Over or Under													

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

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The work station capacity is determined by the same formulae as in "Load-Capacity Analysis."

The problem facing the production manager is to schedule the maximum number of each product to be manufactured each week in order to utilize these facilities to the most productive extent.

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50 Products

		1	2	3	4	5	6 ----------- 50	
Materials	A							
	B							
	C		Amount of Material Required Per Product					
	D							
	⋮							
	Z							

TABLE VI

MATERIAL TOTALS

		Totals
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	B	
	C	
	D	
	⋮	
	Z	

BUDGET SYNTHESES

Another excellent use for the PRODUCTRON is budget synthesis. Again the calculations follow in the same pattern as the load-capacity analysis calculations. Such elements as sales volume per unit, cost per unit, contributed value per square foot, finished stock area per unit of product, floor space per unit of product, box, pack and shipper product and any other constants which pertain to a given product are recorded in the memory. Then by dialing the production quantity requirements the meter will read the dollars of sales, the shipments at manufacturing cost, the total finished stock area required, the contributed value for the department and other pertinent information about the business for computation of the budget.

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MEMORY STANDARDS PER UNIT

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Cost of Sales					
Liquidation of:					
Std. Eng.					
Std. Mat.		Standards Per Unit			
Std. Labor					
Std. Overhead					
Gross Margin					
Comm. & Admin.					
Net Margin					
Etc.					

OPERATING REPORTS

A preliminary profit and loss on operating statement can be computed when factors such as margin, standard material, standard labor, standard overhead or burden, standard engineering, standard tool liquidations and other cost factors are put in the computing memory (Table VIII).

The quantity of the products sold when multiplied by the above factors in the memory will quickly compute the composite margin and the liquidations included in cost (Table VI). If summary figures of actual expenditures are secured from the accounting section, and compared with the budget over/under liquidations are then known for incorporation in the statement. Similarly, changes in inventory of material and labor can be computed for supplemental statement information.

The above elements may be expanded to include necessary and detailed information up to at least 24 categories where beneficial.

TABLE VIII

PRELIMINARY PROFIT & LOSS STATEMENT

	50 Products						Grand
	1	2	3	4	---------	50	Total
Quantity of Products Sold							
Net Sales							
Cost of Sales							
Liquidation of:							
Std. Eng.							
Std. Mat.	Totals of Product Qty.						
Std. Labor	Times (x) Unit Factors						
Std. Overhead							
Gross Margin							
Comm. & Admin.							
Net Margin							
Etc.							

operation instructions

operation instructions

INTRODUCTION

Requirements

The only requirements for the PRODUCTRON are a source of 117-volt, 60-cycle power, an electrical ground connection, and the space allocation of an office desk.

Accessory Equipment

A calibration unit (Figure 1) is supplied for accurately setting up the memory of the PRODUCTRON.

No other accessory equipment is required for operating the PRODUCTRON.

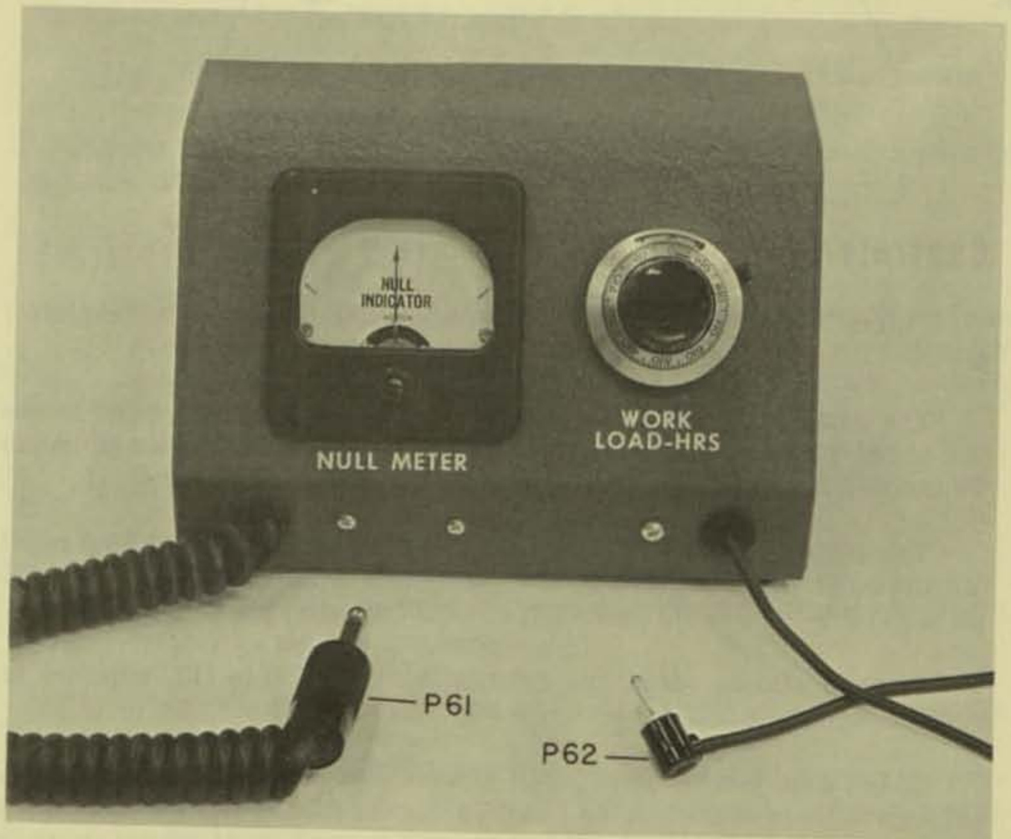


Figure 1. The Calibration Unit

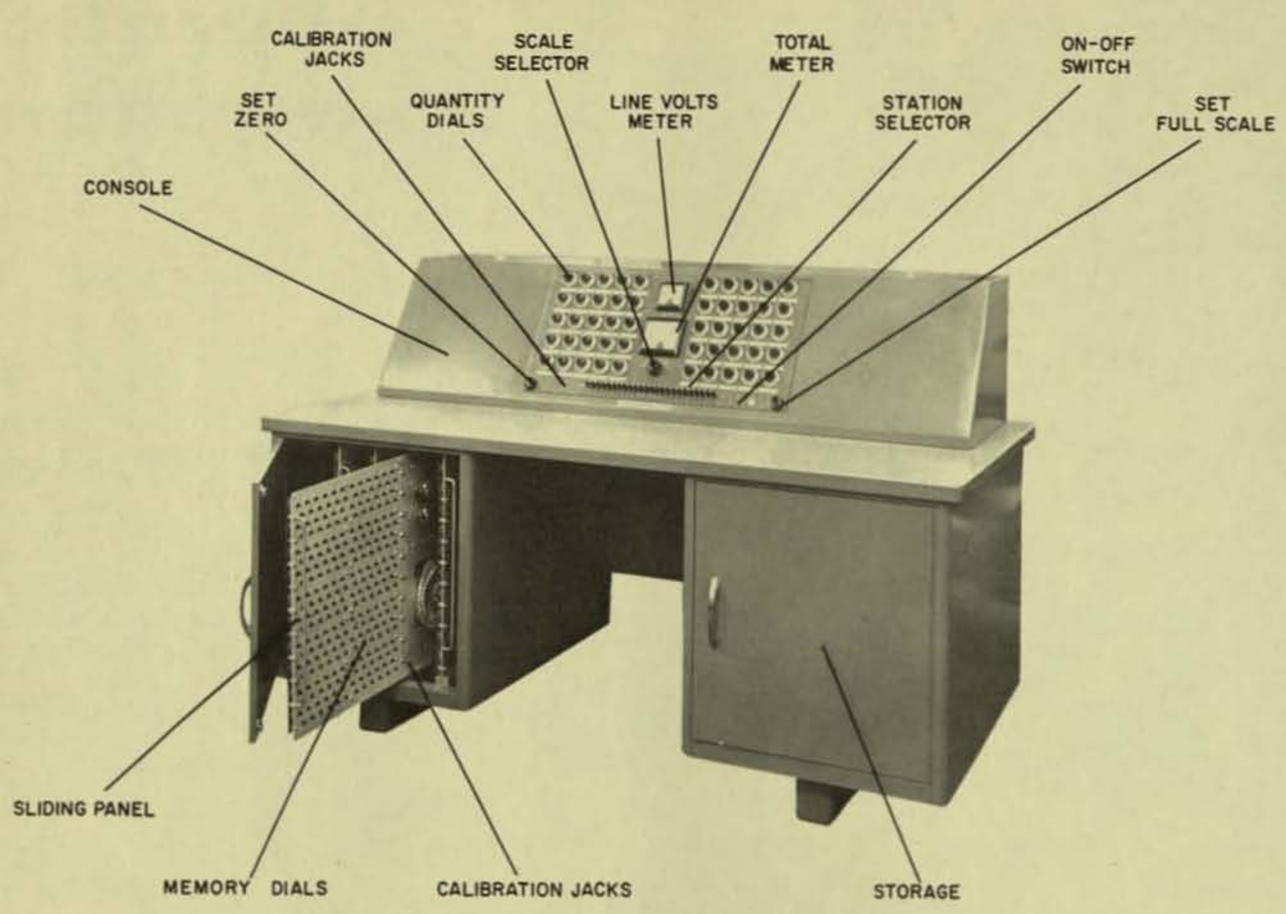


Figure 2. Front View of the PRODUCTRON

Controls

Figure 2 shows the controls that are used in operating the PRODUCTRON.

The QUANTITY dials for products 1 through 25 are located to the left of the TOTAL meter and to the right of the TOTAL meter for products 26 through 50.

The MEMORY dials for products 1 to 10 are located on sliding panel Z1; dials for products 11 to 20 are located on sliding panel Z2; 21 to 30 on panel Z3; 31 to 40 on panel Z4; 41 to 50 on panel Z5.

On each sliding panel are calibration jacks, J1 to J10, adjacent to sets of memory dials.

Calibration jack J1 on panel Z1 is used to calibrate memory dials A through Z for product 1; J2 on panel Z1 is used to calibrate memory dials A through Z for product 2; J1 on panel Z2 is used to calibrate memory dials A through Z for product 11; etc.

OPERATING PROCEDURE

Power Off

With power off, check that the power plug is connected, and that the ground wire has a good connection.

Set the SCALE SELECTOR switch at SET ZERO=

Power On

Turn the power ON-OFF switch to ON.

Check that the LINE VOLTS meter indicates 117 volts, $\pm$5 volts.

Allow the equipment to warm up for 5 minutes.

Set Zero—Set Full Scale

With the SCALE SELECTOR switch at SET ZERO, adjust the SET ZERO control until the TOTAL meter reads 0.

Set the SCALE SELECTOR at SET FULL SCALE.

Adjust the SET FULL SCALE control until the TOTAL meter pointer indicates exactly full-scale deflection.

Calibrate Memory Dials

1. Select the MEMORY dial scale factor for the problem and use this factor for all settings of the MEMORY dials. MEMORY dials at full scale represent factors of 0.1, 1, 10 (hours, dollars, parts, etc.).
2. Depress STATION A of the STATION SELECTOR.
3. Place the calibration unit on the desk top.
4. Plug P62 of the calibration unit into the CALIBRATION JACK located on the console front panel.
5. Plug P61 of the calibration unit into jack J1 of sliding panel Z1.
6. Set the CALIBRATION UNIT dial to the desired setting for product 1 at station A. Adjust the MEMORY dial "A" adjacent to jack J1 until the calibration unit null meter pointer indicates zero deflection from the null or zero position.

7. Repeat steps 5 and 6 for the "A" memory dials of products 2, 3, 4, etc., using jacks J2, J3, J4, etc.

8. After the required number of "A" memory dials have been calibrated, depress STATION B of the STATION SELECTOR and repeat steps 5, 6, and 7, adjusting the "B" MEMORY dials.

9. Repeat step 8 for STATIONS "C" through "Z".

Set Product Quantities

1. Select the QUANTITY dial scale factor for the problem and use this scale factor for all settings of product quantities. (QUANTITY dials at full scale represent quantities of 10, 100, 1000 or 10,000).

2. Set the quantity of Product 1 on QUANTITY dial 1. Repeat this procedure for the desired quantities of products 2 through 50 on dials 2 through 50.

Read Total Meter

1. The total hours for any one station is read on the TOTAL meter. There are four different full-scale readings available. With the SCALE SELECTOR switch in position BLACK (x 10), it is possible to read 10,000 full scale. With the SCALE SELECTOR switch in position RED (x 10), the full-scale reading is 3,000. The BLACK position gives a full-scale reading of 1000, and position RED gives a full-scale reading of 300.

2. These scales are based on the use of 1000 full scale for the QUANTITY dials and 1 full scale for the MEMORY dials. When scale factors other than 1000 and 1 are used, the same scale factor to the TOTAL meter reading applies. (For instance, with a scale of 100 full scale for QUANTITY dials, the TOTAL meter reading would be the indicated reading +10).

3. Always start with the SCALE SELECTOR switch in position BLACK (x 10) and observe the reading. If the output reading is less than full-scale reading of the next lower scale, switch to the next lower scale.

4. By depressing the STATION selector switch successively for stations A through Z, the impact of any product mix will be indicated on the output meter for each work station.

Precautions

1. Always start with the SCALE SELECTOR switch position at BLACK (x 10) and switch successively to lower scales as warranted by the scale indication. This procedure will prevent damaging the output instrument.

2. Be sure that all unused QUANTITY dials are set to zero dial reading and all unused MEMORY dials are in the zero (fully counterclockwise) position.

3. Be sure to use the same scale factor for all QUANTITY and MEMORY settings for any particular problem.

Sample Problems

1. Problem 1

   a. Set QUANTITY dials 1 through 6 to dial readings of 100.

   b. Place the calibration unit on the desk top. Slide memory panel Z1 out and plug P61 of the calibration unit into jack J1 and plug P61 into the CAL jack on the PRODUCTRON front panel.

   c. Set the dials on the calibration unit to 500 and adjust MEMORY pot "A" for Product 1 until the calibration unit null meter indicates a null.

   d. Remove P61 from J1 and insert it into J2 on panel Z1. Repeat step c with potentiometer "A" for Product 2. Continue the process for Products 2 through 6.

   e. Switch the SCALE SELECTOR successively from BLACK (x 10) to RED (c 10) to BLACK and RED. The TOTAL reading should read approximately 300 hours (on the BLACK and RED scales, the reading should be 300 hours, ± 9 hours).

2. Problem 2

a. Switch the SCALE SELECTOR to BLACK (x 10).

b. Set QUANTITY dials 1 through 30 to 500.

c. Repeat steps lc, ld, le for Products 1 through 30.

d. The output instrument should read 7500 hours, $\pm$225 hours.

3. Problem 3 - Repeat the steps of Problem 2 successively for potentiometers B, then C, etc., through Z, checking each time that the proper meter readings are obtained on each scale.

4. Check Problem - The following problem set up is given to provide the operator with a check problem to use in determining the correctness of his procedure and/or the operating condition of the equipment.

The problem is to determine the load impact of five models of the same product on the same 10 factory work stations. Quantities involved are from 100 to 500 of each model, and the work content varies from 0.1 hour (six minutes) to 1 hour per unit at the various work stations.

The answers on the output instrument vary from 550 work station hours to 1900 work station hours as shown in Table IX.

TABLE IX

Model No.	Qty.	A	B	C	D	E	F	G	H	J	K	
1	100	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
2	200	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	Unit
3	300	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	Labor content
4	400	0.4	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	0.3	(hours)
5	500	0.5	0.6	0.7	0.8	0.9	1.0	0.1	0.2	0.3	0.4	
Total hours		550	700	850	1000	1150	1300	950	680	550	500	

To set up for solution of this problem, proceed as follows:

1. Set all QUANTITY dials to zero.
2. Set all MEMORY potentiometers to their full counterclockwise position.
3. Set SCALE SELECTOR switch to BLACK x 10.
4. Set all QUANTITY dials for Products 1 through 5 to 100 through 500, respectively.
5. Connect the calibration unit as described for "Sample Problem" lb and depress work station switch "A".
6. Set the dial on the calibration unit to 0.1 hour (full scale 1.0 hour), and adjust MEMORY potentiometer "A" for Product 1 for a null.
7. Remove P61 from J1 and insert in J2.
8. Set the dial on the calibration unit to 0.2 hour.
9. Adjust the MEMORY potentiometer "A" for Product 2 for a null.
10. Repeat steps 6, 7, and 8 for MEMORY potentiometer "A" for Products 3, 4 and 5.
11. Repeat steps 5 through 10 successively for stations B through K.
12. The TOTAL meter should read the total hours shown in Table IX.

installation and maintenance

installation and maintenance

INSTALLATION

Unpacking

Use care in the uncrating and handling of all equipment. Be sure to check for any physical damage due to shipment.

DO NOT STACK sliding panels, as they are printed circuit construction. Care must also be taken not to drop or bend the panels.

Location of the Production

Locate the PRODUCTRON near a source of 117-volt, 60-cycle power. Make provisions for grounding the equipment either by the use of the power plug provided (third terminal is ground) or by using the power plug with the adapter plug supplied. Connect the ground wire of the adapter plug to an earth ground.

Installation Checks

1. Plug the power cord into a 117-volt, 60-cycle outlet.
2. Turn the POWER-ON switch to ON (Figure 2).
    a. The pilot light should light
    b. The LINE VOLTS meter should read 117 volts, ±5 volts.
3. Using a voltmeter, measure the voltage at the red and black jacks on the rear of the Operational Fourfold (Figure 3). These readings should be +300 and -300 volts d-c; if these readings are not obtained, set to the correct values with the ±300-volt adjust potentiometers (Figure 4).
4. Turn all of the QUANTITY dials to zero.
5. Turn all of the MEMORY dials to the full counterclockwise position.
6. Set the SCALE SELECTOR switch at SET ZERO.

7. Adjust the SET ZERO control for a zero reading on the TOTAL meter.

8. Set the SCALE SELECTOR switch at SET FULL SCALE.

9. Adjust the SET FULL SCALE control for a full-scale reading on the TOTAL meter.

10. Depress the A-STATION SELECTOR.

11. Turn all of the A-MEMORY dials to full clockwise position.

12. Set SCALE SELECTOR switch to RED. The TOTAL meter should read zero. If meter does not read zero, continue with the following "Residual Voltage Zero" adjustment.

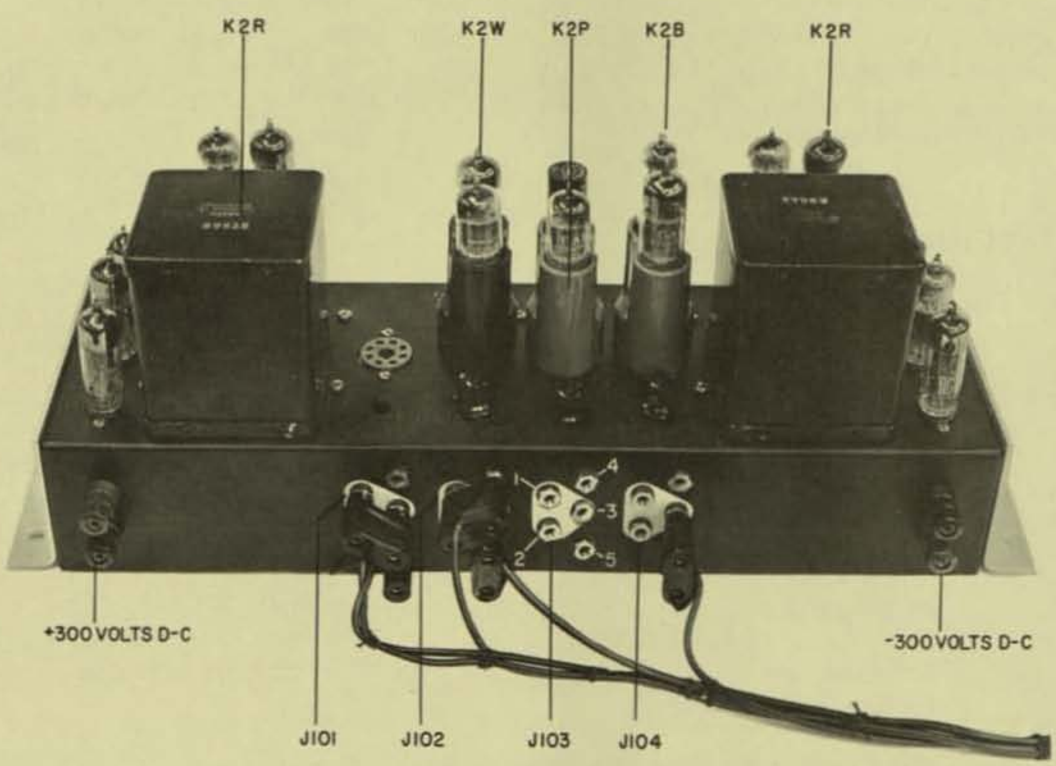


Figure 3. The Operational Fourfold

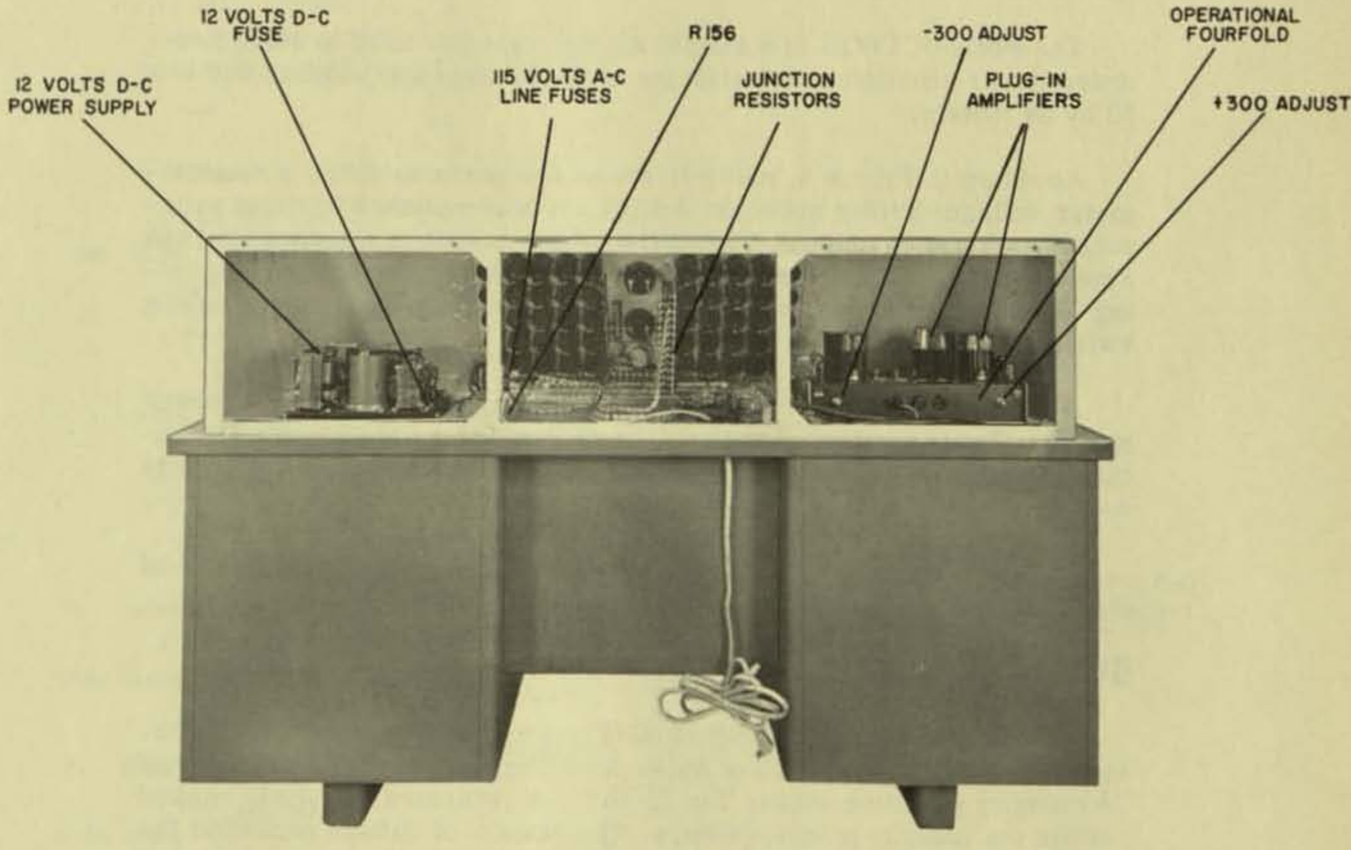


Figure 4. Rear View of the PRODUCTRON Showing Location of Components

Residual Voltage Zero

If after completing the "Installation Checks" the TOTAL meter indicates anything except zero, it will be necessary to adjust potentiometer R156, Figure 4. Unlock R156 and adjust for a reading of zero on the TOTAL meter. This "bucks out" the residual voltage of the quantity potentiometers when they are set at mechanical and gives the system an electrical zero at the same time.

PRINCIPLES OF OPERATION

General Description

The PRODUCTRON is a simple analog computer used to solve first-order linear equations. It performs multiplication and addition within a 50 by 24 matrix.

As shown in Figure 5, multiplications are performed with a potentiometer voltage-divider network. Addition is accomplished by using an input network and an operation amplifier whose output is measured with an ammeter. Selection of the appropriate matrix is accomplished by operating a station selector switch which activates telephone-type stepping switches.

A reference voltage is supplied by a well-regulated 12-volt d-c power supply. Power for the operational amplifier is furnished by the Operational Fourfold supplying +300 volts d-c, -300 volts d-c, and 6.3 volts a-c.

A calibrator is used to accurately set the memory potentiometer of the voltage-divider network.

Quantity Potentiometers

Potentiometers R101 through R150 (Figure 6) are the quantity potentiometers. The slider of each of these potentiometers is wired to a bank of 24 memory potentiometers. The 12-volt d-c reference voltage is applied across the quantity potentiometers. The amount of voltage picked off the slider of the quantity potentiometer is dependent on the position of the dial and is directly proportional to the dial reading. This voltage is then applied across the bank of 24 memory potentiometers for that particular quantity potentiometer. There are 50 quantity potentiometers each with a bank of 24 memory potentiometers.

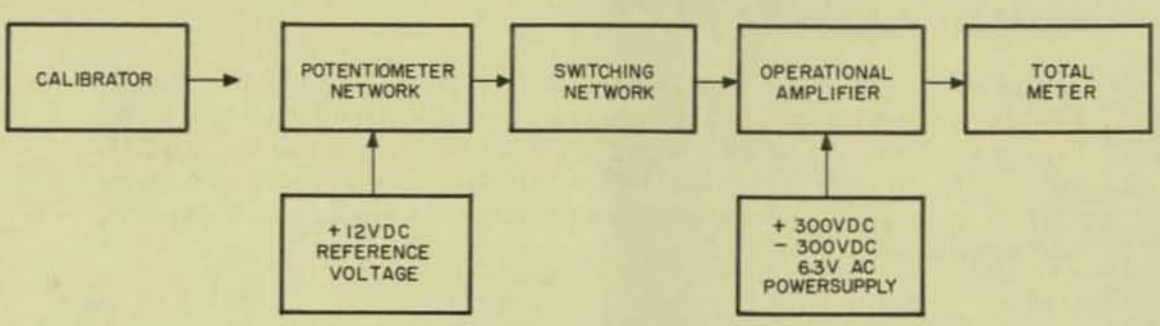


Figure 5. Block Diagram of the PRODUCTRON

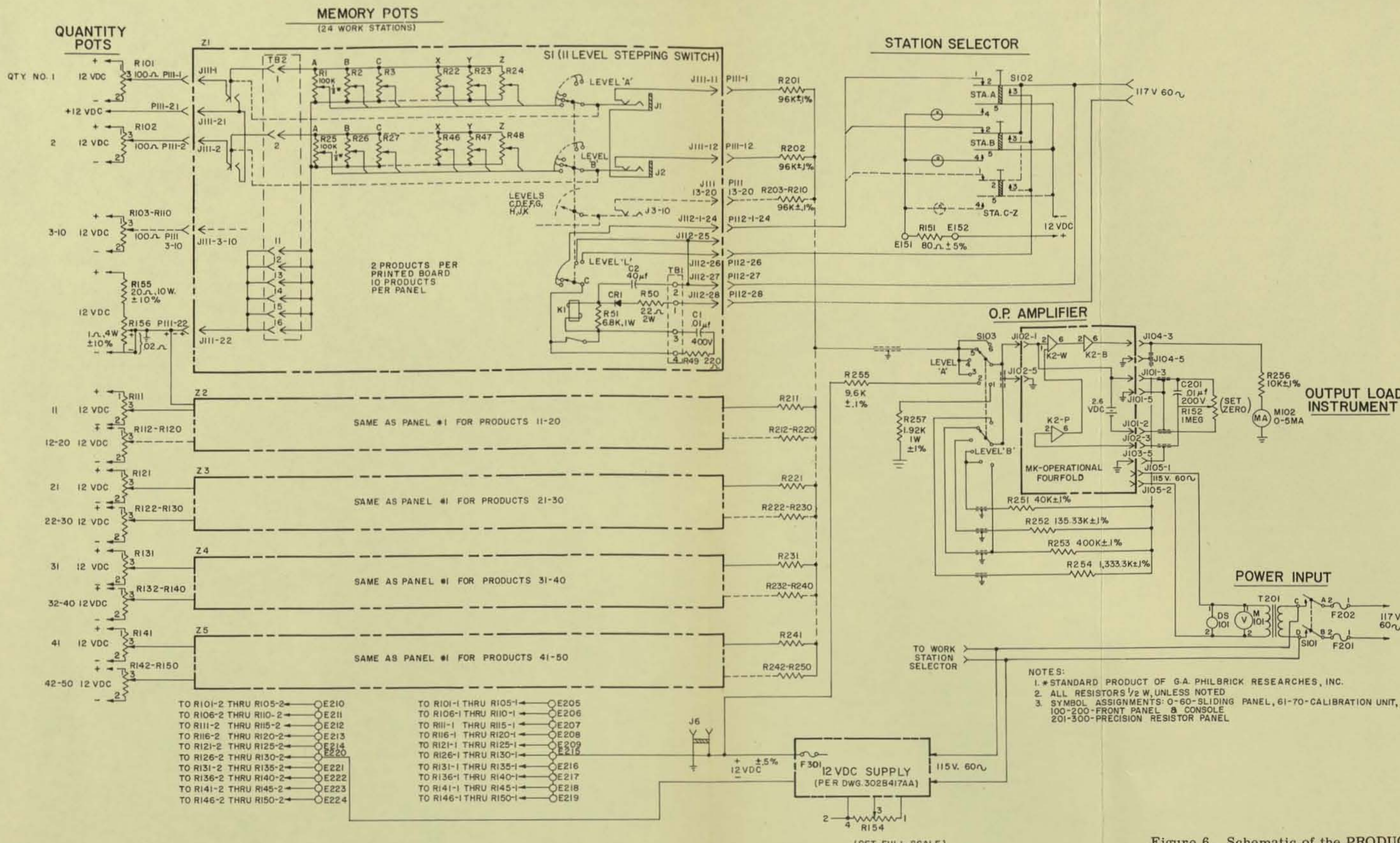


Figure 6. Schematic of the PRODUCTRON

Memory Potentiometers

Memory potentiometers R1 through R24 (Figure 6), R25 through R48, etc., are located on the sliding panels. There are ten banks of memory potentiometers on each panel; one bank for each of ten quantity potentiometers. The first ten banks (R1 through R140) are on the first sliding panel from right to left (panel Z1). The second group of ten are on the second panel from right to left (panel Z2). There are a total of 240 memory potentiometers on each panel and 5 panels are used, making a total of 1200 memory potentiometers.

Stepping Switches

The 11-deck, 25-contacts per deck, stepping switch (Figures 6, 7) is also located on the sliding panel. The stepping switch in conjunction with the station selector switch function to switch in the appropriate memory potentiometers for any given station. For example, if station A is selected, then all the A potentiometers are in the circuit. The output of this circuit is then fed through junction resistors to the summing point of the operational amplifier.

Contacts on the first 10 decks of the stepping switch are connected to the sliders of the memory potentiometers. The contacts on the eleventh back are connected in series with stepping switch solenoid coil, an interrupter contact mechanism, and contacts of the station selector -- all across the output of a d-c rectifier circuit.

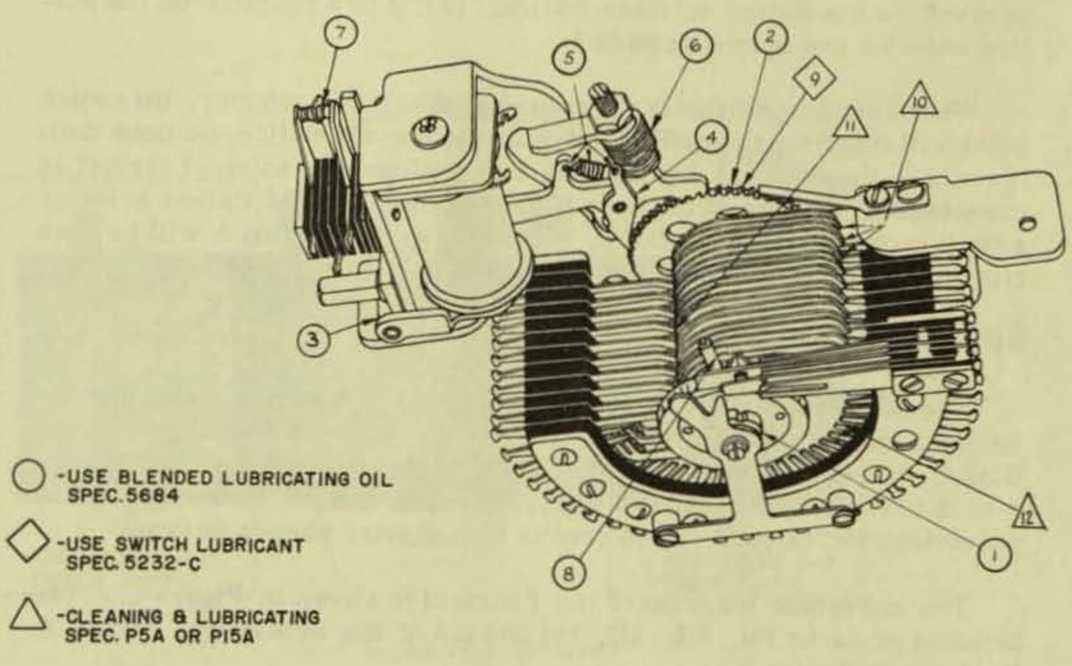


Figure 7. The Stepping Switch

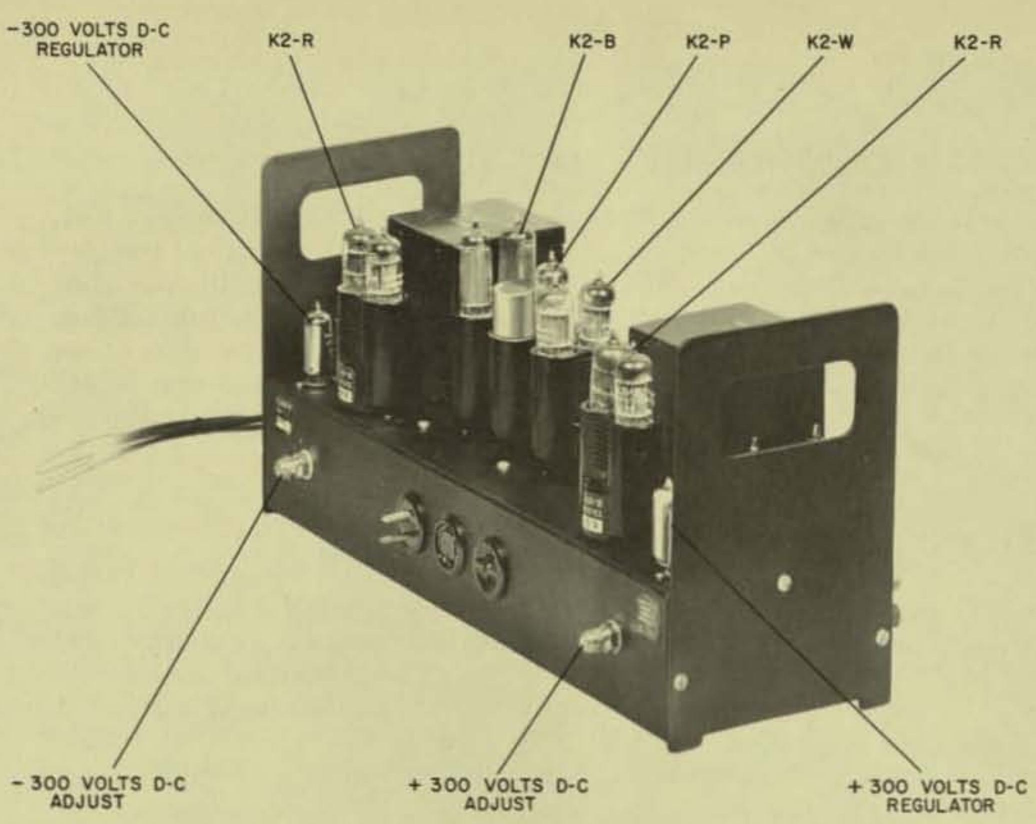


Figure 8. The Operational Fourfold, Showing Plug-Ins

The stepping-switch rotor automatically steps around until the solenoid-coil circuit is unenergized. This will occur at the neutral or 26th position of the stepping switch when none of the stations have been depressed on the station selector switch. (All 2 to 3 contacts on the station selector are open circuited.)

When a station position is depressed on the station selector, the switch rotor will step from the neutral position, through all station positions until it reaches the selected station. At this position the solenoid circuit is unenergized because of the open circuit at the selected station selector switch contacts. (For instance, contacts 1 to 2 of station A will be open circuited when station A is depressed.)

Operational Fourfold

The MK Operational Fourfold (Figure 8) is a standard analog instrument for computing applications of the G.A. Philbrick Researches, Inc., Boston, Mass. It contains two regulated supplies of +300 and -300 volts d-c, a 6.3-volt a-c filament supply, four 2.6-volt d-c bias supplies and provisions for various arrangements of computer plug-in devices.

The schematic diagram of the Fourfold is shown in Figure 11. The location of Jacks 101, 102, 103, 104 and 105 of the schematic, Figure 6, is shown in Figure 3.

In the PRODUCTRON application K2W, K2B and K2P plug-in units perform the function of a stabilized operational amplifier. The operational amplifier, junction resistor, feedback resistor and selector-switch network serves to isolate the output load (the total meter and 10,000-ohm load resistor) from the potentiometer matrix. This combination also performs the function of summing with a voltage at the output of the amplifier proportional to the sum of all the individual potentiometer multiplications at the input.

A simplified schematic of the amplifier network is shown in Figure 9.

The output voltage of this network is:

$$E_o = -\frac{R_2 E_1}{R_1} - \frac{R_2 E_2}{R_1} \text{ ----}$$

and $E_g \cong 0$.

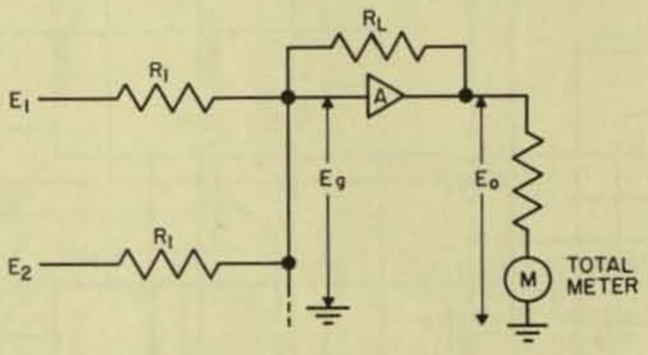


Figure 9. Simplified Schematic

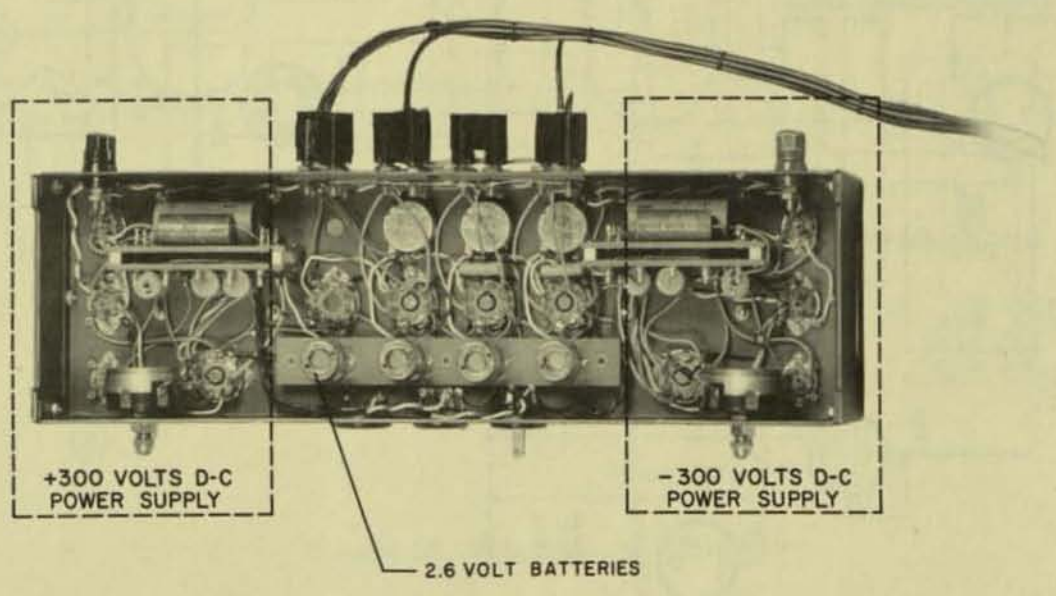


Figure 10. Operational Fourfold, Showing Power Supplies

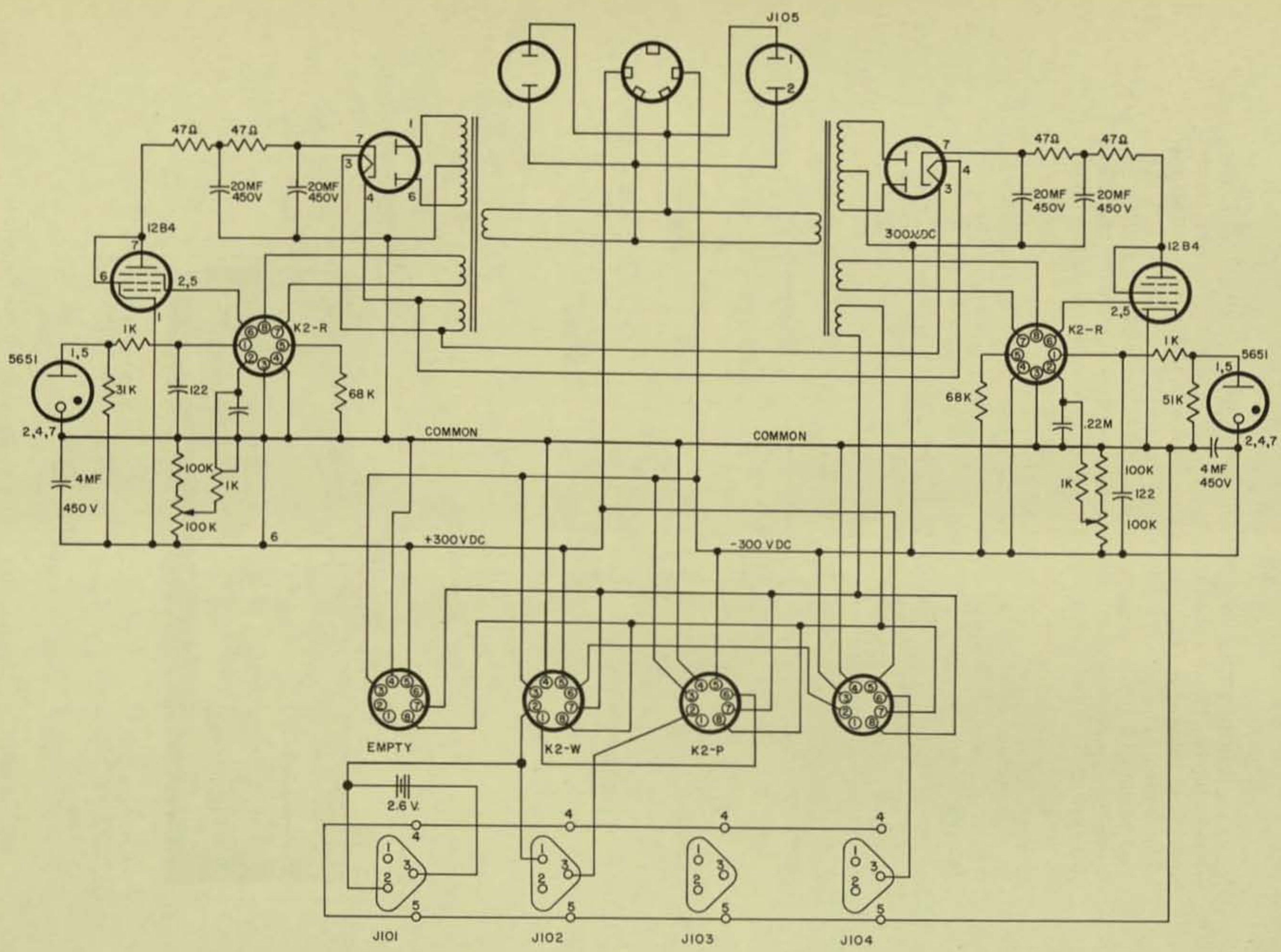


Figure 11. Schematic of the Operational Fourfold

300-Volt Regulated Supplies

The +300 and -300-volt d-c regulated supplies of the MK Fourfold consist of the following stages: transformer, 6X4 rectifier, filter, 12B4 series regulator tube, 5651 voltage-reference tube, K2R control plug-in unit, and set-voltage control. The K2R unit detects any changes in the regulated output voltage and alters the grid of the series regulator tube to counteract that change. For instance, if the line voltage went up, the output of the 6X4 rectifier would go up and the output of the regulated supply would tend to go up. However the K2R would detect this increase in voltage and it would make the grid of the series regulator tube more negative, increasing the drop across the series tube and thus decrease the output regulated voltage back down to its normal value. The set-voltage control sets the desired operating voltage and the 5651 constant-voltage reference tube functions as a reference voltage source for the K2R unit.

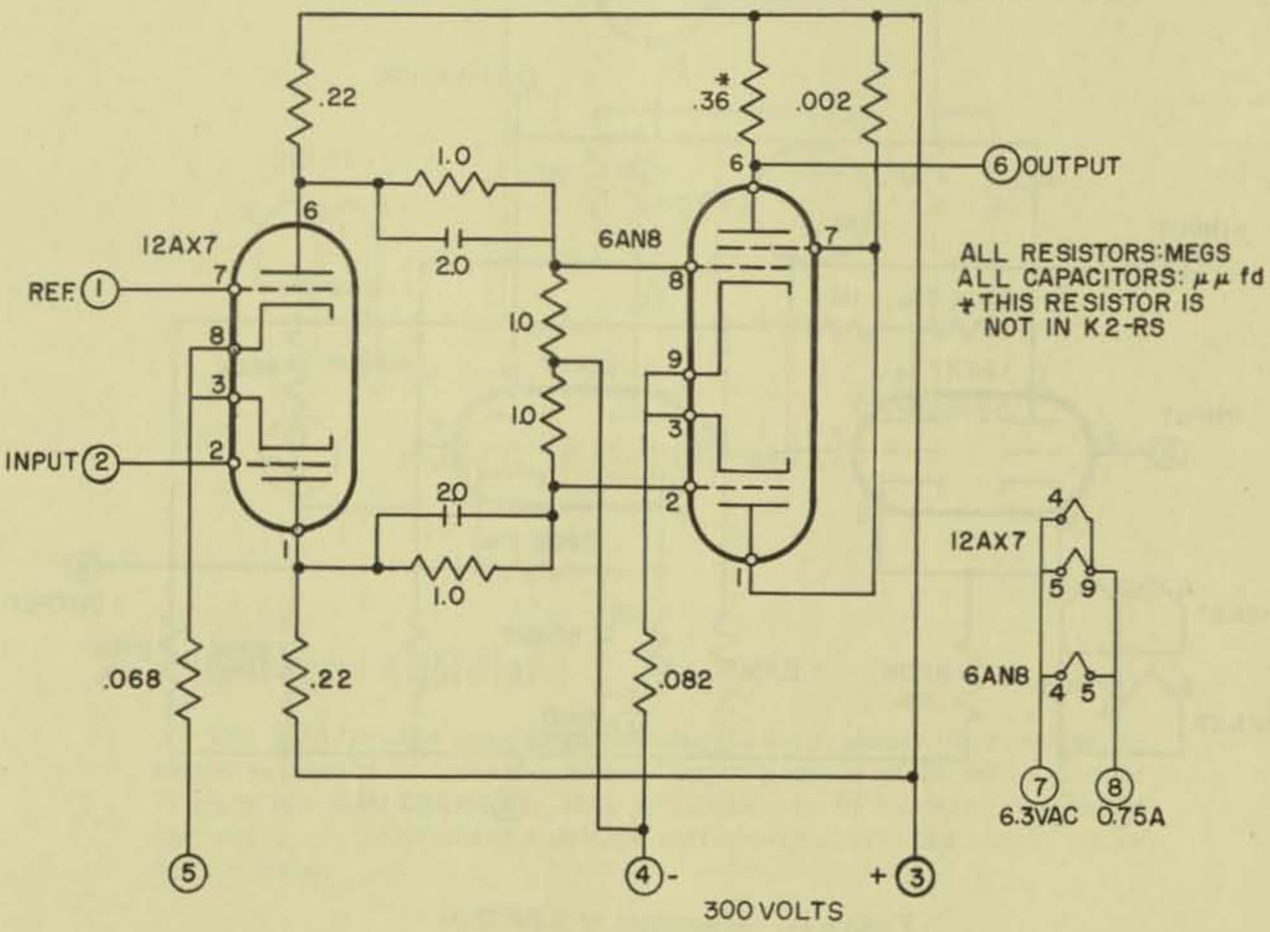


Figure 12. Schematic of K2R Unit

K2W Operational Amplifier

The K2W unit is a high-gain plug-in amplifier with nominal open-loop gain for d-c of 15,000 (Figure 13). It features balanced differential inputs. In this application, one input is used as a summing point and the other is used for balancing and drift compensation.

It is used as a feedback amplifier, with its output equal to minus the ratio of the feedback resistance over the junction resistance X the input signals from the potentiometer matrix.

$$(E_0 = - \frac{40,000}{96,000} E_1 - \frac{40,000}{96,000} E_2 -----)$$

The K2W unit is capable of providing an output voltage up to 50 volts d-c and an output current of 1 milliampere, driving a load of 50,000 ohms.

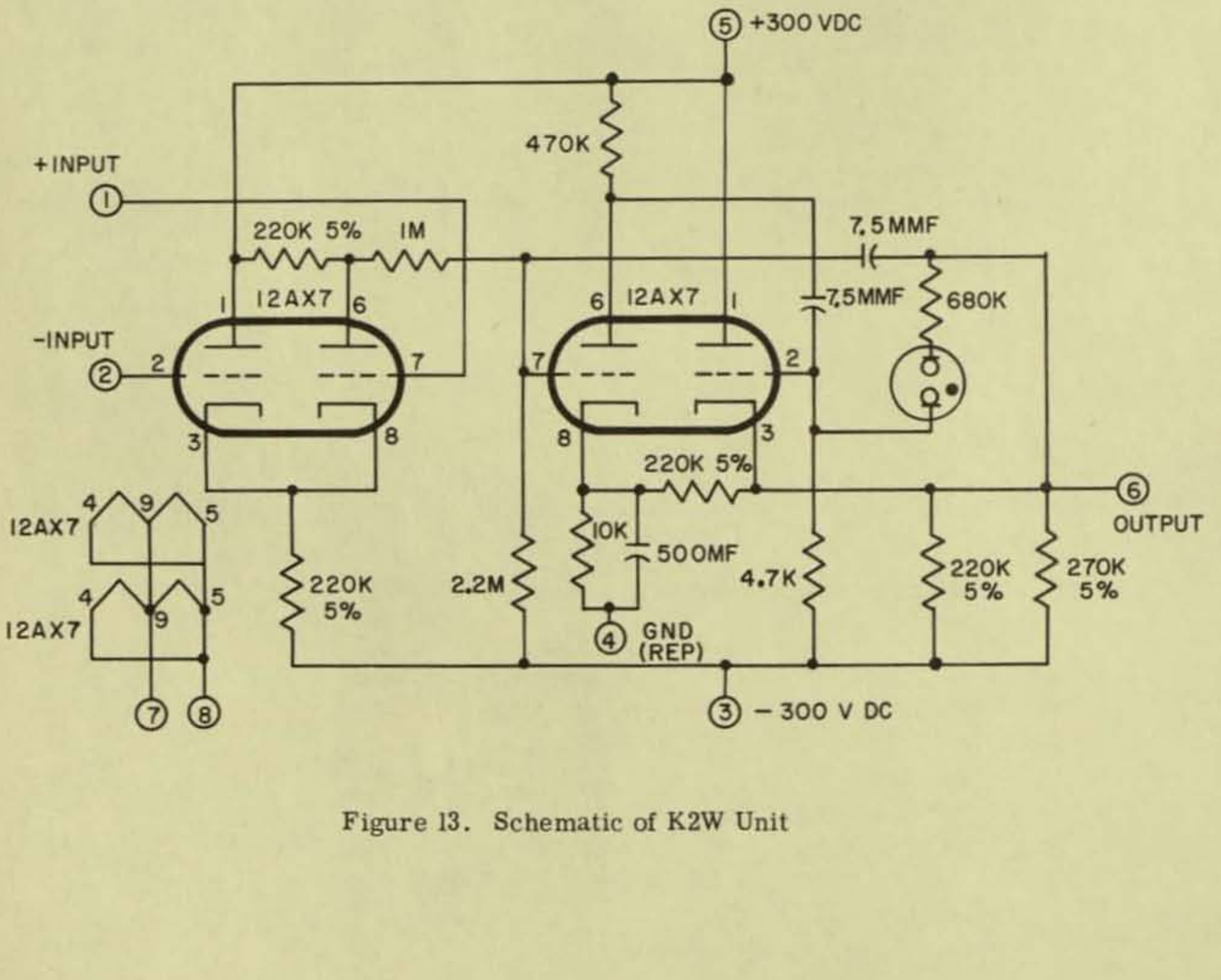


Figure 13. Schematic of K2W Unit

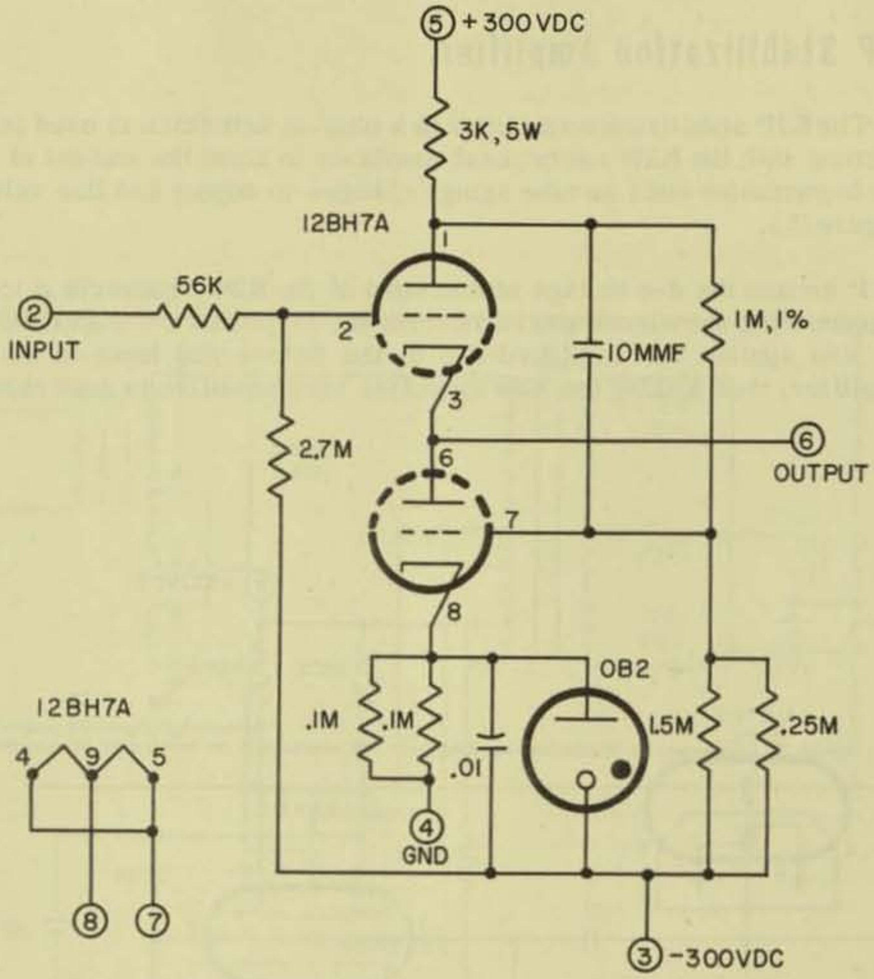


Figure 14. Schematic of K2B Unit

K2B Booster Amplifier

The K2B booster amplifier is a plug-in unit capable of providing an output voltage of 50 volts d-c and an output current of 20 milliamperes (Figure 14). Its function in this application is to increase the output current while maintaining a voltage sufficient to drive the output meter to full scale.

K2P Stabilization Amplifier

The K2P stabilization amplifier is a plug-in unit which is used in conjunction with the K2W operational amplifier to limit the amount of drift due to variables such as tube aging, changes in supply and line voltages (Figure 15).

It senses the d-c voltage at the input of the K2W, converts it to a-c, amplifies the a-c signal and reconverts the amplified a-c signal back to d-c and applies the amplified d-c to the differential input of the K2W amplifier, thus making the K2W amplifier very sensitive to drift changes.

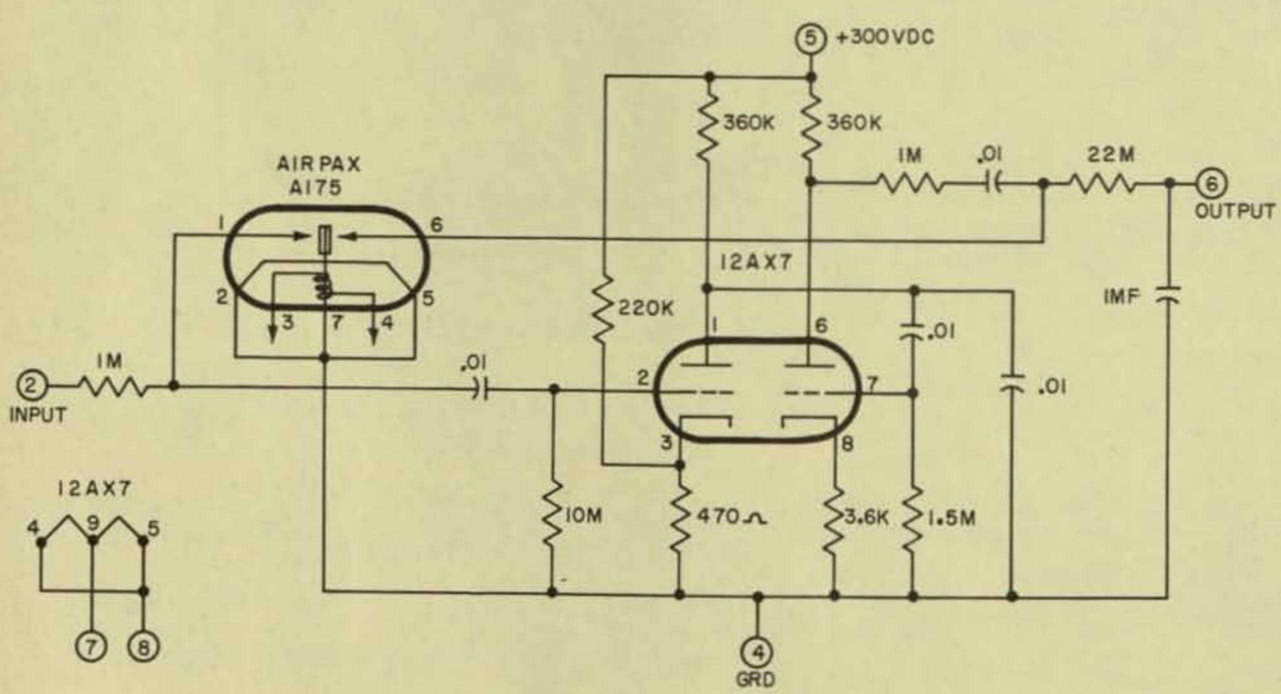


Figure 15. Schematic of K2P Unit

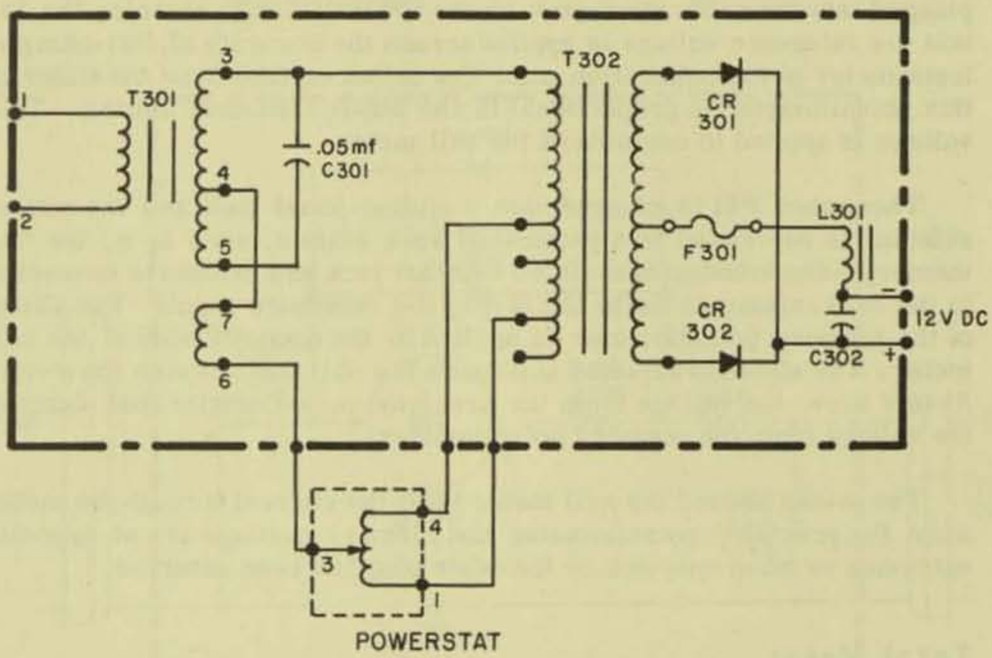


Figure 16. Schematic of the 12-Volt D-c Power Supply

12-Volt D-c Power Supply

Figure 16 is the schematic diagram of the 12-volt d-c power supply. This supply uses a saturable-reactor principle to regulate the incoming a-c voltage. This regulated voltage is then stepped down to a low a-c voltage and then full-wave rectified and filtered to produce the final 12-volt d-c (±0.25 volt), 6-ampere reference supply.

Calibration Unit

The calibration unit is used to accurately set the memory potentiometers. The schematic for this unit is shown in Figure 17. When P62 is plugged into the calibration jack on the PRODUCTRON console, the 12-volt d-c reference voltage is applied across the accurate 10,000-ohm potentiometer of the calibration unit. The output voltage from the slider of this potentiometer is proportional to the desired memory setting. This voltage is applied to one side of the null meter.

Then when P61 is plugged into a sliding-panel jack and the station selector is depressed to a particular work station, such as A, the "A" memory potentiometer associated with that jack and product is connected to the calibration unit and to the 12-volt d-c reference supply. The slider of the memory potentiometer is applied to the opposite side of the null meter. The slider is adjusted until there is a null indication on the meter. At this time, the voltage from the precision potentiometer just matches the voltage from the memory potentiometer.

The diodes around the null meter limit the current through the meter when the precision potentiometer and memory settings are at opposite extremes or when only one or the other plug has been inserted.

Total Meter

The total meter is a milliammeter with a full-scale deflection of 5 milliamperes and an accuracy of one percent of full scale.

The output of the operational amplifier is fed through a scale-factor resistor, to the meter, and then to ground. The current through the meter is proportional to the sum of all of the inputs (multiplications) to the operational amplifier.

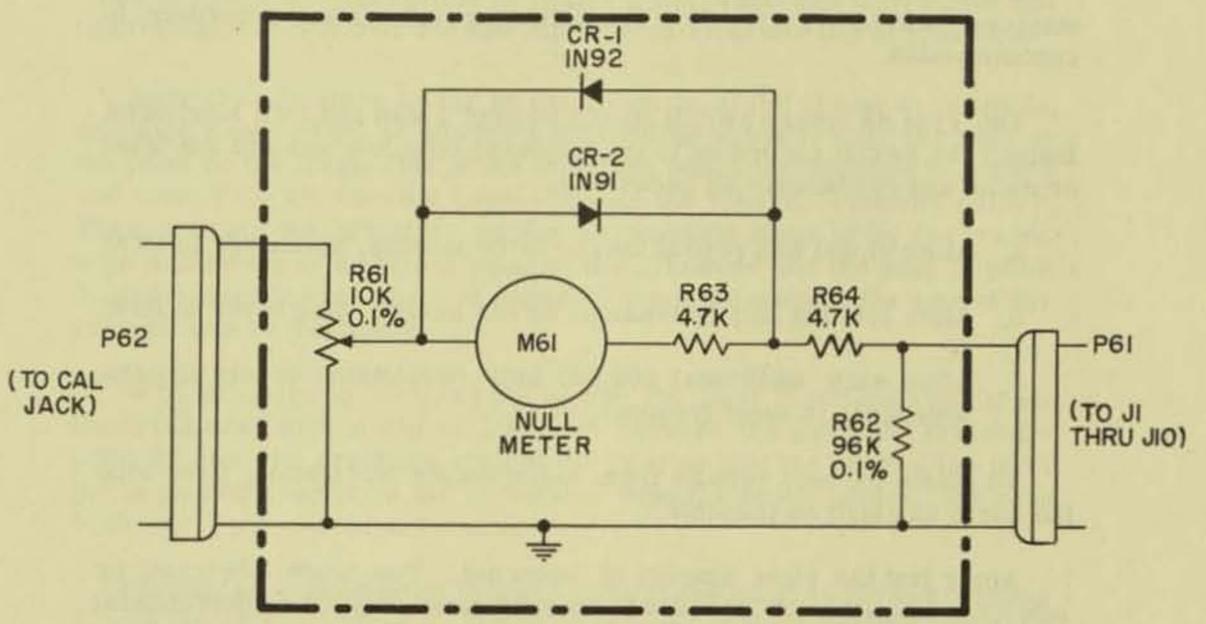


Figure 17. Schematic of the Calibrator

PREVENTIVE MAINTENANCE

Dust

Keep the PRODUCTRON free of dirt and dust, particularly the stepping-switch contacts, switch contacts, calibration-jack contacts and connector contacts.

Lubrication

The only portion of the PRODUCTRON that needs lubrication are the stepping switches (Figure 7). The following lubrication procedure is recommended:

The Type 45 rotary switch should be kept clean and well lubricated. Inspect the switch according to the following schedule and add lubricant or clean and relubricate as necessary.

a. After 50,000 half revolutions or three months, whichever is first.

b. After 250,000 half revolutions or six months, whichever is first.

c. After each additional 500,000 half revolutions or six months, whichever is most frequent.

To obtain the best results from maintenance lubrication, first wipe the parts as clean as possible.

Apply just the right amount of lubricant. Too much lubricant, or lubricant on parts not intended to be lubricated may be as detrimental as insufficient lubrication.

To assure the proper amount, the term "DIP" will be used as a guide.

To obtain one "DIP" of lubricant, dip a No. 4 Artist's Sable Rigger brush into the lubricant about 3/8 inch, then wipe the brush gently against the side of the container to remove the drop which forms at the end of the bristles.

In most cases, one "DIP" will be sufficient to lubricate several parts since only a light film of lubricant is desired on each part. Brush the lubricant lightly over the parts; do not scrub the brush on the parts because such action usually results in too much lubricant on the first part and surrounding parts, and little or no lubricant on succeeding parts.

During manufacture the wiper assembly bearings are lubricated. The center of the wiper hub which has been hollowed out larger than the shaft diameter to form a reservoir for lubricant is completely filled with ANG-3-A grease before the shaft is assembled to the hub. This lubrication is good for the life of the switch and needs replacing only when replacing the wiper assembly.

If it is deemed necessary to add lubricant at this point, dip a clean brush in the blended lubricating oil (Spec. 5648), wipe the brush on the edge of the container, and wipe the lubricant around the shaft at points 1 and 2, (point 2 is not visible in Figure 7 but is between the ratchet and the frame). If required use one dip at point 1 and one dip at point 2.

Move the armature as far in the direction of the frame as possible, and wipe a second dip of lubricant between the armature and the yoke at the point on the frame side of the armature which corresponds to point 3 and around the pin where it passes through the yoke just opposite point 3. Then, moving the armature as far as possible away from the frame, wipe a third dip of lubricant between the armature and the yoke at point 3, and around the pin where it passes through the yoke on the side of the yoke closest to the frame.

With pressure on the pawl pin so that the pawl is pushed away from the armature, wipe a dip of lubricant between the pawl and armature point 4, then with pressure against the pawl so that the head of the pawl pin is pushed away from the armature, wipe the brush between the head of the pawl pin and the armature.

Spread the remainder of this dip through the coils of the pawl spring 5, and the driving spring 6, and into the holes in the armature and pawl where the pawl spring is engaged.

Dip the brush in the lubricant, and wipe the bristles nearly dry against the edge of the container.

With the brush so prepared spread a thin film of lubricant over the end of the interrupter spring buffer 7 which strikes the armature arm, and over the off-normal actuating arm bushings on switches equipped with off-normal springs 8.

Using a clean brush, dip the brush in switch lubricant (Spec. 5232-C), and with the switch rotating, touch the brush to the ratchet at point 9 turning the brush to transfer the maximum amount of lubricant from the brush to the ratchet.

Repeat this process with a second dip of lubricant.

Inspect, clean and lubricate the stepping switch contacts and wipers after each 15,000 half revolutions or once a month whichever is first, according to the following procedure:

Use a mascarra brush with a "3 to 4" handle (or equivalent brush).

Dip the brush into the cleaning and lubricating fluid* periodically when cleaning the wiper springs, point 10, brush springs, point 11 and contacts point 12.

With the wipers standing off the bank, rotate the brush at the wiper tips, so as to scrub between the tips with the brush bristles.

Rotate the wiper assembly 180 degrees, and repeat the cleaning operation for the other end of the wipers.

To clean the brush springs, set the wiper assembly so that the wipers are setting on the 25th contact, then brush fluid against the insides of the wipers at a point near the hub so that when rotated the brushes will contact the lubricated portion of the wiper.

When all the wipers have been lubricated in this manner, rotate the wiper assembly 180 degrees and repeat the process.

Periodic Checks

Periodically run sample problems on the PRODUCTRON which use all the quantity and memory potentiometers. If the answers, as indicated on the total meter are not correct within ± 3 percent (1 percent of full scale +2 percent of reading), consult the section on "Corrective Maintenance".

*E. C. Millen Co., petrolatum solution P5A, for low temperature and dusty areas, or P15A for areas at room temperature or above.

CORRECTIVE MAINTENANCE

General

Before attempting trouble shooting or replacement of parts, be sure that the correct operating procedure and installation instructions have been followed.

Sliding Panel Tests

1. Wire check and megger for conformance to Figure 6.

   a. Check for proper continuity between J111, J112, TB101, TB1, MEMORY potentiometers, calibration jacks, and stepping-switch connections.

   b. Insert a telephone plug in each of the calibration jacks and test to see that the proper circuit continuities are made.

   c. Check for continuity between chassis ground J111-22 and the ground side of all potentiometers and jacks.

   d. Lift chassis ground and megger all circuits to ground with a 500-volt megohm bridge (should be 100 meg.).

2. Stepping-relay functional operation

   a. Short J112-1 through J112-25 to J112-27.

   b. Apply 115 volts 60 cycles across J112-27 to 28. (This should step the switch around to the C or neutral position).

   c. Now unshort J112-1 and short J112-26 to J112-27. (This should step the switch around to position 1).

   d. Continue this process, unshorting J112-2 through J112-26 one at a time and shorting the proceeding wire to J112-27. (This should step the switch successively from position 2 through 24).

3. Memory potentiometer functional test

   a. With the stepping switch successively in positions 1 through 24, vary the memory potentiometers for station A through Z, and see that the resistance measurement from J111-1 to J111-11, and J111-2 through J111-20 to J111-12 through J111-20 varies through the range of 0 at the ground end, 25K, $\pm$20 percent at mid-scale, and 4K, $\pm$20 percent at the fully clockwise position; also, see that there is no discontinuities as the slider is moved.

CORRECTIVE MAINTENANCE

Trouble Shooting Chart

TROUBLE	PROBABLE CAUSE	REQUIRED ACTION
With power switch ON, pilot light and line-voltage meter inoperative.	F201 or F202 blown	Remove center panel on the back of the console, check for continuity of fuses with an ohmmeter, and replace as required.
With power switch ON, pilot light is inoperative.	Pilot light burned out	Replace with new pilot light.
Unable to SET ZERO	Trouble in Operational Fourfold	1. Check that all tube filaments are lit. 2. Check for +300 volts d-c at the Operational Fourfold terminals. 3. Substitute plug-in units. 4. Depending on the results of (1), (2), and (3), remove tubes and check them for correct operation or substitute spare tubes.
Unable to SET FULL SCALE	Inoperative 12-volt supply trouble in Operational Fourfold	1. Depress the push-button switch to any station position. If the 12-volt supply is OK, that station will be illuminated. 2. Remove the fuse on the power supply, test for continuity and replace as required. 3. Make checks of set zero required action above.
PRODUCTRON fails to give correct answers	1. Misadjusted potentiometer settings.	1. Check the calibration of potentiometer settings.
	2. Stepping-switch failure	2. Depress station selector buttons and observe for proper rotation of the stepping switch contacts.
	3. Work station contacts dirty	3. If all stepping switches are sitting at the same position but fail to rotate on depressing the next station, clean the contacts of the station at the affected station.
	4. Poor sliding-panel connector connections	4. Narrow the trouble down by setting up a problem that uses only one sliding panel at a time (panel 1, products 1-10; panel 2, products 11-20; etc.)
	5. Poor memory potentiometer solder connections. 6. Calibration jack contacts dirty.	
None of the above symptoms	Or unable to find the cause	Proceed through the factory test instruction procedure to narrow down the trouble.

Console Test

1. Wire check and megger for conformance to Figure 6.

   a. Check for proper continuity between quantity potentiometers, 12-volt d-c supply, J111 and J112 for panels 1 through 5, junction resistors R201 through R250, work station selector, operational amplifier and power supply, output instrument, terminal boards TB201 through TB205 and power input leads.

   b. Lift all chassis grounds and megger all circuits to ground with a 500-volt megohm bridge (should be 100 megohms).

2. Power ON

   a. With sliding panels removed, with the 12-volt d-c supply and operational Fourfold power disconnected, operate S101. The pilot light should light up.

   b. The line-voltage instrument should indicate 117 volts a-c, $\pm$5 volts.

3. 12-Volt D-c Supply

   a. With the power connected to the 12-volt supply, measure the voltage at J62 (CAL). It should be 12 volts d-c, $\pm$0.5 percent.

   b. Adjust the SET FULL SCALE to see that the 12 volts d-c can be varied by $\pm$0.25 volt.

   c. Vary the line voltage from 112 to 122 volts to see that the 12 volts stays within 0.5 percent.

   d. Depress the selector stations successively from A to Z. With each station in the depressed position, that station should be illuminated.

4. Operational Amplifier

   a. With the SCALE SELECTOR set at SET ZERO and with the power connected to the operational Fourfold check to see that the filaments light up, check the +300 and -300-volt supply voltages for proper reading.

   b. Adjust the SET ZERO control for a zero reading on the output instrument. See that there is adequate control of this setting.

   c. Change the SCALE SELECTOR dial to SET FULL SCALE, adjust the SET FULL SCALE control for full-scale reading on the output instrument. See that there is adequate control of this setting.

5. Calibration Unit

   a. With P62 plugged into J62, the calibration potentiometer set for full scale, and P61 plugged into any sliding panel jack, adjust the appropriate MEMORY potentiometer to full clockwise rotation. The null meter should indicate a null.

   b. With the calibration dial set at half scale (500) adjust the appropriate MEMORY potentiometer to again obtain a null. Vary the calibration dial from the null in both directions and come back to a null. The null-position dial reading should be repeated within, ± 1 dial division.

6. Sliding Panel and Output Instrument Tests

   a. Place the sliding panels in the console, one at a time, and check for proper operation of the stepping switches as the station selector is varied through station A to Z.

   b. Set all the QUANTITY potentiometers to 0, set the SCALE SELECTOR successively to black (x 10), red (x 10), black and red. The output instrument should read 0. If it does not, adjust R156 until a zero output reading is obtained. (Be sure that the Set Zero step has been performed before proceeding to this step).

   c. Make functional checks for upscale readings of the output instrument by varying QUANTITY and MEMORY potentiometer settings to obtain various output readings.

7. Accuracy Tests

   a. With scale reading on red (300 hours), set any one QUANTITY potentiometer to a dial setting of 300. The MEMORY potentiometer for that station should be set at a maximum. This should give a full-scale reading ± 3 percent.

   b. With the scale reading on black (1000 hours), set any one QUANTITY potentiometer to full scale, and the appropriate associated MEMORY potentiometer to full scale. This should give a full-scale reading, ± 3 percent.

c. With the scale reading on red (x 10), set any three QUANTITY potentiometers to full scale and the appropriate associated MEMORY potentiometers to full scale. This should give a full-scale reading, ± 3 percent.

d. With the scale reading of black (x 10), set any ten QUANTITY potentiometers to full scale and the appropriate associated MEMORY potentiometers to full scale. This should give a full-scale reading, ± 3 percent.

e. Repeat steps (a) through (d) with various combinations of QUANTITY potentiometers that will give summation voltages to the input junction resistors of 3.6, 12, 36, 120 volts for scales red, black, red (x 10) and black (x 10), respectively, (for instance on the red scale another possible combination is to set three QUANTITY potentiometers at dial readings of 100).

f. Repeat steps (a) through (d) above with various combinations of QUANTITY settings and calibrated MEMORY potentiometer settings to give summation voltages to the input junction resistors of 3.6, 12, 36 and 120 volts for scales of red, black, red (x 10) and black (x 10), respectively. (For instance, on the red scale, a possible combination is six QUANTITY potentiometers at dial readings of 100 and the appropriate MEMORY potentiometers calibrated for .5).

g. Repeat step 6 for various combinations of QUANTITY and MEMORY potentiometers that will check out the function and accuracy of all potentiometers.

h. Check for ±3 percent accuracy of any problem combination: (1) with line voltage at the extremes of 112 and 122 volts, (2) repeat runs of problems; (3) two hour stability at any one problem condition.

MAINTENANCE PARTS LIST

ELECTRONIC COMPONENTS PARTS LIST

FOR

PRODUCTRON (Figure 6)

Part (Symbol No.)	Description	Location
C1	0.01 mfd, 400 v	Sliding Panel
C2	40 mfd, 450 v	
R1 to R48	100K, 1/4 w potentiometer (B749149184)	
R49	220 ohms, 1/2 w, ±10%	
R50	22 ohms, 2 w, ±20%	
R51	6.8K, 1 w, ±20% (C3R788682K)	
CR1	Half-wave rectifier (1006A) Automatic Electric Co. Printed wiring board (6740100)	
S1	Stepping switch (C7776694)	
J1 to J10	Jack (M2R57P25)	
J111 & J112	Connectors (7775345 P18, 19, 21 and 22)	
R1 to R150	100 ohms, ±0.5%, 5 w (7770548P6)	Front Panel
R151	80 ohms, 1/2 w, ±5%	
R153	1 meg, 1/2 w, ±5%	
R154	Type 10 powerstat (Superior Electric Co.)	
M101	150 v a-c instrument (7491605P1)	
M102	0-5 ma output instrument (7491605P2)	
S101	ON-OFF Switch (7109677P1)	Front Panel
S102	Station Switch (7776744P1)	
	Lamps for Station Switch (7776744P1)	
S103	Selector Switch (7491663P1)	
J62	Calibration Jack (710494185)	
DS101	NE-51 Lamp	
C201	0.05 mfd, 200 v, (C7491096P11)	
R201 to R250	96K, ±0.1% (B7491543P4)	Precision Resistor Panel
R251	40K, ±0.1% (B7491543P3)	

Part (Symbol No.)	Description	Location
R252	133, 33K, ±0.1% (B7491543P6)	
R253	400K, ±0.1% (B7491543P7)	
R254	1333.3K, ±0.1% (B7491543P8)	
R255	9.6K, ±0.1% (B7491543P1)	
R256	10K, ±0.1% (B7491543P2)	
R257	1.92K, 1/2 w, ±0.1% (Mepco Co.)	
R155	20-ohms, 10 w, ±10% (Ohmite Mfg. Co.)	Console
R156	1-ohm, 4 w, ±10% potentiometer (J.P. Mallory Co.)	
F201, F202	3AG-5A fuses (Littlefuse Corp.)	
F101	3AG-8A fuses (Littlefuse Corp.)	12-v supply
T201	150 va voltage-stabilizer, Superior Electric Co.	
12 v d-c supply	Model 9T91Y3253, per dwg. 302B417AA (specialty transformer Dept., G.E. Co., Ft. Wayne, Ind.)	
6X4	Vacuum tube	MK Operational Fourfold
12B4	Vacuum tube	
5651	Vacuum tube	
12AX7	Vacuum tube	
12BH7A	Vacuum tube	
OB2	Vacuum tube	
M61	100-0-100 ma. meter, Model 301 (Weston Electric Instrument Co.)	Calibration Unit
R61	10K, ±0.1% Potentiometer (7770548P7)	
R62	96K ±0.1% resistor (B7491543P4)	
R63, R64	4.7K, 1/2 w, ±10% resistor	
CR1, CR2	1N91 diode	

Progress Is Our Most Important Product

GENERAL ELECTRIC

PROduction CONtrol
INFORMATION LETTER

Volume 3, No. 1 March 27, 1957

Productron's Debut an Unqualified Success

On October 22, 1956, a brand spanking new Productron Load-Capacity Computer was installed in Appliance Motor, DeKalb, Illinois, and it carried the distinction of being the first production model manufactured by the Computer Department. With a 40,000-unit weekly output and a wide range of motor models (50), Appliance Motor is an ideal application for the versatile Productron. Since that time Productron's shakedown cruise has been carefully plotted and followed to make sure its performance lived up to advance billing. The successful handling of 12 major schedule changes in one week proved to be the acid test for the desk-size computer. Planned operation times are loaded into memory for all models over 12 load stations. Capacity is determined by a uniform calculation, and the various elements of the formula are reviewed periodically and revised as needed. Weekly production requirements are then dialed in on the console and the load-capacity comparison read out on a meter in front of the operator. In this way the scheduling specialist can make quick, easy evaluations of load impact for a given schedule, and then reschedule as often as changing plans may require. Chuck Glinsky, Specialist-Inventory Control and Systems, was instrumental in gathering the data and preparing for Productron, and Donald H. Blight, Schedule Planner, is responsible for its operation (see pix). The fact the first Productron is located in DeKalb is due to Materials Manager Brooks Brickley's foresight and pioneering spirit. For those who may want to know more about it, a supplement to "Pro & Con" is enclosed, which summarizes remarks made by Ford Dickie, Burt Grad, and Tom Kavanagh at the kick-off meeting for Productron in Schenectady.

Family Patterns Simplify Material Control at GPC

The grouping of products into families of like types frequently spells the difference between order and confusion in a business such as General Purpose Control. At Bloomington over 1,500,000 devices are offered to the market in 30 major product lines. Out of 20,000 active models, 4,250 account for 98 percent of the orders. Detailed studies indicated these 4,250 models could be boiled down to 130 basic families, and further investigation of this historical sales data by family and its parts mix revealed such significant, fairly stable patterns that sales could be forecasted with a reasonable degree of accuracy. Based upon these findings, the solution to the problem of ordering material and planning labor was simplified.

For each basic collation part within the 130 families, a card is punched with the part name and drawing number, collation line number, ABC classification, buyer code, main stock location, first manufacturing area, procurement code, raw material data, unit quantity and the historical parts mix ratio (H.P.M.R. – which is the probability that the specific part will be required in each unit of the device family). Multiplied by the total scheduled units of a family, the product should equal the total family requirements for the part in question. For example, the H.P.M.R. for part X in a family of five would be calculated as follows:

Device	Sales	Units Req'd to Liquidate Deficit	Adj. Total	Unit Qty	Adj. Total	Renewal Parts and Shrinkage	Total
A	1,000	100	1,100	1	1,100		
B	200	50	250	0	0		
C	10,000	3,000	13,000	2	26,000		
D	500	- 200	300	1	300		
E	100	0	100	5	500		
	11,800		14,750		27,900	10%	30,690

$$\text{H.P.M.R.} = \frac{30,690}{14,750} = 2.081$$

Once monthly sales forecasts by family and specific warehouse requirements have been compared to factory capacity, planned production rates are punched into collation header cards. When the IBM 604 Calculator has extended the H.P.M.R. times the planned production rate, sorting and listing provides raw material requirement data and information for factory scheduling. A reduction in the over-all manufacturing cycle has resulted from this mechanized ordering routine, according to George LeBaron, Manager–Materials.

Power Transformer Puts Incoming Material on Right Track

After a long and coldly calculated look at the new receiving setup in Fenton McClintock's Power Transformer Department, a neat annual savings tag of $34,500 has been attached to the operation. And this is all for real, tangible reductions in overtime, personnel, and demurrage charges. Vendor material is now transferred directly from the carrier to pre-positioned 4-wheel yard trailers. They are hooked up in tandem and towed around the area, with the material to be delivered first on the rear unit. Four times a day deliveries are made to "point of use" storage areas. Material now remains at the unloading docks no more than 2 1/2 hours and is transported to an appropriate destination 4-5 hours after receipt. A decentralized open purchase order file is maintained at each stock area for preparation of the receiving report. Inspection is also performed in these locations. Vendors have been asked to co-operate by clearly marking each package for delivery area destination. The Pittsfield "Toonerville Trolley" is a good example of the solid savings one can squeeze out of good ideas and work simplification.

Receiving Paperwork Obsolete at Jet Engine

The elimination of 70,000 pieces of paper per year is a very desirable achievement for any receiving unit, and this has been recently accomplished at Jet Engine, according to Jim Walsh, Specialist–Production Systems. Here all copies of purchase orders typed up on Bell Teletype equipment are automatically reproduced in the receiving section on 5-channel tape. This tape is wound on standard typewriter ribbon spools with the purchase order showing on top to facilitate easy reference in terminal digit storage files. When material is received, the proper tape is withdrawn from the Supercarder files and fed into a transmitter to produce typed receiving copies for Purchasing, Accounting, Project, and Receiving functions. At the same time a component disposition card is being generated in Quality Control. An average of 170 receipts per day are processed in this manner. Needless to say, Jim finds that he is getting accurate information faster and more efficiently, and without those 70,000 pieces of paper cluttering up the joint!

Television Receiver Consolidates Inbound Freight

"Full trucks save bucks" may well be a slogan circulating around Jack Walter's Materials section at Television Receiver in Syracuse, when it comes to moving LTL (less truck load) materials into the plant. Since June 1955, incoming LTL materials shipments have been accumulated at key points for consolidation into full truck load lots before moving them to Syracuse. At the Chicago consolidation point alone, some 4,000,000 pounds of material has been shipped at a savings of $80,000 in direct freight costs. Another advantage of the plan shows up in expediting expense. A representative truck load may contain shipments from 40 to 50 vendors, each of which may have been contacted by expediters under the former plan to assure on-time shipment. Under this new plan, one telephone call to the consolidation center late in the afternoon will answer questions regarding any item on the truck. Other advantages are obvious: (1) There are fewer trucks unloading at the receiving docks, (2) one freight bill takes the place of 40 or 50 processing through the paperwork system, and (3) fewer carriers need to be contacted about intransit movements. The carrier also guarantees 24 hours on the road from Chicago, which is the same time the airlines agree to on air freight.

Names in the News

Elwin F. Pearson, formerly of Outdoor Lighting, is the New Materials Manager at Missile and Ordnance Systems in Philadelphia. . .Small Aircraft Engine announces the appointment of Charles J. Trees as Manager–Materials. . .C. Leroy Spearen has been appointed Materials Manager at X-Ray's new St. Petersburg, Florida, operation. . .At Light Military Electronic Equipment, Edward P. Heinemann takes over the Materials function in place of departing Bob Sonnekson. . .Jack L. Veeneman is now Manager–Materials for Aircraft Nuclear Propulsion in Cincinnati. . .Charles E. Underhill takes over the position of Materials Manager at Medium Steam Turbine in Lynn from Lloyd R. Stanley, who moves over as Superintendent in the same department. . .Also at Medium Steam Turbine, Joseph T. Reilly has been promoted to Manager–Inventory Control and Systems Analysis. . .Clayton R. Liddell, a recent MTP graduate, has joined Harold F. Briggeman's Materials section in Specialty Transformer as a Specialist–Production Control. . .Harold G. Norris, former Specialist–Inventory Control and Systems at General Purpose Control in Bloomington, Indiana, is now Manager–Engineering Administration. . .John A. Adams has been appointed Materials Manager at Silicone Products in Waterford, New York. . .At Appliance Motor in DeKalb, Brooks Brickley is the New Manager–Manufacturing Engineering, and Stephen T. White has taken over as Manager–Materials.

R. R. Smith, Editor
Production Control Service
570 Lexington Avenue
New York 22, N. Y.

P

PRODUCTRON

Extracted from quotation letter dated 7/5/55 from
K.R. Geiser, Manager - Computer Engineering
General Engineering Laboratory

"The subject of this letter is a computer which will make possible accurate and rapid work load programming of manufacturing facilities. As a brief example let us assume that a manufacturer assembles four different products in his plant. Each unit of product has a different work load impact on any one work station. A work station could be a single punch press or an entire packaging department. Since it is of economic importance to have a constant work load on each station so that there are a minimum of peaks and valleys in work demand, than a big help in achieving this end is to know what the work load for each work station will be if a certain number of each product are to be manufactured. A computer can be built to do this. The two types of inputs will be: (1) The number of each product to be assembled. (2) The impact in hours/product, of each product on each work station. The computer then multiplies the number of products by its work factor for each station. All of the products of any work station are then automatically added together to give a total in hours, of the work load on that station produced by all the products in that manufacturing plant. Various combinations of quantities of products can then be rapidly tried on the computer to achieve efficient station loading. At present, a computer which is capable of handling up to 48 different products and 25 stations is economically and technically conceivable.

"It appears that for ease of maintenance, reliability, cost and use of proven components, a potentiometric (variable resistor) matrix type computer is best suited for this application. It is comparatively rugged and simple to operate. Only about seven electronic tubes are used in the computing circuits and none of these are critical in performance.

"Figure 1 is a sketch of the PRODUCTRON as it may appear. It is proposed that the computer be housed in a cabinet approximately the size of a desk. The size of the matrix solved would be 48 x 25. The quantity of each product would be hand set on a calibrated dial attached to each of the 48 "P" potentiometers located on the center panel of the rear of the desk. The "B" or "time per unit product" values are set on 1200 small potentiometers located inside the computer. These are accessible from the outside for adjustment. The "B" potentiometers are set to an accuracy of 0.1% of full scale by utilizing a bridge circuit and master potentiometer located on the left console panel. The instruments mounted on the right console panel monitor the AC line and DC Computer voltages. The controls and output instrument may be located on the surface of the desk for easy readability and fast operation while the operator writes down data.

"The AC power from the line, approximately 500 watts, will enter through a line contactor relay and an AC line stabilizer which will hold constant voltage on the computer. The stabilizer will supply the computer DC power supply and the operational amplifier power supply. The DC power supply is adjusted to produce a certain voltage at the top of all the "P" potentiometers. This voltage is the computer base voltage and could be approximately 12 volts DC. The output of each "P" potentiometer is a voltage analogue of the "P" valve and each one is applied to all the "B" station potentiometers affected by it. The output of the wiper of any "B" potentiometer is a voltage analogue of the product "P x B". It is proposed that there be 1200 such products in this matrix. The "B" potentiometer may be connected to the contacts of some rotary switches. In response to a signal from the computer operator, the rotary switch shall scan that particular row of "P x B" products and feed consecutively, each "P x B" product of any one particular station into an operational integrator amplifier. The sum of all the "P x B" values of the particular station being scanned will be accumulated by the integrator capacitor and can be read on the output instrument as hours of load on that particular station. The operator can write down this reading and by actuating a button will cause the computer to scan the values for the next station. Each scan will take approximately one second and with operator write down time we may allot 5 seconds per station. Therefore, an alert fast operator can complete computer cycle in approximately 2 minutes. If 10 trys are needed with 3 minutes for setting new values on certain "P" potentiometers, then the entire iteration will take approximately 1 hour. As an engineering goal, it is likely that with inexpensive components an accuracy of $\pm$ 5% of full scale may be attained."

This engineering specification write-up should give you a little clearer understanding of what is proposed in the way of equipment. Below is a written description of the detailed mathematical specifications as presented by Production Control Services to the General Engineering Laboratory.

"The first problem would be to determine whether the shop has a fixed lead time relation for each of its components and a single time period impact for station utilization. This machine load determination problem is characterized by the following definitions and equations:

Q_p = quantity for each product in the work mix.

$U_{p,s}$ = unit labor or machine content for each product at each work station or machine area.

$\sum_p L_s$ = total load for any station or area for all products.

C_s = capacity of work station or machine area to produce during the same work period at the product schedule.

Q_p and $U_{p,s}$ must be specified.

$1 \leq p \leq 48$ ($p = 1$ would be a trivial situation)

$1 \leq s \leq 25$ ($s = 1$ would be a trivial situation)

U is a cumulative figure covering all parts used in a certain product and requiring a specific static equation:

$$\sum_{p} Q_p \cdot U_{p,s} = \sum_{p} L_s$$

$\sum L$ is to be direct reading.

Total time consumed per trial is to be under 15 minutes.

Provision is to be made for:

$.1 \leq U \leq 99.9$
$1 \leq Q \leq 1000$

The accuracy on both is to be plus or minus one-half of the smallest unit.

The read out accuracy is to be within 3 to 5%.

T. F. Kavanagh
MTP
Production Control Services

8/10/55

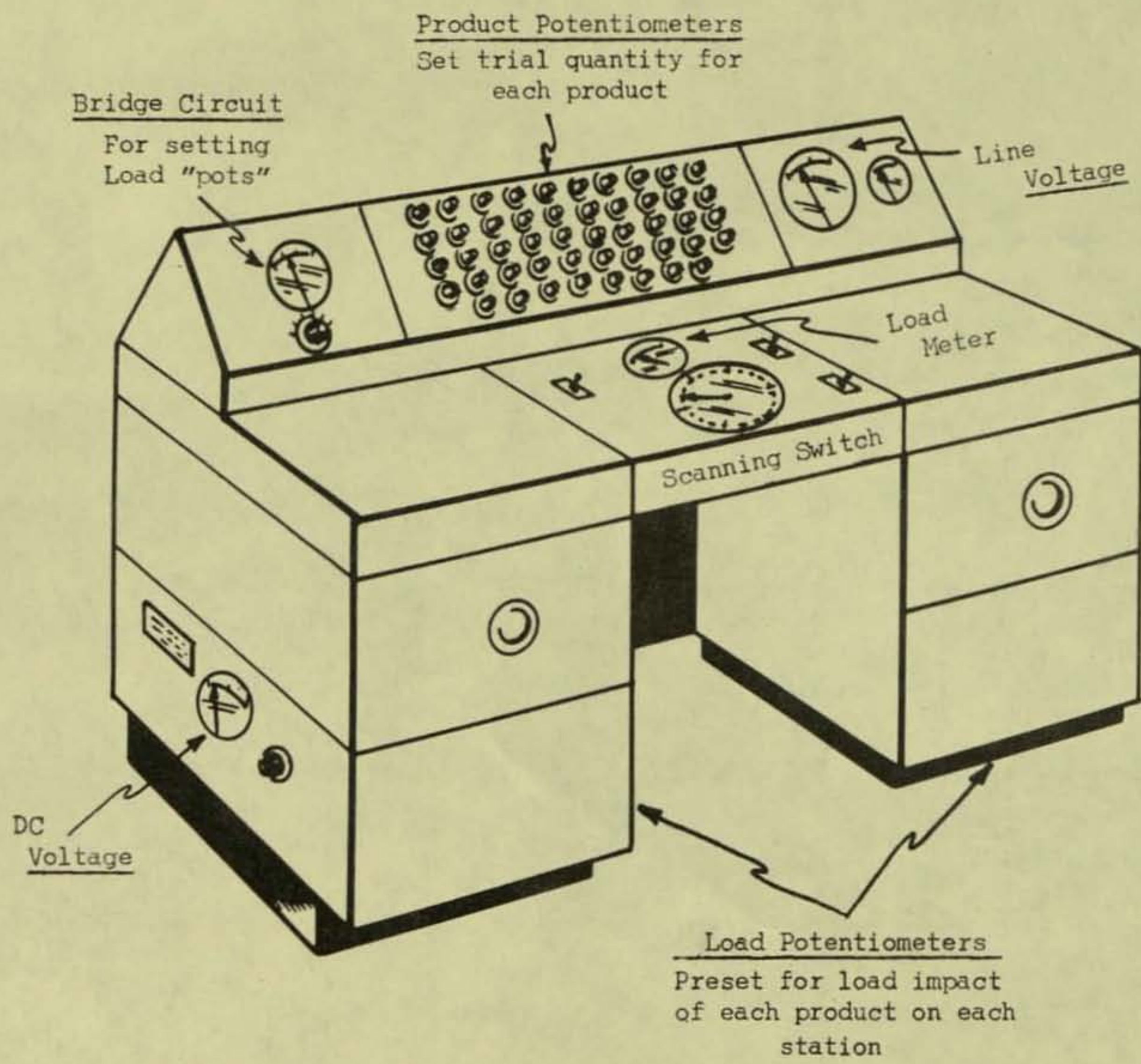

Product Potentiometers
Set trial quantity for each product
Bridge Circuit
For setting Load "pots"
Line Voltage
Load Meter
Scanning Switch
DC Voltage
Load Potentiometers
Preset for load impact of each product on each station

FIGURE 1

PRODUCTRON

LOAD-CAPACITY ANALYSIS

COMPUTER

PRODUCTRON MEETING

Production Control Service

Van Curler Hotel
Schenectady, New York
November 4, 1955
9:30 A.M.

PRODUCTRON MEETING

Van Curler Hotel
Schenectady, New York
November 4, 1955

9:30 A.M.	A Foundation for Better Scheduling Decisions H. F. Dickie, Production Control Service
10:00 A.M.	The Load-Capacity Analysis Problem B. Grad, Production Control Service
10:30 A.M.	Coffee Time
10:45 A.M.	Productron Tackles Load-Capacity T. F. Kavanagh, Production Control Service
12:00	Lunch
1:30 P.M.	Productron -- How Does It Do It J. P. J. Gravel, GE Laboratory
2:00 P.M.	The Future for Productron K. R. Geiser, GE Laboratory
2:30 P.M.	Discussion with free-running time on demonstration model of PRODUCTRON

PRODUCTRON MEETING

Productron--A Foundation for Better Scheduling Decisions

Mr. A. F. Vinson, Vice President, Manufacturing Services, has recently found, without exception, that the manufacturing operations observed to be in trouble have weak scheduling plans--very often marked by inadequate personnel. He has indicated strongly his belief that the foundation of a sound manufacturing plan--the utilization of manpower, machines, and materials--is a sound production schedule.

Good or improved manufacturing scheduling seems a particularly timely topic as the era of automation arrives. With automation, it appears that the fixed investment will be far greater than our present conception permits us to imagine. In addition, the automated equipment will lack flexibility that the present general machine tools offer. Therefore, we must do our long-range planning and scheduling more intelligently so that we have the very minimum of equipment utilized to the maximum--probably on a seven-day, three-shift basis.

Equally timely is the approaching guaranteed annual wage, which has also highlighted the scheduling activity. As Peter Drucker, one of the outstanding contributors in the field of industrial management, has so clearly pointed out, there was the time when our problem in production leveling was balancing the cost of carrying inventory against the costs of fluctuating production, and the layoff of employees was put down as a small intangible of good will, but now a layoff of G. A. W. becomes a real tangible cost.

Also a factor in our current economy, though maybe less in the headlines, is the stiff competition which requires shorter and more reliable production promises. The early promise that is too short can be disastrous for you and the factory--the promise that is too long may lose you business, and if made in an atmosphere of ultraconservatism, can cause uncomfortable stretchouts in the factory. If we must meet the demands of King Customer, we must have earlier warning of load impacts. The precious time between promise and execution cannot be spent in breathless waiting. This time is needed for rearrangements, shifting of loads, starting overtime, extra Saturdays, and so on.

To me personally I think it would mean fewer ulcers for production men, who issue an educated promise on requisitions and hope that everything comes out all right. As most of you know, this is very trying. I feel that the ability to have good early sound evaluation of even the propositions which we promise is a necessity for a sound business operation, and the accompanying confidence and peace of mind.

Our genuine concern for the improvement of production scheduling even within our Production Control Services organization is clearly shown by the most recent addition to our small staff. Mr. Alan Rowe very recently joined our organization and was selected because of his interest, experience, and unusual capabilities in the area of business production scheduling, etc.

I would like to trace my own personal observations in the area of production scheduling, for I think they will clearly explain to you our thinking in the development of Productron to which you will shortly be introduced.

Nineteen years ago our Transformer Department was experiencing considerable difficulty in establishing good production promises and schedules in the early proposition stage--when probability of getting the order is not known and engineering design work had not been completed. However, it was encouraging to find that the costs established at the proposition stage were reasonably satisfactory, which indicated that if a similar amount of attention were given to proposition scheduling as given to proposition costing, considerable improvement could be made. This was accomplished by having a capable production supervisor join the cost estimator, proposition engineer, and planner. There developed good early production scheduling which proved to have an accuracy of plus or minus 3 per cent in its prediction of the loads in various portions of the manufacturing section. Certainly, there were small surprises in work load and a spotty amount of overtime, but there were no great changes required on a crash, red, white and blue basis. The smaller shifts in volume or type of work were somewhat anticipated by a calculation of the load by matching groups from the live loads in the dispatch cages. In brief, each requisition or proposition was broken down into a dozen components of work load, and these were tabulated and broken down into time periods. Particularly significant was the fact that the man scheduling could clearly see the whole scheduling scheme, and the amount of calculation was sufficiently small so that the work load could be manipulated to obtain the best balance for the greatest benefit of all concerned.

Mechanically this was simply a multiplication of the number of components times estimated direct labor and a summation of these extensions by work areas, by time period--simply a series of multiplications and running additions.

Five years ago the Aeronautics and Ordnance Division tackled the job of scheduling our Schenectady Ordnance operation. The approach was detailed data loading of every operation and every work station from detailed planning. This proved to be unwieldy in volume and actually rather late development of bad news, and it became very obvious to me that the big improvement lay in better techniques of good original master scheduling long before detailed engineering and planning were even available. The information developed from detailed planning simply told us the mistakes we had made. The volume of work and data was not manipulatable and served little purpose other than to give us a short period of advanced notice of the troubles for which we already had committed ourselves. We even lost faith in this short notice because handling of engineering and scheduling changes was a clerical impossibility.

Again, you can quickly visualize the mechanics of this work which was the same, quantities multiplied by labor standards and a running summation of direct labor totals by time periods.

Two years ago we visited Philadelphia and reviewed their IBM system for detailed loading. At first this seemed to offer a fine improvement in the mechanics of handling the job we had recently found so unwieldy at A & OS. With the quantities of the particular orders punched into the IBM cards, the machines rapidly estimated, sorted, and totaled the load ahead by individual work areas. However, by the time we were there to inspect the system, all the superintendents but one had dropped it and labeled it as misleading because they had found that even with their mechanical handling of data, changes in engineering and schedules could not be handled economically. Only one superintendent kept it, stating that it was better than no prediction at all. This plan seemed to have failed because again we find an inability to update information, to adjust it for changes, and the information simply tells us the mistakes we have created in poor original intuitive scheduling.

The mechanics of the Philadelphia system featured one important improvement. The multipliers, the fixed direct labor cost of doing an operation, were punched in master IBM planning cards which can be simply reproduced. It seems we should profit from this idea.

Even a few weeks ago our office, as part of our self-educational program, visited AM & F on Long Island to explore their Remington Rand detailed load planning system. It was another large extension and summation job not only rather more unmaneuverable but also timeless because they simply load it and subtract from one large floating pool for each type of machine tool. Although it gave them a trend in total load, it lacked again because of its volume the ability to cut and try, rearrange and improve; and again they simply found out something of the problems they had created for themselves in their original "guesstimating," and the volume was so large that changes in plan were not carried through the system.

In June, 1954, George Howell, Manager of the Fort Wayne plant of the Hermetic Motor Department, met me in the lounge of the Statler Inn at Cornell University in Ithaca. Stimulated possibly by the generous flow of champagne at an earlier banquet, he expressed with considerable clarity his basic problem of production scheduling in their Hermetic Motor business.

Periodically the three plant managers meet with marketing, production, and the general manager to establish their short-range manufacturing plan. At the time the meeting was done on a motor-units basis. Everyone knew that all motor-units were not alike. Even these plans, which might better have been made on the basis of an analysis of the labor in each of the component motor-units, were soon upset by frequent demands for rapid changes from one very large and important customer--Tecumseh. George's appeal was for a means of rapid calculation of significant labor loads at the time if initial planning so assigned quantities between various plants could be rearranged to allow for best distribution of the load Then he felt this same process should be available for quick evaluation of the changes requested by their customers. The system must be quick, must be simple, must be so understandable that various combinations can be made with facility to find the best mix. Their cycle is so short and competition so heavy that they must make one- and two-week promises that are sensible, practical, and not uneconomical to carry out. So our first ideas for Productron were given birth. Subsequently, we have looked at a number of departments where we have been visiting. To select one of several, the Capacitor Department at first glance showed hundreds of items to be loaded. This seemed too large for our initial concepts on Productron. This certainly presented a problem. Further analysis with Harold Frank showed that initial loading could be done well on the basis of 18 broad family or prototype classifications of Capacitor's.

Large Steam Turbine and Large Motor Generator seemed to have problems that were entirely different, and yet even there we found that initial planning could be well guided by classifying their various types of apparatus into a few dozen or so critical bottleneck stations. However, for Productron in this type of scheduling problem there remains the difficulty of varying time periods.

In all of these problems we see the need for speed in making extensions and additions. We should not have to redetermine fixed multipliers but should proceed from the concept of the reproduced punched cards with labor values already on it. Second, there must be an ease of manipulation so that we can back up, reconsider, make changes, cut and try, and lastly the system must be simple enough so that the master scheduler can have a full grasp of the over-all problem. Productron represents our first pass at meeting this problem.

One word on Productron. We believe it is quite promising, but please understand we are not here to sell it. Our presentation is what we believed would be the most useful for most of you, but in the last analysis you are the designers--the consultants sitting here today. You also are the board of directors for this Productron company. You will decide if it is to be produced, and its final form is also in your hands.

I should like to comment also on one remark which has been made. "It is swell. We need one, but I guess we can't afford it because we wouldn't use it full time." The machine is a simple one. I believe the General Engineering Laboratory should be complimented on their economy in selection of components and economy of design. Any of the suggestions you might have for further simplification are most welcome. But if the machine is as simple as it can be for the job we have, I feel the value of good original production scheduling that can be kept updated and potential shortages evaluated even while you are on the telephone is great and very hard to estimate. At the same time don't forget the first computer bought in the company for commercial applications was Appliance's UNIVAC, ordered with plans for utilization of twenty hours per week.

So I wish to thank George Howell for his original inspiration and Cornell for the champagne that stimulated our enthusiasm, the Hermetic Department for giving us a typical problem to visualize twenty years of troubles in production scheduling, to make me a fanatic in pursuit of improved techniques and mechanics of early maste production scheduling.

And lest it be overlooked, I want to be sure that every credit is given to Tom Kavanagh and Burt Grad of our organization for their work on the project and this meeting, as well as Don Garr and his associates and the computer section of the General Engineering Laboratory for their participation, interest, and ingenuity in this project.

H. Ford Dickie
11/4/55

PRODUCTRON--LOAD CAPACITY ANALYSIS

The Load-Capacity Analysis Problem

Scheduling is the art of planning the use of the productive elements so as to obtain the greatest long-range profit from your business.

Load-Capacity Analysis is the means for measuring for feasibility of a scheduling plan.

The nature of the business sets the scheduling theme and hence the load-capacity theme.

Custom Designed

Let's look at a business which emphasizes uniqueness and design to suit customer wants. The Rolls Royce lets you select your own features and will build the basic car to your specifications. Although this practice may cost a little more money, in many lines of GE products the custom design approach is essential. Naturally, in a business of this type, the scheduling problems will be somewhat unique also.

When products are custom designed, the master schedule is determined almost entirely by the number of customer orders or proposition commitments on hand. These orders are generally firm. But in planning the master schedule, we must allow time for design engineering and production planning in addition to the time needed for materials procurement and product manufacturing. When completed, the finished product is normally shipped direct to the user. The key factor, therefore, is that no finished goods are warehoused, and the master production schedule is essentially the same as the backlog of firm customer orders.

Standard Components Assembled to Make a Large Mix of Finished Products

Now let's look at the Buick. Even though the variety available seems immense with all the different colors, accessories and body styles, there is a very high level of standardization--the components are the same. This leads to concepts such as family scheduling and loading and the use of an average unit or typical unit.

When standard sub-assembly components are assembled in many different combinations, very likely there will be a large mix of finished products. Some of these may be quite popular sellers; others may be sold only once in a blue moon. So in determining the master production schedule, we may decide to produce some of the "popular types" for warehouse stocks, while others are produced only when customers place orders. On the other hand, the master schedule may be comprised only of firm customer orders; it may be too risky or too costly to produce even one type for finished stock. Generally, the important distinction is that many component parts or assemblies have been previously fabricated in anticipation of orders. Since product design work is virtually complete and standardized, the master schedule need not include much consideration of the time required for engineering or for standard parts procurement.

Standard Components Assembled to Make a Small Mix of Finished Products

To see the other side of the coin, we can look at the Willys jeep. Here the emphasis is placed on the product's versatility so that basically only one model is offered for sale.

When the factory produces a small mix of a standard design product, finished goods are usually assembled and shipped to various warehouse stocks for further distribution to the customers. Because of the design standardization, there is less risk in producing before the actual sale to the ultimate customer; therefore, stocks of finished goods can be kept in many marketing areas. Based on past experience we can usually measure accurately the amount of risk involved.

Materials Schedule

Stock	Non-stock	Rated
. Order point	. Ordering	. . Support of a continuing program
. Order quantity	. Allowance for spoilage	. "A" items primarily
. Protective stock		
. Historical or mortgage or prediction		

In the case of purchased parts, there are relatively few load restrictions. In general, scheduling merely involves setting a due date and a desired quantity. The difficult feature is schedule maintenance which requires effective expediting and contacts. Although few materials sources will be bottlenecks on a going basis, they often set a limit on the speed with which increased business can be accepted.

Manufacturing Schedule

The concepts which will be introduced here concerning the job shop and the flow shop are somewhat different than those you may have seen in other books and articles. This is influenced by the fact that in planning the manufacturing schedule, consideration is primarily given to the actual layout of the shop: the way in which the material flows from machine to machine.

In the job shop, the layout is of a process variety; that is, the milling machines are together, the drills are together and the numerous parts all cross basically the same machine tools. However, each part has a different machine sequence and timing for its operations. This is sometimes called an intermettent or lot type production.

The flow shop, as the name indicates, has its machines laid out in accordance with the product being manufactured so that the operations follow one another in the same sequence as the stations on the production line. This is sometimes called mass production and is seen in GE in the matched conveyer system as well as the high volume appliance plants. In the area of manufacturing schedules there are many load-capacity problems. They deal with the basic operation sequence and job interferences. In addition, there is always the consideration of feasibility versus optimality. It seems that manufacturing scheduling is today our biggest factory headache.

The Need For Load-Capacity Analysis

To repeat, scheduling is the art of planning the use of the productive elements so as to obtain the greatest long-range profit from your business. There are many levels to the scheduling problem all the way from the master schedule, which establishes what products are to be made over some period of time, down to the detailed factory dispatching "schedules" which determine the sequence in which various jobs will be processed on the available facilities. The common thought which runs through all these problems is that of harnessing time-making the greatest return from the time available on the various facilities.

Proposing a scheduling plan without knowledge of your business is like constructing a boat without blueprints--you need a specific design to guide your construction. However, at different levels of management you need blueprints of different degrees of detail. For instance, in making an original commitment to the customer, generally all that will be necessary is an over-all evaluation as to whether there will be enough total manpower and sufficient bottleneck facilities to do the job as roughly described. But as construction proceeds, we start to need specific detailed blueprints, telling us exactly how many of each part will be needed, when they will be used, how they are to be made, and how long they are going to take for each process.

Our general profitability and competitive position are heavily dependent upon the effective scheduling and use of our facilities. Good scheduling cannot be realized without adequate and accurate means for determining ahead of time the results of our scheduling decisions. This leads to the conclusion that knowledge of the capabilities of our equipment and the impact of our products is a prerequisite to good scheduling. With this background we can see that a new set of tools must be forged to strengthen our techniques of Load-Capacity analysis, which is critical to successful scheduling.

Measuring Your Schedules

The load-capacity analysis tends to show how far "gone" your schedules are in terms of committments of your facilities versus available time. This measurement is the means for planning your expenditure of money--of building your inventory and of promising delivery to your customers.

What then are the elements to this comparison? First, we must know our capacity; next we need to know the load-impact of each product on each of our productive elements and finally we must have a proposed schedule to be evaluated. These three factors are the keys to the problem: Capacity, Load-Impact, Schedules.

Capacity is the planned availability of the productive elements during the time periods under discussion. It takes the basic work time and adjusts it to reflect incentive earnings, vacations, holidays, absenteeism, hunting season, etc. Some of these factors may even increase the time available but most, unfortunately, seem to reduce our capacity. A simple approach is often to use as a capacity figure the net time available: for instance, 36 hours rather than 40 hours for a one-shift operation. The load-impact data is merely a consolidation of the planning sheets for all the parts which go into a given product. It details the load that each product causes on each element at the various periods of time preceding the completion of the product.

The schedule is the product demand for each time period. It is characterized by:

. A demand for a group of products

. A group of elements to be used in making these products
. A time period during which this demand is to be satisfied by the available elements.

How Big is the Problem

Now this problem can very quickly become preposterous in size so we must identify carefully what factors are being dealt with and how they can be reduced to more manageable proportions.

First, look at the key decision areas:

. Breadth of analysis--products, stations, time
. Type of analysis-continuous, periodic
. Unit of measure for product--dollars, gallons, pieces
. Amount of recycling--(feedback)

Then examine each of the basic items:

. Products--parts, assemblies, major components, finished models, prototypes, model lines, products as a whole.

. Elements--stations, similar stations, progressive stations (balanced), functional areas (fabrication, assembly, presses, etc.) sub-sections, entire shop, bottleneck stations. These can represent machines, men, or materials.

. Schedule and Load Time--the number of time-periods covered by the proposed schedule. Maximum load periods equal schedule periods minus maximum lead time.

. Lead Time Relationship--the number of time periods during which a group of products impact on a productive element. If lead times are constant for each element, regardless of specific product, then the lead time relationship equals 1.

Thinking is Still Allowed

There are unfortunately many factors which cannot easily be incorporated in a formula or represented by a precise mathematical notation. These might be called overriding judgment factors:

. Timing
    . Level--proposition, requisition, parts list, planning, dispatching
    . Kind--master, materials, manufacturing
    . Changes--frequency, magnitude, and importance
    . Accuracy

- Periodic or continuous plan
- Response speed

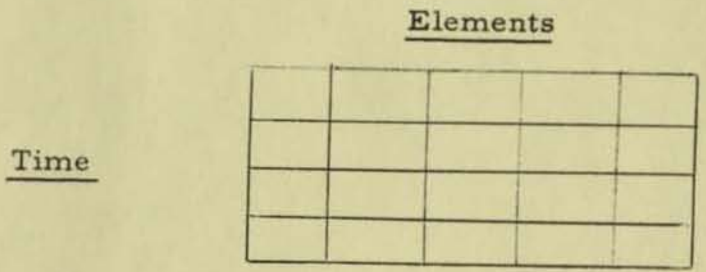
- Feedback
- Organization
- Product dynamism
- Redundancy
- Communications

The Tic-Tac-Toe of Load-Capacity

But in spite of these special considerations, load-capacity analysis can be reduced to a relatively straightforward, essentially mathematical, problem.

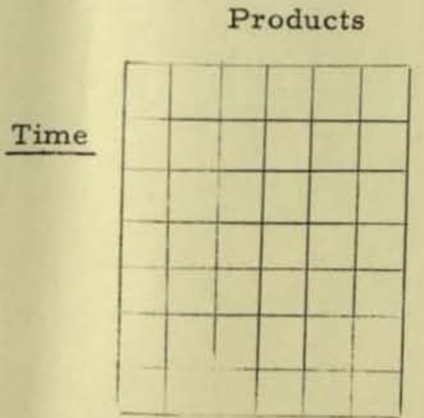
Fortunately, each of the load capacity analysis problems has an identical mathematical structure. The solution is expressed by a table which indicates the load for each production element. This table would look something like:

Resultant Load

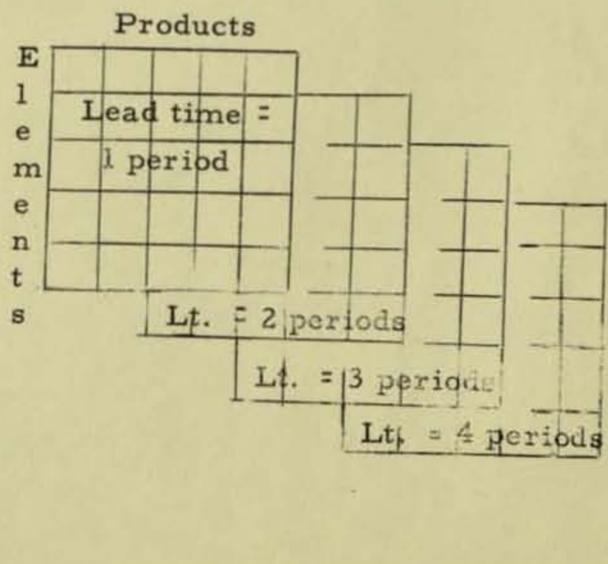


This table is derived from multiplying the schedule by a series of load-impact tables:

Schedule



Load-Impact



With certain departments this can be simplified since there is only one lead time with which to be concerned or the lead times are constant for any given element regardless of the product. This simplification which is so useful in speeding up the load-capacity analysis is often a great factor in those very efficiently scheduled plants you hear about. The handling of these tables or matrices is a straightforward and quite logical process. Later discussions today will emphasize how these tables are processed to yield simple, usable results. Here then is one key to effective load-capacity analysis: a standardized simple, effective technique for representing the problem with concise mathematical formulation. But there are two locks on this door and it is not enough to release the first lock by starting the problem in an efficient manner. The second key that is necessary is the ability to recycle, to check various schedules to see if they are better or worse than the original one proposed--possibly our new motto should be:

"Since at first you won't succeed, try, try again".

B. Grad
10/28/55

PRODUCTRON TACKLES THE LOAD-CAPACITY PROBLEM

At Last What is PRODUCTRON

Now to the reason behind this meeting -- PRODUCTRON. Unlike the fabulous snake oil of the 1880's, PRODUCTRON will not cure all ills nor will it handle all problems. It is a small, desk-sized computer specifically designed to handle the load-capacity problem which has been developed in the preceding presentations. For this specific purpose it comes admirably equipped. PRODUCTRON stands ready to provide you with the total factory load by workstation for any production requirement which you place on its console and it does this with a speed which will more than match other types of computational equipment and with all the accuracy that is warranted by the input data. PRODUCTRON, by removing the clerical detail from the load-capacity problem, provides more time to think--to prevent, or at least organize to meet, the emergency situations which are bound to occur from poor evaluation of factory commitments. PRODUCTRON places the manufacturing load plan before your eyes as the ink dries on the marketing commitments.

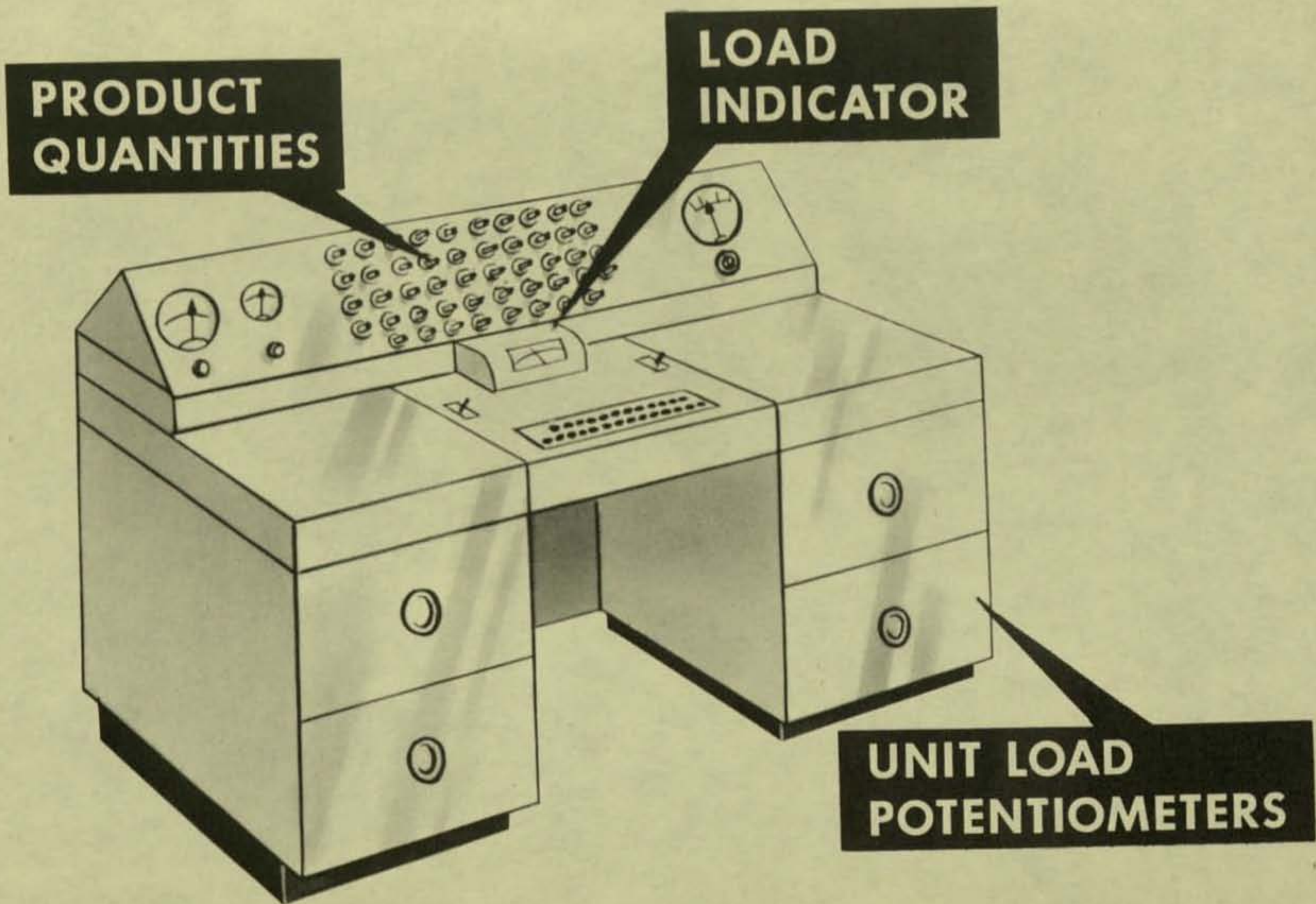
What Does PRODUCTRON Look Like

PRODUCTRON is the size of an ordinary office desk. It has been designed so that it will fit harmoniously into any office facility in the General Electric Company. Conspicous by their absence are costly air conditioning units, separate power supplies, and a host of other elaborate, complicated accessories normally associated with computers. PRODUCTRON is wholly contained within the desk that you see before you. It has been designed so that the only installation work required is to place the power cord into an ordinary 115V wall-socket.

The lack of elaborate accessories for PRODUCTRON is significant for two reasons. Quite obviously, such accessories cost a substantial amount of money. Being able to do without them has enabled us to bring PRODUCTRON to you at a substantially lower price. This lack of accessories is also important because it illustrates concretely the fundamental simplicity in PRODUCTRON's design. The complicated electronic and mechanical design which has almost become synonomous with the word computer just does not exist in PRODUCTRON. PRODUCTRON utilizes basic fundamental principles of electricity which has been tried and proven many times over.

Let's look more closely at this desk sized computer. What are its important elements? Perhaps the most significant, at least to the production man, is the answer -- the load. The answer in the total loads by workstation are displayed on an instrument, housed in this console directly in front of the operator. This instrument is calibrated to read whatever load units that your

PRODUCTRON


PRODUCT QUANTITIES
LOAD INDICATOR
UNIT LOAD POTENTIOMETERS

particular department desires -- dollars, hours or various other equivalents. For the sake of uniformity, our work will be entirely in terms of hours in this presentation.

Directly above the load indicator on the PRODUCTRON console is a series of direct reading dials on which the product quantities are recorded. Should you decide at any time to change these quantities for any or all of the products, all that you have to do is to turn the dials to the new product quantities for which you wish to analyze the load.

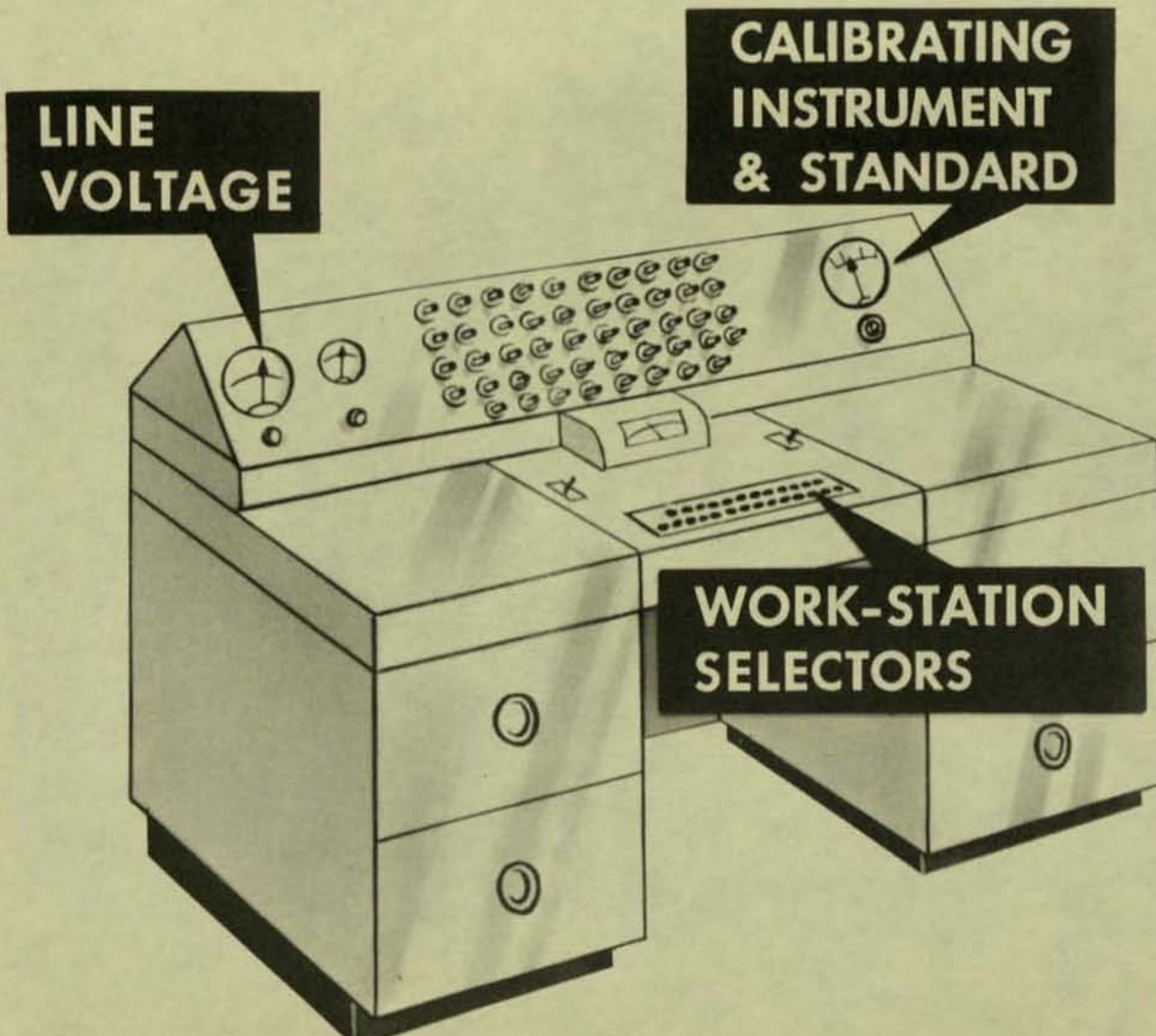
Following the general sequence the next point of interest is the unit load impact table, that is, the record of the load which a single unit of each product would have on each of the work stations to be analyzed. These values are recorded on tiny variable resistors--the kind that you see used in hearing aids as sensitivity or volume controls.

Since these quantities are not nearly as subject to change and would most likely remain constant throughout any given series of load-capacity analyses, they have been stored in the upper right hand drawer of the desk. PRODUCTRON will have 1250 such tiny resistors. This is analagous to saying that PRODUCTRON has a 1250 word memory which is substantially larger than that found in most desk sized computers. By way of comparison, the Burroughs Corp. recently announced that they have expanded their desk sized computer, theE101, to a 220 word memory. The E101 is in the $35,000 class. The use of these tiny variable resistors exemplifies the type of cost conscious thought which the general engineering laboratory has poured into the design of PRODUCTRON. They have found an expedient way to use stable low cost resistors and still preserve the accuracy which obtained through using the most costly high precision components at considerably reduced cost.

Well now, what else goes into this machine? In the lower left hand drawer is a completely independent power supply which provides all of the electrical power requirements for PRODUCTRON from an ordinary wall-socket. Because this is an analog machine, the accuracy requirements for the operating components is high. So a volt-meter and a small rheostat has been included on the control console to enable the operator to check and, if necessary, adjust the line voltage when the machine has started. Further adjustment, however, is not necessary while the machine is operating as the power supply can take care of the Joe Joneses and the Sam Smiths who drop 25 horse power motors directly across the line out in the factory.

Since we have introduced the word analog, a few words on the difference between analog and digital computer will help to clarify just how the engineers were able to make PRODUCTRON's so simple. A digital computer, as you know, keeps track of all of the numbers in any given problem in counters and might be said to literally count its way through a problem a unit at

PRODUCTRON



LINE VOLTAGE
CALIBRATING INSTRUMENT & STANDARD
WORK-STATION SELECTORS

a time. Of course it does this counting at electronic speed. The analog machine on the other hand attempts to set up a specific problem using physical phenomena which behave the same way that the actual problem behaves when its elements are changed. Thus the analogist looks into mechanics, electricity, magnetism, hydraulics and in cases a combination of these to represent his problem.

PRODUCTRON sets up the load-capacity analysis problem as a voltage analog and reads total workstation load by measuring a series of voltages.

In the upper left hand drawer is the heart of the computer mechanism which amplifies and integrates the voltages transmitted from the unit load impact table and provides the resultant integrated voltage to the load indicator. The mechanical switching which is required for the computer to select the correct work areas and to establish the time base required to perform integration is located in the lower right hand drawer.

How Do We Get An Answer

Well now, how do we make this computer work? To make the computer indicate the total load for any given factory workstation, you depress one of the 25 buttons which are stretched out on the desk top before the console operator. Each of these buttons represents one of the factory workstations which the machine has been set up to analyze. These workstations may represent one machine or any series of machines which can be conveniently grouped in your department. Once depressed, the required circuits will energize the load indicator which will instantaneously display the total load on that particular area.

When presented with a production requirement which has to be evaluated, all that has to be done--assuming for the moment that there are no changes required to bring the unit load impact table up to date--would be to:

- turn on the machine
- set the production requirements on the dials across the top of the console
- check the line and the computing voltage
- depress the workstation selector for the area that the total load impact is desired.

If you wish to make a complete analysis of all of the 25 workstations, you would start by pushing down the first button, read the load indicator and write down the total load for the first workstation. Then selecting the second button you start cycling the same way until all the stations have been recorded.

As those of you who are motion conscious know, the actual sequence of operations was inverted for logical demonstration purposes. Actually, you would depress the workstation button for the next station before writing down the load indicator reading. This combines the time of the meter with the writing time and will reduce the over-all time required to read a 25 workstation cycle.

Setting Up The Unit Load Impact Table

On the right hand side of the console, there are two items marked Calibrating Instrument and Standard. This is used to set values into the unit load impact table. The value which you desire to put into the load table regardless of its location is set on the standard dial. Then the operate--calibrate switch is thrown over to calibrate and two internal switches not shown are switched to the field location in the tables by product and workstation.

Then, after opening the upper right hand drawer, and selecting the tiny resistor which is to be changed, rotate the potentiometer until the calibrating instrument reads zero. For those of you who are electrically inclined, this is a simple Wheatstone bridge circuit and, as you know, it is extremely accurate. That is all that is required to put new values into the unit load impact table.

We would like to point out that prior to lunch and during the balance of the day, a mark up of PRODUCTRON display will be exhibited at the rear of the room. In addition, many of the operating components which will be used in the manufacture of the computer will also be on display.

The Demonstration Model of PRODUCTRON

Unfortunately, available time and available money do not permit the construction of a complete PRODUCTRON computer. I think that you will understand that the pioreering method of this undertaking in equipment development and because of our responsibility as a service to General Electric operating departments, it is extremely important for us to make certain before placing PRODUCTRON in the hands of an operating product department, we must make certain that this is the machine that you want. To provide you with a better illustration of the principle of operations of the machine and to provide you with something concrete so that you could understand the concept of the computer, the General Engineering Laboratory has constructed a demonstration model of PRODUCTRON which has all of the elements which will be included in the final machine.

Before opening our little blue box, I would like to make one very important point. This is only a miniaturized demonstration model of PRODUCTRON. PRODUCTRON is capable of doing 72 times more work than our

PRODUCTRON

OPERATING INSTRUCTIONS:

- • Turn power on
- • Check voltages
- • • Enter product quantities
- • • Depress work station selector
- • • Read load indicator

speckled traveling case. PRODUCTRON is a desk sized computer. The demonstration model was built only as a means of illustrating the job which the computer can do, and the complete simplicity of design found in its construction. PRODUCTRON will have many, many more components than our little demonstration model but it will have the same simple circuitry and the same simple operating steps which were used in the demonstration model.

The principle item of interest on the model as well as the finished PRODUCTRON that we discussed before will be the load indicator. The load indicator is calibrated in hours. The second item on the control panel are the product requirement dials on which the number of products desired is recorded.

Below this is the area selector switch which is used to select the area for which the load is desired. Underneath the main panel onthe subchassis is the unit load impact table for a 4-product, 4-area load-capacity analysis.

In addition, there is a volt meter and a rheostate to adjust line voltage.

Lastly, there is a Calibrating Instrument and Standard to set-up the unit load impact table.

Also included on the switch are the on-off switch and the operate-calibrate switch.

How Does It Operate

The actual operation of the demonstration model of the computer is quite simple. The operating steps for the demonstration model are the same as they will be for the finished PRODUCTRON;

1. Turn the power switch on.
2. Set the operate-calibrate switch to operate
3. Set the production requirement in the product quantity dials.
4. Select the work station
5. Read the load impact on the load indicator for the workstation selected on the computer.

All that is required to read the balance of the workstations is to depress the next button and read the new load. Thus, by successive cycling, it becomes a very simple matter to read a 25 workstation load.

Production Programming

Many of you have spent a wonderful week with the International Business Machine people at Endicott learning about punched card equipment and many more of you may have spent two, three or four weeks with Remington

Rand or IBM learning to program one of their computers. In the short time that I have been speaking with you, you have become production programmers. There's nothing more to it.

Before you leave this afternoon, I hope that you will not only be production programmers but that you will also be effective console operators as well. While we make no guarantees concerning the ability of PRODUCTRON to do all of the things of these other elaborate computing devices, we do state that for the specific purpose for which PRODUCTRON was designed, it stands ready to give any other computational device known to man an excellent run for its money. Now that's quite a statement and it brings up the subject of what are the alternate ways of attacking the load-capacity analysis problem.

Comparison of Different Methods of Performing Load-Capacity Analyses

In examining different methods of attaching the load-capacity analysis one is prompted to ask about PRODUCTRON's position in relation to other mechanization programs which are already underway. Being a special purpose machine PRODUCTRON does not interfere in any way with other systems work which you may be doing. Rather PRODUCTRON supplements this work by providing quick valuable assistance in the master planning area at a reasonable cost.

The Manual Approach

Of the many ways to approach the load-capacity analysis problem the simplest method is to do it manually. A manual explosion of the load impact of fifty different products on twenty-five different workstations is an extremely laborious job with a high probability of error. As a matter of fact, a trial run seems to indicate that a manual analysis of this size would take approximately thirty-seven hours of good, solid computation. This is roughly a man-week of applied effort. Quite naturally, there are not too many operations where the time and the money will permit load-capacity analyses of this type, but many of you at one time or another in your years of experience may have made such a single explosion for a manufacturing review for some other important occasion. Certainly, if the thought of attacking the problem came to mind, the actual performance of a single such analysis would stifle anyone's attempts to repeat such an explosion at any time in the near future. Yet PRODUCTRON is capable of performing such an analysis in a few short moments. While admittedly not too practical, the manual system is important because the same basic operations performed manually are merely speeded up in the various other available types of equipment. Load-capacity analysis will always be a long series of multiplications of unit load impacts by total number of products and successive summing of these products to obtain total work-station loads.

About Comptometers

A comptometer is a fairly standard piece of equipment in most production offices throughout the Company, and when analyses of this type must be made, it is normally the business machine on which they are done. To help illustrate this approach to the load-capacity analysis on a comptometer, Miss Sadie Jones, who is one of the technical calculators at the General Engineering Laboratory, has consented to come over and assist us by demonstrating the calculation steps required.

One of the first things that you will notice as Miss Jones is going through the calculations is that each and every key must be depressed to enter each number in the multiplicand. Since we are multiplying by successive addition, the operator has to remember the number of times that she has depressed the keys in any given single multiplication. These two elements combine to increase the possibility of human error and also to lengthen the time required to do the job. You can readily imagine what would happen if there were a long series of 9's in the problem.

The results of a series of trials indicate that the time required to do a load-capacity analysis for 50 products in 25 stations would be approximately 1 1/2 to 2 hours.

This, however, is far from the major disadvantage encountered in using the comptometer approach to load-capacity analysis. The element that is most annoying is that as you progress through the problem, you completely destroy all of the partial total information in the process of synthesizing the total work load for any one workstation. This means that it is impossible to check or to regenerate the load without doing the entire problem all over again. This also means that each new trial must be treated as a complete new problem--successive trials merely multiply the cost of the first trial. Thus if one trial takes about two hours--a figure which more nearly approximates the time required for personnel normally available in Production Control offices--ten such trials would take twenty hours and cost say thirty dollars in clerical labor costs alone.

The Tape Adding Machines

A second approach to the load-capacity analysis problem is the use of the Remington Rand 10-key tape adding machine which offers some advantages over the comptometer in that it provides a permanent record which can be verified for accuracy and has a key board which is more convenient to work with. Verifying however, is a difficult and tedious job. Like the comptometer Remington Rand tape adding machines around the offices nowadays are dependent upon the operator counting the number of successive cycles which the machine goes through in order to multiply by successive addition. Thus, this particular machine has the same disadvantage as the comptometer. Recently, however, some tape machines featuring automatic multiplication by successive addition have been announced. Most of these machines form a step between the comptometer and the desk calculator.

The Desk Calculators

Freiden and Monroe type desk calculators are the next in the line of business machines which can be used to perform a load capacity analysis. These machines feature automatic cumulative multiplication, which would seem to provide a quicker way to perform a load-capacity analysis. It has been our experience, however, that the time to do the load-capacity analysis on a comptometer is normally less than the time required to use a calculator. However, the automatic multiplying feature will probably decrease the chance for human error. With all deference to the people who manufacture desk calculators, it seems harder to find personnel in production who have acquired dexterity in running the desk calculators, than it is to find a person qualified to operate the comptometer.

Punched Cards

Punched cards provide a variety of ways to solve the problem. Because, load-capacity analyses require multiplication, the IBM installation must have at least an IBM 604 or 607 to effectively compete against a simple adding machine. The IBM 602 is effectively removed from competition because the number of cycles required to do a load-capacity type problem reduces the machine speed to 25 cards per minute and increases the time per trial to almost one and one half hours.

To handle the problem on punched cards, a variety of machine operations are required. Assuming for the moment that you have a master deck with the unit load impact table already punched and verified and that you have also available the production requirements deck all set, then you must:

- collate the production requirements with the master deck (240 cpm = 5 minutes)
- gang punch and reproduce (100 cards per minute = 12 minutes)
- sort by work stations (650 cards per minute on a two-colum sort = 4 minutes.)
- multiply (100 cards per minute = 12 minutes)
- sort masters and sort trailer cards (= 4 minutes.)

Thus, it will take approximately 40 minutes of machine time to process this single load-capacity analysis report. This, however, is not the entire story because most of the tabulating rooms in the Company are shared propositions. The chances are that your job will have to get in line with a host of others. The real answer then may be that your punched card load-capacity analysis may take you an entire day and the best that you can do is to know the results of your first trial tomorrow.

This, of course, is a substantial improvement over not having a load-capacity analysis at all or receiving rough estimates of unknown accuracy. This will certainly point out your future trouble spots well in advance of their occurence. But, there is one thing that we have lost and that is the chances to negotiate changes in schedule because the time for such negotiations has already slipped. Thus if this repetitive cycling to find agreeable production schedules is not quick, the benefit in making master plans is lost.

Lest we paint too dark a picture, we should point out one very important feature of the punched card system and that is that it is inherantly capable of handling the multi-time period and the multi-lead time problem with extreme ease.

Medium Sized Computers

In using the punched card approach, we have probably noted that we have now begun to progress into equipment which has really started to cost money. Whereas the one or two hours of clerical labor required above might normally be obtained for less than $5, IBM installations come at a substantially higher price. Following the IBM 604 and 607, there is the card program calculator which is capable of handling the computation (after set up) in approximately 12 minutes. Lastly, the IBM 650 is capable of doing a 50 product-25 area analysis in about 6 minutes at a rough rental fee of about $3750 per month.

Now About PRODUCTRON

PRODUCTRON does not share the disadvantages of the preceding semi-manual systems and incorporates many of the advantages available in the computers which have been mentioned before. PRODUCTRON, for example, has a permanent memory. All the information which is placed in the machine will stay in the machine so that it is possible to check or regenerate the factory load for any workstation instantaneously--just press the workstation selector button and read the load. The entire process time for a 50 product 25 workstation load-capacity analysis, including the set-up of the 50 product-quantities, is about 7 minutes. Retrials may be accomplished by simply resetting the desired product dials and then rereading the load impact meter. The actual reading of the load meter for 25 workstations can easily be accomplished in two or three minutes. It is anticipated that 10 trials, during which each successive trial depends upon the results of the preceding trial, can be recorded and analyzed in approximately thirty to forty minutes.

A Demonstration Problem For The Demonstration Model

Perhaps the best way to illustrate just how PRODUCTRON tackles the load-capacity problem is to see what type of questions PRODUCTRON might help the owner of some mythical factory to answer--in short lets try some sample problems on our demonstration model and see how PRODUCTRON can help answer them--remembering of course, that our demonstration model is only capable of handling four products and four factory areas.

Enerstat

As you may well have expected, trying to find a product which at one time provides interest to the entire range of General Electric Product Departments is extremely difficult. The easiest solution to the problem, seems to be found by looking into the future, for no Product Department in the General Electric Company has existed without radical changes over the years, so the product of the future will be the product any one department represented here today.

The product of the future we have selected is ENERSTAT, and it is to be manufactured by the Nuclear Component Devices Department of the General Electric Company of which anyone of us is a potential employee. What is ENERSTAT -- ENERSTAT's function, as a future outgrowth of our present day THERMOSTAT, will be to report and integrate the need for additional energy to the individual atomic furnaces which will supply power to the home and factory of the future. Specifically ENERSTAT will be programmed to supply energy to:

1. Control temperature, humidity, and oxygen content, and pollen count of any internal atmosphere.
2. Control visual lighting depending upon the ambient external light level or any other pre-determined standard
3. Control doors, sliding walls, louvers and any other ventilating devices to compensate for temperature changes or for storms.
4. Integrate the electrical load to meet the demand of television sets, and other assorted electrical appliances.
5. Open and close carport doors upon receipt of appropriate signals.
6. Automatically supply heat to the roof, driveway, and sidewalk in the event of ice or snow storms to prevent the accumulation of ice and snow in these areas.

ENERSTAT will come in various ratings and sizes--50kw., 75kw., 100kw., 125kw.

These units because of their low cost and high degree of standardization will be recommended almost exclusively on the expected connected load. For example, the 50 kw. ENERSTAT would be used in the single or duplex type of home. The 75 kw. rating would be installed in small stores, clubhouses, bars, and small garages. The 100 and 125 kw. deluxe model would be used in multiplex unit apartment houses and individual, decentralized, automated factories of the future. We recognize, of course, that now ENERSTAT has as yet not been designed or built, but ENERSTAT has certainly been thought about and the functions we have ascribed to this product are not beyond present technology.

You will notice that it resembles a modern day toaster with some funny looking gadgets sticking out of the top which in our artist's mind represent the sensory devices necessary to make ENERSTAT work.

The important thing though is that we have chosen to break ENERSTAT down not into its physical components--nuts, screws, bolts, die castings, etc. but rather we have broken it down into its unit load impacts. We have color coded the model to indicate the quantities of these load impacts so that, for example, all of the red on the ENERSTAT model which you see on the screen represents units of lathe work which are caused by the orders to manufacture a single ENERSTAT. So now our concern turns not to components but to the labor required in the factory to build the various models of ENERSTAT.

Now what is it that PRODUCTRON does? PRODUCTRON in a certain sense, acts like a meat grinder in that it grinds all of the ENERSTATS which you are making, down into their basic elements of load. This is the reason for its existence. It does this extremely well and for the other things, not of the same nature as the load capacity problem, it is of little use.

In order to accomplish its task, PRODUCTRON has to have the same information which is required to do a load-capacity analysis under any system. You must know the effect of each unit of product upon each of the factory workstations which you intend to load. In addition, you must have a working knowledge of the particular restrictions under which your business operates.

In our hypothetical ENERSTAT problem, we have set up the following unit load impact table. You will notice that the quantities are all in 10ths of shop hours and all have two significant digits.

Parenthetically, I would like to comment on the particular values which are in the table which you see before you. PRODUCTRON is capable of handling three significant figures both in the unit load impact table and in the production requirements. Such a fine degree of accuracy is often attained in departments which have a substantial portion of their jobs on motion time study and dimensional time analysis or standard time study prices. It should be pointed out, however, that such accurate figures are not always necessary, and in some respects from a production control view point, the accuracy is unnecessary. Many departments do not load in terms of specific products--rather they use prototypes. Similarly, there are many departments who do not have accurate planning information at the time of loading because most of the products have never been built up to that point. In such instances, it is only natural that PRODUCTRON would be used with engineering and planning estimates, historical data, and prototype information. With unit load impact factors which are shrewdly calculated, PRODUCTRON may be used to effectively show potential danger spots of either underload or overload, whether you're capable of using three significant figures or not.

On the particular unit load impact table which is on the screen, you will notice that as we progress from left to right, from the smallest to the largest the total unit of direct labor increases. You will also notice a significant decrease in the use of die castings as you progress from smaller to larger, and an increase in lathe impact as you progress from smaller to larger. Thus, it seems that as far as this particular product is concerned, we may count on the first two models--A & B--to supply most of the die cast load and models C & D to provide the principle portion of the lathe load.

Capacity

The next item that is important in a load-capacity analysis is to understand the capacities which are available to you. In our particular plant, there are sixteen lathes, twenty mills, ten punch presses and eight die casting machines.

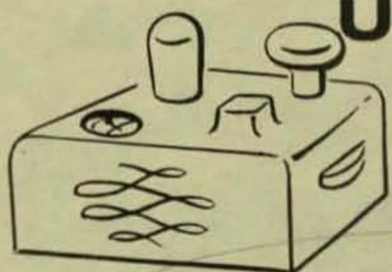
We have also assumed that all of these machines are 75% efficient, i.e., that 75% of the time they are producing work at the same rate upon which the unit-load impact is based.

Thus there are two types of fudge factors which can be used in this type of analysis. Where a specific problem appears to be area oriented, i.e., centered in the lathe area, you may make allowances by decreasing the available lathe capacity. Where manufacturing problems appear to be product oriented, i.e. that one product is "harder" than another, then it is possible to weight the unit load impact table to reflect this condition. This is particularly applicable when you are working with engineering estimates and planning estimates in trying to compile a reasonable factory load.

PRODUCTRON Calculates Factory Load

Although I am sure that many of you with your wide production experience have already made some quick and rapid conclusions about loading such a product mix bear with me for a moment while we see actually just what it is

ENERSTAT



UNIT LOAD IMPACT TABLE
(Hours Per Product)

(MODELS)	w **A**	x **B**	y **C**	z **D**
A **LATHES**	.410	.510	.750	.880
B **MILLS**	.240	.310	.450	.520
C **PUNCH PRESS**	.190	.240	.350	.370
D **DIE CAST**	.450	.550	.150	.170

	units	A	B	C	D
w	4250				
x	3750				
y	1000				
z	500				
		485	282	225	420
	9500 dNE	490	310	250	430

	L	M	P	D
A	410	240	190	450
B	240			
C				
D				

that PRODUCTRON does. In synthesizing the total load per workstation, PRODUCTRON multiplies the number of model A to be manufactured by its particular impact on lathes, thus indicating the total amount of lathe load caused by model A. To this it adds the product of the number of model B times its unit load impact on the lathe area. To this total it adds the product of the number of model C's to be manufactured multiplied by its particular unit load impact and lastly, it adds the product of the number of model D's and its unit load impact. Thus, what we have then is: (A x B) + (C x D) + (E x F) etc. PRODUCTRON does this instantaneously.

The Sample Problem -- Manufacturing ENERSTATS

The paramount objective of putting PRODUCTRON to work is to determine the load impact of any given set of requirements upon each of the factory areas which we wish to analyze. Lacking a marketing organization to provide us with production requirements we have selected a series of our own.

Mr. Fred Larson will place the quantity which you see displayed on the flannel board into PRODUCTRON--models A, B, C, D--425, 325, 100, 50 respectively. For those of you who have not met him, Fred Larson is with General Engineering Laboratory and is their contact man on PRODUCTRON as well as the other computers which the Laboratory is developing.

Fred will put the product quantities into the control console by turning the dials to read the proper quantities. Now all that has to be done is to place the workstation selector on the desired factory area. So tell us Fred, what is the factory load caused by these product requirements in the lathe area. (460 hours on the lathes).

To find the load impact in the milling area all that Fred will have to do is turn the workstation selector up one notch. Okay Fred, how much milling work do we have. (274 hours of milling.)

And how much work will there be in the punch press area. (212 hours on punch press.)

And finally, how many hours of direct labor will there be for the die cast machines.

Now let's compare these figures with the capacity as we have available. We see from the slide that we have 480 hours of available capacity in the lathe area, 300 hours on the mills, 240 on the punch press, and 420 on the dye cast machines. Making the total we see that we are not over-loaded in any area. If we were over-loaded we have options which are available to us.

Conditions of Over-load

One reasonable approach is to decide on ways of increasing to capacity. For example, a 20% increase in capacity may be obtained by working on Saturdays. A lesser percentage of increase may be obtained by working shorter periods of time--perhaps, as over-time during the week. As an alternative on master scheduling problems, it may be necessary to divert work to other sources through internal or external sub-contracting.

Another approach which might be used in solving the over-load problem is to expand your present facilities through the acquisition of more factory equipment, or additional personnel. Both of these items require substantial time and planning and certainly one of the advantages of using PRODUCTRON is the rapid speed with which it uncovers such potential over-load conditions.

The last alternative way of approaching the over-load problem is to examine the possibility of changing the production schedule. It is important to realize here that we are dealing with the over-all loading problem and in the sequencing of machine parts. With PRODUCTRON you will be able to evaluate production requirements as soon as demands are made upon you. This means that you will have the required load information in time to secure, through negotiations, required changes in schedule before marketing makes firm commitments to customers. With PRODUCTRON you will have an opportunity to develop several alternative plans. Certainly marketing must have some preference. These preferences will be catered to but by the same token if the over-load condition is allowed to persist then marketing must share the responsibility for the excess manufacturing costs. The important point is that now you have a factual basis for the plans which you propose to management as alternate solutions to the manufacturing problem. Prior to this time so much of our initial manufacturing plans have layed upon emotional persuasion and past experience.

Conditions of Under-load

There is another significant factor and that is the areas which are under-loaded. Unused facilities cost money. Unused man hours cost money. Though you may think you are escaping these costs by laying off manufacturing personnel, the cost to the Company of laying off and re-hiring personnel is sometimes greater than the cost of generating inventory. In addition if the condition that we now see before us is typical for the department it would certainly seem that a certain portion of their milling and punch press machinery is unnecessary except as potential stand-by insurance. This machinery represents idle capital investment which should be reclaimed and put to more profit making uses if possible.

<u>Optimum Machine Utilization</u>

Since we do not have a marketing organization and since the establishment of a case problem in the minds of a large group of people is a time-consuming process, we have decided to parallel a production schedule negotiation problem. We are doing this because we cannot appreciate the factors which are critical to the master manufacturing plan for each of your specific departments. You may be concerned with getting the requirements of a smaller group of customers. Perhaps seasonal demand is your big problem. But in any event, there are many pressures which are exerted on production schedules. PRODUCTRON is concerned with only one of those pressures--will the production requirements fit inside of your factory? These other elements are still dependent upon such management personnel as yourselves.

To simulate these successive retrials lets determine the particular set of production requirements which will best utilize the factory facilities available to us. The way that this problem is handled is quite simple. The technique for solution which is often used by mathematicians, scientists, and engineers, is called iteration. To get right down to the basic facts each of us use it every day--but we call it "trial and error". In short, the second trial and each successive trial thereafter, will try to correct the errors which we observe in the preceeding trials.

So Fred, let's try manufacturing 100 of each of the 4 models of ENERSTAT. How much load does that generate. (Lathes, 260; Mills, 155; Punch Press, 118; Die Cast, 135). Okay Fred, now let's try 200 ENERSTATS--isn't it fast how we get these answers written down? (Lathes, O. L.; Mills, 302; Punch Press, 231; Die Cast, 265.) You will observe that we are already exceeding our available lathe capacity. Up to this point we have not tried to use our head however, now that we approach the limit of capacity we can see by comparing total loads, the quantities, and the unit inpact table we cannot make very many more of models "C" and "D" since they are rapidly eating up all of the available capacity which we have in the lathe area. Be the same token we see that we do not have too much work in the die cast area so the obvious thing to do would seem to be to increase models "A" and "B" and decrease "C" and "D" so as to achieve both balances of factory load.

It might be well to pause here for a moment and point out that in this short time, we have already gone into three trials. You could go just about as fast with 50 different products.

The balance of the sample problem presentation is summarized below.

PRODUCTRON - LOAD-CAPACITY-ANALYSIS

(1) What is the load impact for these production requirements?

Product Quantities

A	B	C	D
500	400	0	50
250	125	300	100

Factory Areas & Capacities

L (480)	M (300)	PP (240)	DC (420)
450	265	208	453
482	285	222	245

(2) How many hours of overtime are needed for these production requirements?

Product Quantities

A	B	C	D
350	550	50	0
700	300	50	0

Factory Areas & Capacities

L (480)	M (300)	PP (240)	DC (420)
453	270	215	462
470	275	220	480

(3) How many backlog units of Model A can be produced in excess of the schedules given?

Backlog

A	150
B	350
C	100
D	400

Product Quantities

A	B	C	D

Factory Areas & Capacities

L (480)	M (300)	PP (240)	DC (420)

(4) If you must make Model A at a 600 unit rate, how many of Model C can also be made, assuming you do not make any of Model B and D?

Product Quantities

A	B	C	D
300	0		0
300	0		0
	0		0
	0:		0
	0		0
	0		0

Factory Loads

L (480)	M (300)	PP (240)	DC (420)

(5) If you must make Model D at a 150 unit rate, what production schedule will provide best utilization of the facilities under these conditions?

Product Quantities

A	B	C	D
			150
			150

Factory Loads

L (480)	M (300)	PP (240)	DC (420)

PRODUCTRON - LOAD-CAPACITY-ANALYSIS

Optimum Product Mix for Best Utilization of Facilities

Schedules: Models A	B	C	D	Factory Areas & Capacities: L (480)	M (300)	PP (240)	DC (420)
100	100	100	100	260	155	118	135
200	200	200	200		302	231	265
300	200	100	100	390	230	180	280
400	200	100	100	432	253	198	323
400	300	100	100	482	282	221	375
425	325	100	50	460	274	212	394
425	375	100	50	485	282	225	420
				(101%)	(94%)	(94%)	(100%)

Accuracy Test

Schedules: Models A	B	C	D	PRODUCTRON Factory Areas: L	M	PP	DC	Calculated Factory Areas: L	M	PP	DC
100	100	100	100	260	155	118	135	255	152	115	132
200	200	200	200		302	231	265	507	305	230	265

PRODUCTRON - Load-Capacity Analysis

A Quick Evaluation Of Process Change

- Model C:

Due to cost reduction activities it is required to change the Bracket and Spacer Assembly which consists of several parts into a single die casting.

This will change the Load impact:

	Present	Proposed
Lathe	.750	.550
Die Cast	.150	.225

Anticipated Production Rates

Model

A	B	C	D
375	375	200	25

Conclusions

Die Casting Machines must be run on thrid shift, or additional machines must be secured. These additional costs must be considered before making the final decision.

PRODUCTRON - Load-Capacity Analysis

Maximum Production Limitations

Maximum Number of Model per time period		Percentage Unused Facilities L	M	PP	DC
A	935	20	25	26	
B	765	17	21	24	
C	640		4	7	77
D	512		11	21	79

Conclusions

- Advance toward larger models will obsolete die casting machines and demand more lathe capacity unless more die cast parts can be economically designed into Models C & D.

- Increasing requirements for Models A and B will require more die casting capacity.

- Feasible and optimum production schedules must be within these imposed limits. The optimum product mix will tend to have more of Model A than D.

Alternate Planning of Manufacture

One of the problems which appears recurently in many of the operating departments is alternate plans of manufacturing. While this problem appears to a greater or lesser degree in all operations, there are some departments where this is a major decision. PRODUCTRON is capable of helping you with that decision in a variety of ways. Where the number of models is less than 50, you may use the remaining spaces on the PRODUCTRON console to record alternate plans of manufacture, you would have the model A manufactured under plan X and model A manufactured under plan Y as two separate products. Quite obviously, you would record on the dials the number which you hoped to make under each of the alternative plans.

Another way of approaching the problem would be to actually change the unit load table in the machine. Such a plan would, of course, be necessary for any one who is using the entire 50-product console. This would be particularly applicable where the alternative plans of manufacture represented major changes of planning which influenced the entire flow of work in the factory. Such flexibility of planning is the coming thing. We have recently watched the automobile industry graduate from the mass flow production techniques to one where almost an infinite variety of basic similar products are manufactured on the same assembly line with a minimum change in set-up. These concepts can only be brought into reality by an excellent grasp of the load-capacity analysis problem coupled with a detailed knowledge machine product sequence.

Equipment Utilization

One of the problems of computers in general, and it certainly applies to PRODUCTRON in particular, is the problem of equipment utilization. Idle equipment costs money and won't PRODUCTRON be idle a substantial amount of time?

PRODUCTRON will be idle a substantial portion of the time but actually the equipment utilization shouldn't really bother us. In a certain sense, PRODUCTRON is very much like a hay bailer. If you drive along the highway fall, winter, spring or summer, the chances are that you will see any number of automatic hay bailers standing on the farms in the New York State countryside. These machines are used but once or twice a year, yet they do the job so efficiently that it pays the farmer to have the equipment for use one or two weeks and permit it to stand idle for the balance of the year.

Use of PRODUCTRON in Materials Explosion Problems

PRODUCTRON is a special purpose computer especially designed for load-capacity analysis. It is basically a multiplication and summation device. There are a number of business problems which fall into this category. Perhaps the most prominent of these is Production Explosion.

Now, we are not going to recommend that PRODUCTRON be used to extend bill of materials in Large Steam Turbine, Large Motor & Generator or any of the similar apparatus type businesses. There are, however, a number of departments whose controlling items of inventory are not very much larger than 25 in number, and usage is spread over the entire product line--a few concrete examples--plastics, chemicals, meters and the like. Because of the inherent value of the material and the large variety of quantities which are required for various product mixes, these departments are often faced with constantly calculating and recalculating total requirements, and compare this quantity with their existing inventory and scheduled receipts for coming periods. For the people who fall in this category, PRODUCTRON may also be used as a parts explosion tool which will greatly relieve the clerical burden required to perform these multitudinous material explosions.

Production Changeover

At this time it might be well to state what is involved in converting PRODUCTRON from one job to the next. To convert PRODUCTRON from a load-capacity analysis to say, for example, a parts explosion problem would require changing each of the 1200 little resistors which are in the upper right hand drawer of the PRODUCTRON console. This is not a terribly difficult job but is time consuming and this time should be borne in mind. It is estimated that it will take approximately 7 hours to change over the machine from a load-capacity job to a parts explosion job. This may sound quite high, however, once set up in this fashion, it is capable of performing the parts explosions in the same 3 or 4 minutes that was required in the load-capacity analysis. Thus, from a job that is done very uneconomically, you have perhaps utilized idle equipment and thus, even with the long set-up, increased the yield from your PRODUCTRON.

Use of PRODUCTRON in Budget Synthesis

Another excellent use for PRODUCTRON--once again the calculations follow in the same pattern as the load-capacity analysis calculations--is for budget synthesis work. For example, if instead of unit load impact or material requirements per products we record on the tiny resistors such elements as cost per unit, sales volume per unit contributed value per square foot, finished stock area per unit of product, floor space per unit of product, box, pack and ship per product and any other as a whole series of possible parameters may be placed in the unit load impact table. Then by recording the production requirements on PRODUCTRON, it will be possible to read the dollars of sales, the shipments at manufacturing cost, the total finished stock area required, the contributed value for the department and a series of other possible business parameters.

Thus, in this fashion, the PRODUCTRON may be again used to assist the department in finding quick answers to its budget synthesis problem and instead of spending valuable work hours in constant retrials of various budget proposals, you can perform all your trials on PRODUCTRON and then spend the real "down to the penny" efforts on the manufacturing plan which seems most advisable.

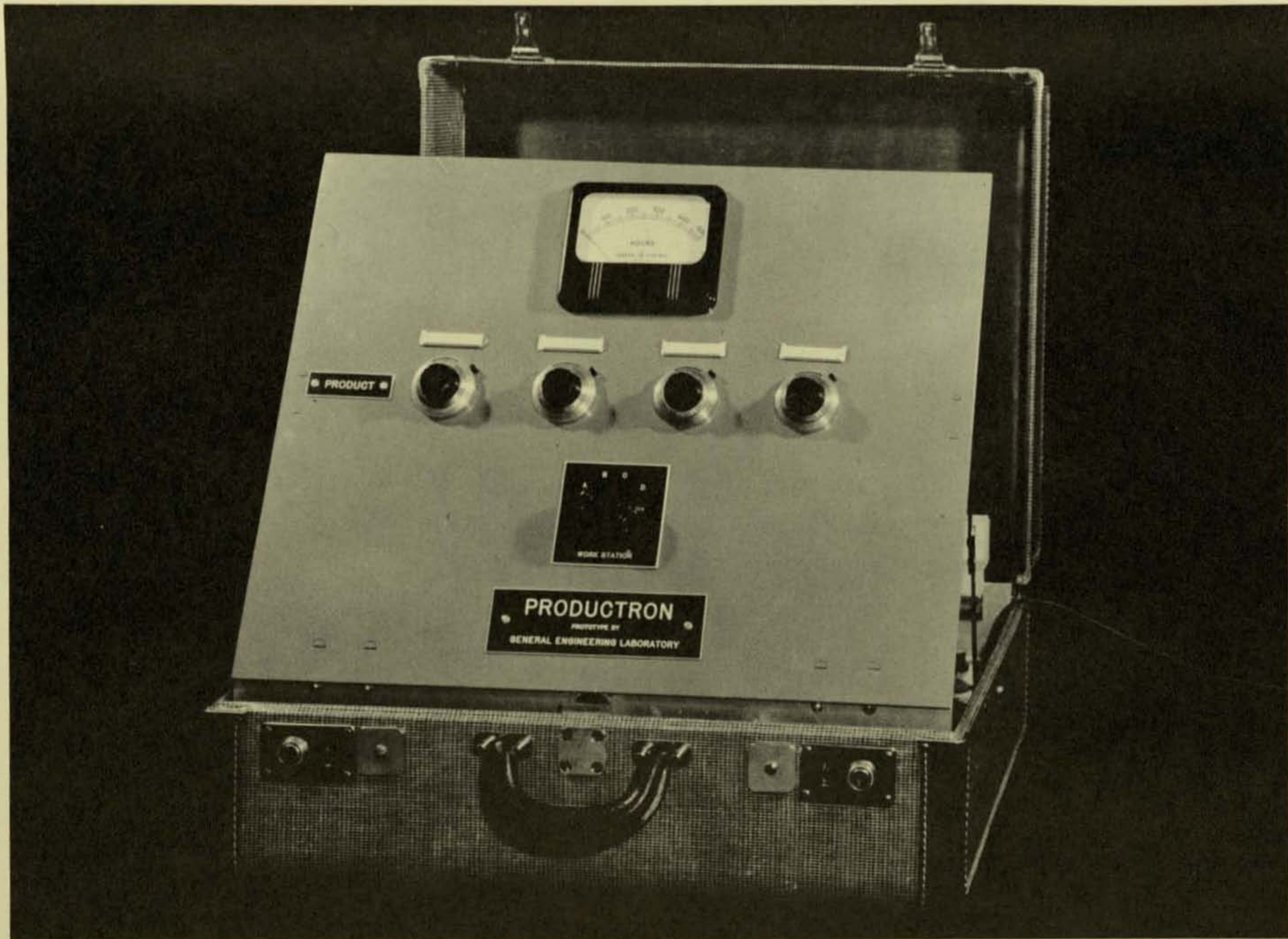
Cost Savings

Now I know that there is at least one person in the group who is saying to himself that this is all quite alarming but--this here PRODUCTRON costs about \$15,000 and that's 3 or 4 people in my operation for an entire year--that's a heck of a lot more than a comptometer. As a matter of fact, \$15,000 is pretty hard to swallow on most material control budgets.

You know and I know that I cannot intelligently discuss savings with any one of you for you are the ones who know where they are. I do not know enough about your business to know where you can save \$15,000, but I am willing to bet any one that the \$15,000 and many times the \$15,000 is there to be saved.

Let's consider the problem this way. Drive from your mind for the moment the fact that this machine costs \$15,000. Suppose that you can have this machine available in your own office. Then sit back and reflect, exercise your vision and imagine what you could do with PRODUCTRON to improve your operations. Examine how PRODUCTRON could help you. Place these accomplishments in your business pattern of the future and observe the progress.

Return now, if you will, to the present and look upon the world of reality in terms of the future progress which you have just envisioned. I feel certain that if you follow this process, you will find all of the \$15,000 that you need to justify PRODUCTRON. As a matter of fact, many of you may ask how have we managed to exist without such a device.



LI-184408 - Demonstration Model of Computer

HOW THE COMPUTER WORKS

J.P.J. Gravel

Gentlemen, so far you have heard about the Why and the What of the Productron - Why we need it, and What it will do. This presentation is about the How - How it does the job. I'll break it down into six categories in which I will cover the principles of operation, the reliability and accuracy, the speed of operation, the features of construction, service and maintenance, and the probable cost and lifetime of the device.

We must go back to the basic equation in order to understand the principles of operation, or How the Productron Computes. The information that we want is the hour impact loading on a particular work station, as affected by the number of products or product lines which you will be sending through the plant. There will be room on the Productron for 50 different products or product lines and you will be able to get answers (load information) on 25 different work stations. Each product has a unit load impact on a particular work station. Since there are 50 products and 25 work stations, by multiplying you will have 50 times 25 or 1250 unit impact loadings to set in before the machine is first used.

Now what do we do? We multiply the number of units of products type by the unit impact loadings and come out with some numbers in hours. For example, to find the total work load on station 1, take the quantity of product #1 times its unit impact loading on station 1. The result is a value in hours which is the unit impact loading of product 1 on station 1. Then multiply the quantity of product #2 times its unit impact loading on station 1 which results in the unit impact loading in hours of product 2 on station 1---- and so on through all the 50 products. This involves 50 multiplications. When all the hour impact loadings of each product on station 1 are added, the result is the total work load on station 1. This is repeated for the other 24 work stations.

Specifically, how does the Productron do this job of multiplying and adding? The following simplified example will explain the principles of the computer's operation. We will show in the small example how the computer multiplies and adds. In effect we will build a small electric model that is analogous to the real problem being solved. Incidentally, the word "analog" was derived to describe an electric model analogous to the actual problem.

In slide II, we will assume a scale factor of One Volt = One Product. As you can see on the slide, we start out with a voltage, which in this case will be 12 volts. This is a very low voltage and there is no danger to personnel should they come in contact with it. It is the same voltage which is now used in late-model cars. The 12 volts is connected across a potentiometer which is simply a resistor with a sliding contact on it. The knob which moves the slider for this example is calibrated so that whenever 12 volts is read on the slider, 12 products will be read on the knob. For this example, the slider will be at the top of the potentiometer and 12 volts will be feeding out into the external circuit from the slider of the potentiometer. If, instead of 12, we only wished to set in six products, we turn the knob of the potentiometer, which is mechanically linked with the slider, until the knob reads six products. Through the mechanical linkage this automatically moves the slider of the potentiometer down from 12 to six. At this point we are reading six volts which is equal to six products.

Now that the Product Values have been set in at six products, let us look at the Setting-in of the Unit Load Impact. This is done electrically in the same way in which the product values are set. Assume that one volt is equal to one hour per unit product. The top of the work-station load-impact potentiometer will read one hour per unit product. If one volt is fed into the circuit, and the wiper is at the top, the dial will read one volt. As another example, if the unit load impact is one-half hour per unit product, this work station will require one-half hour on each product or unit of products going through this particular work station. Set the product knob at one-half and this will position the unit-load impact-potentiometer half-way down. If there were one volt on the top of the potentiometer, it would read one-half volt out on the wiper. Therefore, it would be possible to have an instrument connected to the unit load impact potentiometer wiper to ground, and it would read the voltage to ground. This instrument could be calibrated to read in hours instead of volts. In this particular case, since the potentiometer wiper is half-way down, the one-half volt on the instrument will read one-half hour.

Let us correlate the two: the product and the unit load impact potentiometers. We wish to multiply the number of products by the hours per unit product to give the total load of a product on one particular work station. If the wiper of the product potentiometer is connected to the top of the unit impact loading potentiometer, it will feed in a voltage proportional to the number of products. In the preceding slide six volts equaled six products. The unit load impact potentiometer had been set at one-half hour per unit which meant it was set half-way down on this particular potentiometer. Therefore, if there were six volts at the top of the potentiometer and it is now set half-way down, we read out three volts. Since we previously picked the scale factor of "one volt is equal to one hour", the output meter will read three hours. It is apparent that this is consistent with the scale factor since there were six products at one-half hour per unit product, resulting in the answer, three hours.

This illustrates the impact of one single product upon one particular work station; there are 1250 of these multiplications being worked out simultaneously by the computer -- each multiplication involving two potentiometers. Some of these potentiometers are shared so that only 1300 potentiometers are necessary, rather than twice 1250. For example, if you use the total capacity of the machine, Station 1 is affected by 50 products. Thus, there are 50 of these two-potentiometer combinations for Station 1 -- 50 products and 50 unit load impacts on products 1 through 50 for their impact on station #1. All these voltages are taken and summed into a device called a Summing Operational Amplifier, which takes the unit loads and adds them into a totalizing hour-meter. This instrument presents a total of all the unit load impacts on a particular work station and sums them up to read a total load in hours.

Speed of Operation

The speed of operation designed into the Productron is such that you will be able to get the answers out of the computer as fast as you can write them down. It's simply a matter of pushing a button and writing down the answer, which amounts to about three or four seconds for each. Since you will have 25 answers, one for each station, it takes only a couple minutes to get the total work load impact on all of the 25 different work stations.

Construction

The simplicity of the proven components in the Productron will result in great reliability, and should mean no loss of operating time. It has potentiometers, it has stepping switches which will connect the read-out device to the particular work station to be read out. It has a power source which will set the reference voltage at 12 volts. This power source is not subject to line fluctuations because of certain inherent regulating characteristics.

The Productron will be a rugged device you may set on the factory floor or in the office, for it will require no special electrical set-up. No special high power is required to operate it: the Productron will use approximately 300 watts of power-- less than that required for your TV set at home. The ordinary atmosphere that you would provide in an office or a fairly clean production-line type of area, will be quite satisfactory as far as special facilities are concerned. An air conditioned room is not necessary, since the device will not be affected by dirt and dust, although any corrosive fumes in the area may adversely affect the stepping switch. When you get the Productron just set it up where you wish, plug it into the wall as you would a TV set, flip on the power switch, set your values, and you're ready to go.

Service and Maintenance

Service and maintenance will be at a minimum. There will be some small dry cells and a small electric vibrator chopper which should be replaced approximately twice a year, and seven electronic tubes to replace annually, but they will not have to be specially selected, for any electronic tube of that type can be used.

This twice-a-year and once-a-year replacement is simply a safety measure to continue the effectiveness of the Productron. The life of the device, if it is used eight hours a day, will be such that we will have a two-times safety factor; even without replacements of the weakest elements it should cause no trouble for one year. The total cost of replacement parts per year will be about $67.20, and with the addition of man-hour expenses, maintenance and servicing per year should not exceed $100 in total.

Cost

Now, what will the Productron cost? It has been figured that production models of the Productron will be in the area of $15,000. Life estimates of the stepping switch, the only other moving mechanism, is approximately 10 years.

Summary -

To sum up what has been said about the Productron, it uses the simplest components available for doing a product multiplication and summation. It is highly reliable and not subject to frequent breakdown because the components themselves are very sound. It is of fairly rugged construction, housed in a steel cabinet which will help to protect it from dust and humidity, and it will not need air-conditioning or special electrical installations. Its accuracy is two percent and it is fast. Its servicing and maintenance are very simple, just a matter of pulling out the old tubes and plugging in new ones, pulling out the old batteries and plugging in new ones. The cost of maintenance is very low-- about the lowest cost of any computer on the market today, and the life is very long-- 10 years. In the Productron you have a really reliable, long-lasting, accurate, fast piece of equipment. Thank you.

At this time I will be very glad to answer questions on any of the aspects which are not covered in this talk, or explain anything about which you wish further information concerning components, construction, reliability, accuracy, speed of operation, servicing and maintenance cost or life.

PRODUCTRON PROTOTYPE DEVELOPMENT

D. E. Garr

The preceding speakers have said a great deal about the operation of the Productron, how to use it, the benefits to be gained from it, and many other pertinent factors. Now I would like to tell you the background of how this computer came into existence. The magnitude of this initial step, that of introducing new ideas and products, is quite intriguing and is not generally known, understood, or appreciated.

Basically, and it is true in many circumstances, the idea of the Productron came from you, the consumer. It might have been stated as "This scheduling job is murder, how did I ever get into this type of work," or "I wish someone would build a device to solve this eternal irritating problem".

Production Control Services noted these "gripes" or hints and tried manual and semimanual possibilities, but without too much success. Either it took too long, was too expensive, was extremely complicated, or was dependent upon other mechanization plans.

Having been in contact with Computer Engineering of the General Engineering Laboratory on other occasions, Ford Dickie and his associates visited Schenectady to ask if such a device existed, could we make one, etc. Manufacturing people had the problem well defined and were able to describe exactly what was needed and from this specification the problem was reduced to a mathematical solution and thence to a computing device as a final solution. This came from and was similar to a previous development.

Earlier this year the General Engineering Laboratory shipped the Penalty Factor Computer to the American Gas & Electric Company. This computer was used to solve transmission line losses or penalty factor of this utility in transporting electric power over long distances. The principles used in making this computer are similar and applicable to those of production schedulers. It might be noted that the utility expected to save enough money with this computer to pay for it within one year. The other day, I noticed a magazine article and from the savings mentioned, only six months was needed. I have wandered a bit from my topic, but I did want to mention this similar, larger computer and the fact that (a) it works, (b) it is saving them money, and (c) it provided the basis for the Productron.

In spite of the fact that a solution to the work loading problem was made, and that a previous, much larger computer had been built; the stringent requirements of you, the users, still had to be met. These requirements were the 3% accuracy, the high reliability and ease of maintenance, the 48 product lines and 25 work stations, and selling price. The first four were easy, but combining it with the $15,000 price tag made it rough. However, using principles and techniques we know to be sound, along with new, low-cost, yet reliable components, we firmed up estimates of the Productron. This was the completion of steps Nos. 1 and 2; namely, the coming up with a solution and then the tentative proving of the economics of the possible solution.

Step No. 3 was the building of a breadboard model to verify the engineering thinking. Step No. 4 was the "rethinking" of Manufacturing Services and the General Engineering Laboratory as to whether this was the proper approach to the problem, or was there a better solution. As our approach was deemed sound by all concerned, we progressed to step No. 5 , the announcements in the newsletters, the creating of interest through personal contacts, and the informal contacts with manufacturing personnel to verify our approach.

Assured of product department interest, step No. 6, the preparations for a seminar, took shape coincidentally with step No. 7, the building of a demonstratable, miniaturized prototype of the computer itself. Step No. 8, the interest of a product department to assume commercial responsibility and to manufacture the Productron in quantity lots was next, and you will hear more about this from the Technical Products Department, Syracuse.

This then is a condensed statement listing in chronological order the steps taken to date. The Productron is, I believe, a good example of the way Service Divisions and Operating Departments can work together to the advantage of the Operation. One Service Group from its wide contacts with many operations recognized a need. A second Service Group had the specialized knowledge needed for a solution. Result - a working prototype of the Productron which you can try and decide for yourselves how good a job it does. The next step — putting the Productron to use — is up to you.

PRODUCTION MEETING

November 4 1955

C B Anderson
Power Transformer Dept

D F Bell
Large Motor & Generator Dept

D L Betters
Capacitor Dept

W Bobear
Aircraft Products Dept

W B Boyd
Evendale Operating Dept

B F Brickley
Appliance Motor Dept

J F Brislin
Light Mil Elec Equip Dept

C E Brown
Power Transformer Dept

W E Brown
Evendale Operating Dept

F L Buckland
Canadian General Electric Co

M Calderella
Power Transformer Dept

H C Clayton
High Voltage Switchgear Dept

J G Cooley
Materials Services Dept

J P Dempsey
Instrument Dept

H F Dickie
Materials Services Dept

E M Donegan
Rectifier Dept

H D Egger
Hermetic Motor Dept

R J English
Meter Dept

D Everest
Naval Ordnance Dept

R D Farnham
Naval Ordnance Dept

J R Ferry
Heavy Mil Elec Equip Dept

F L Gale
Specialty Comp Motor Dept

S J Garahan
Large Steam Turb - Gen Dept

J S Gargett
Wire & Cable Dept

E J Gerds
Automatic Blanket & Fan Dept

R L Getic
Comm & Ind Air Cond Dept

L Giroux
Aircraft Products Dept

G P Gladue
Light Mil Elec Equip Dept

B Grad
Materials Services Dept

J P Gravel
General Engineering Laboratory

D E Garr
General Engineering Laboratory

E O Haase
Light Mil Elec Equip Dept

R Hardiman
Light Mil Elec Equip Dept

V D Hedderick
Home Heating & Cooling Dept

J C Haugee
High Voltage Switchgear Dept

E H Hovemeyer
Evendale Operating Dept

R H Huebenthal
Technical Products Dept

W R Jacobson
General Engineering Laboratory

T F Kavanagh
Materials Services Dept

D O Knight
Medium Induction Motor Dept

F S Larson
General Engineering Laboratory

R T Lens
Appliance Control Dept

O K Lindley
Technical Products Dept

A V Logreen
Jet Engine Dept

T F Maher
Cathode Ray Tube Sub-Dept

R McClelland
Hermetic Motor Dept

F C McClintock
Power Transformer Dept

G M McCoy, Jr
Automatic Blanket & Fan Dept

R H Merrill
Wire & Cable Dept

D H Middleton
Large Steam Turb -Gen Dept

D C Miller
Materials Services Dept

J W Neuenschwander
Radio & Television Dept

P Petersen
Aircraft Products Dept

J W Pontius
Office Procedures Service

J Porter
Instrument Dept

G E Quinlan
Naval Ordnance Dept

G Rhodes
Aircraft Products Dept

A J Rowe
Materials Services Dept

A V Simpson
Office Procedures Service

B F Smith
Aircraft Products

R R Smith
Materials Services Dept

J R Spease
Capicitor Dept

E. Strong
Materials Services Dept

J. Stubbs
Canadian General Electric Co.

P. B. Sturgeon
Naval Ordnance Dept

E. C. Throndsen
Materials Services Dept

W. D. Vinson
Automatic Blanket & Fan Dept

R. S. Williams
Hermetic Motor Dept

G. T. Jacobi
General Engineering Laboratory

M. W. Hively
General Engineering Laboratory

W. Buxsel
AGT Jet Engine Dept

J. T. Malsh
Jet Engine Dept

J. H. McElwee
Lochs Dept

G. V. Sparks
Receiving Tube Dept

R. J. Greene
Light Mil. Elec. Equip. Dept

S. F. Kaplin
Low Voltage Switchgear

E. L. Massihomer
Low Voltage Switchgear

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Aircraft Products Dept.

J. P. Rubie
Welding Dept

F. L. Wellman
Aircraft Products Dept.

D. C. Hartmann
Medium Induction Motors Dept.

R. J. Barclay
T. P. D. Dept

R. F. Crawford
Gas Turbine Dept.

A. E. Koeis
Gas Turbine Dept

F. S. Gibson
Gas Turbine Dept.

R. R. Johnson
Electronics Dept.

G. A. McCune
Lg. Motor & Gen. Dept.

T. E. Kenney
Lg. Motor & Gen. Dept.

J. B. Zocchi
Motor Dept

W. Barnes
Med. Induction Motor Dept.

P. W. Justs
Capacitor Dept.

W. T. Goggins
Capacitor Dept.

L. B. Coleby
Capacitor Dept

E. J. Martin
Canadian General Electric

J. R. Etu
Capacitor Dept