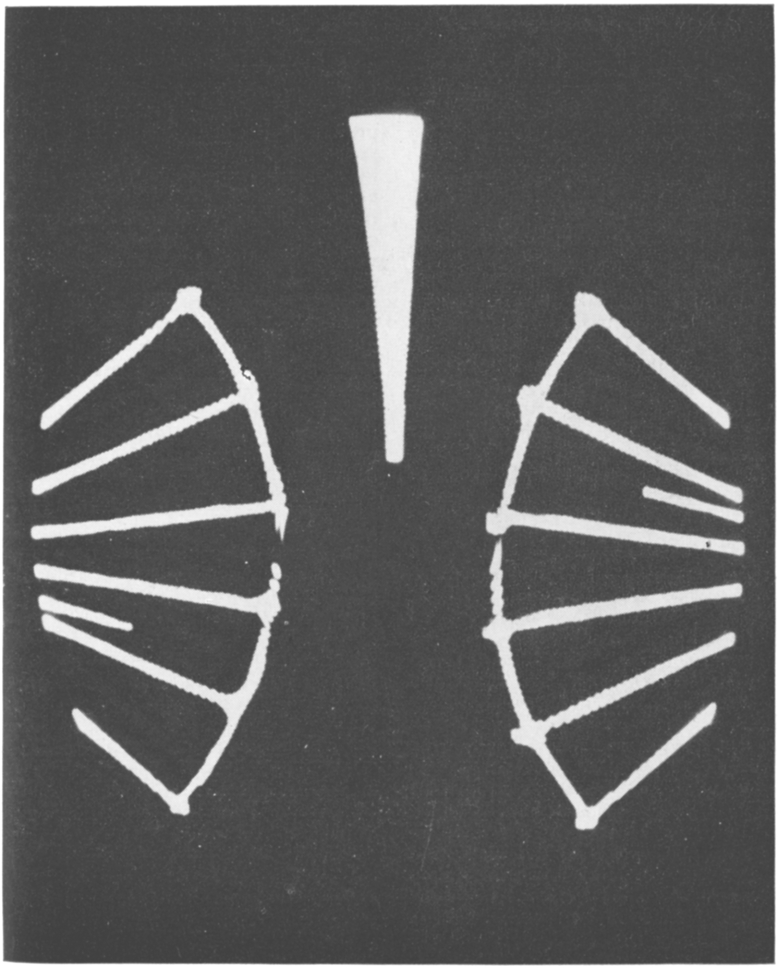
ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

APRIL | ATLANTA, GEORGIA | 1953



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Published quarterly in January, April, July and October by the Engineering Experiment Station of the Georgia Institute of Technology, Atlanta, Georgia, Volume 7, No. 2. Entered as second-class matter September 20, 1948, at the post office at Atlanta, Georgia, under the act of August 24, 1912. Acceptance for mailing at the special rate of postage provided for in the act of February 28, 1925, Section 538, P. L. & R., authorized October 18, 1948.

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OUR STAKE IN RESEARCH

Research this year will give the average American a present beyond price—five and four-tenths months on earth he would not otherwise have had. That is the annual rate at which our expected life span has been extended over the past decade—54 added months of life in a ten-year period.

These four and one-half years of added life should be fruitful ones. New knowledge of human diet has been estimated to prolong the useful, active period of life by more than a dozen years. Good progress also is being made in research's fight against the degenerative diseases. High blood pressure is rapidly being robbed of its crippling effects by the development of effective vasodilating chemicals. Cancer is being combated by an enlightened program of early recognition and by research on its prevention, detection and cure. So, also, with the other ills of age.

As pointed out in our last issue, the average working man today puts in only half the on-job time of his counterpart a century before. And at least

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Statistics on scientific education in Russia indicate that the Soviet Union is making an intensive effort to catch up with us in technically trained manpower. Russia reportedly now has about 475,000 engineers and natural scientists engaged in manufacturing, construction, transportation and communication. We have a comparable figure of 650,000—450,000 engineers and 200,000 natural scientists.

In 1950, some 21,000 Russians were studying for doctoral degrees. Last year our educational institutions turned out approximately 35,000 Ph.D's, but only 586 of these were in engineering.

A recent survey of American graduate students in the natural sciences found that our graduate schools could accept nearly 8,000 more students for doctoral studies and about 11,400 more for work toward master's degrees in science. Based on the academic year 1951, this survey showed that some 7,800 of the 16,250 first-year graduate students possessed the qualifications necessary to earn doctoral degrees. However, it predicted that three out of five of these "doctoral potential" students probably would not complete their studies for the doctorate.

This academic year 1952-53 (as of October 6, 1952) there were enrolled in all United States undergraduate engineering schools approximately 160,000 students. Less than 20,000 of these will receive bachelor's degrees this year. On the graduate level in engineering we have approximately 17,300 candidates working for a master's degree, and it is estimated that about 5,000 master's degrees will be awarded. On the doctorate level in engineering we have slightly less than 3,000 candidates, and certainly less than 1,000 of these will complete their work this year. This is a pitifully small number to meet our increasing needs.

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TELEMETERING BY TELEVISION MEANS

By M. A. HONNELL,* J. JAMGOCHIAN** AND R. E. HUMPHREY**

While standard industrial television systems can be utilized to read meters at a distance and perform other telemetering functions, they convey more information than necessary. This article describes Station development of a simplified television telemetering system that offers the advantages of reduced bandwidth and less complex equipment.

An electric telemeter is defined by the American Standards Association to be "the complete measuring, transmitting and receiving apparatus for indicating, recording or integrating at a distance, by electrical translating means, the value of a quantity." A basic telemetering system comprises three parts: a transmitting device which converts the measured quantity into an electric signal; a wire or radio circuit which conveys the signal to a convenient location; and a receiving device which indicates, or records, the magnitudes of the measured quantity.

Historically, simple electric telemetering systems were patented as early as 1885. A primitive telemetering system commonly used in automobiles is the gasoline level indicator which employs a float mechanically arranged to vary a resistor connected in series with the car battery and the gas gage on the dashboard. The resultant deflection of the gas gage is proportional to the volume of gasoline in the gas tank. For many years power companies have employed telemetering systems to indicate at a central control point the voltage, current and power supplied by a remote generating plant. The fact that several hundred patents have been granted in telemetering is a good

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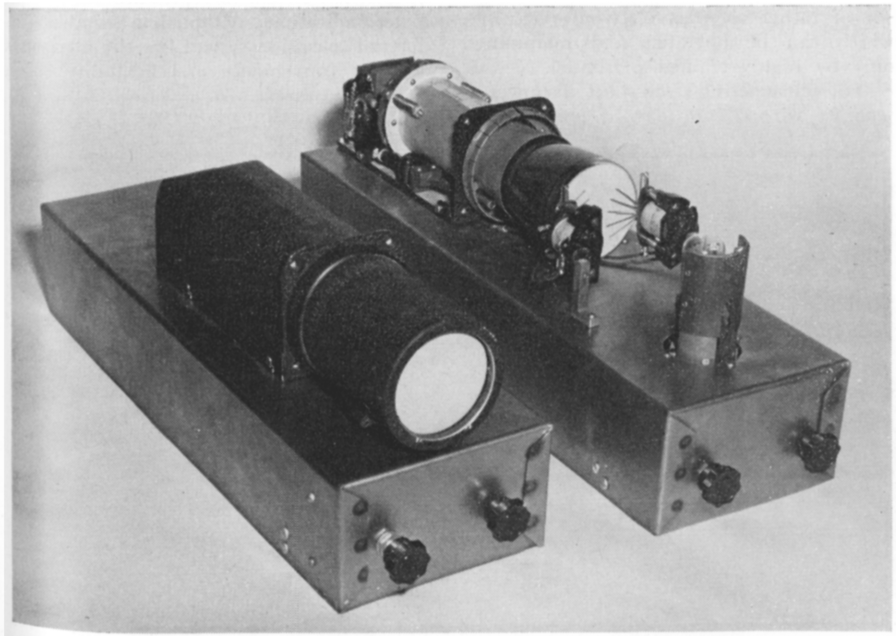

Figure 1. The transmitter (right) scans the meter graduations and pointers in front of its cathode-ray tube, and the receiver reproduces the image at a distant point.

criterion of the importance and magnitude of the field.

Every year, more and more difficult instrumentation problems are solved through the use of telemetering. For example, very elaborate telemetering systems have been found essential in operating nuclear reactors and in recording data during guided-missile test flights. In the latter case, for example, a considerable quantity of important data are recorded at the telemetering receiving installation while the missile is in flight. The data would be completely lost in many cases if they were recorded in the missile and ejected and parachuted to earth.

From the communication engineering viewpoint, electric telemetering systems may be classified in one of the following categories: amplitude systems, frequency systems and pulse systems. There are numerous subdivisions of these classifications.

In many telemetering applications, it is necessary to transmit several meter readings simultaneously over a single pair of wires, or over a single microwave radio circuit. Needless to say, some of these systems consist of rather complex electronic circuitry, which can be operated and maintained only by highly trained personnel.

For telemetering over short distances, a separate wire circuit may be economically justified for each measurement message to be transmitted. However, for long-distance telemetering over wires, or for telemetering over a radio link, special techniques have been developed to transmit a group of messages simultaneously, or sequentially, over a single channel.

Factors of importance in telemetering systems vary with the particular application. For example, the telemetering equipment in a Radiosonde weather balloon must be small and light in weight, and some sacrifice in other factors may be made to achieve this. On the other hand, in a telemetering installation in a power plant, size is of less importance than accuracy. The factors of basic importance to all telemetering systems are: accuracy of measurement, reliability, type of data presentation, initial cost and cost of operation.

Georgia Tech Investigation

During the past year, the Engineering Experiment Station sponsored an investigation of the obvious technique of employing a television system to reproduce a group of meter indications. Although a standard industrial television system has the attributes of great convenience and flexibility for a

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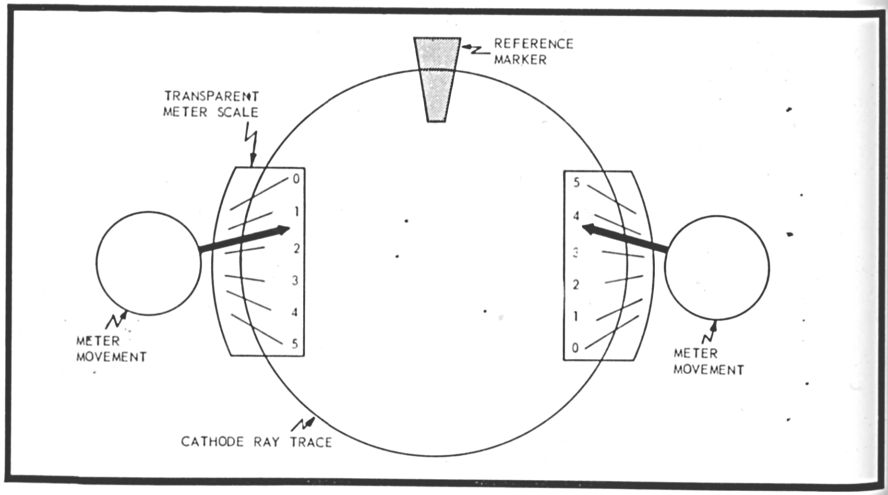

Figure 2. The opaque markings on the transparent meter scales and the opaque meter pointers and reference marker interrupt the scanning trace, thus producing the reading.

APPLICATIONS OF COMPUTING MACHINES TO THE PROBLEMS OF GENERAL STAFFS

By Russell J. Brooke*

This article poses an interesting and significant question: "Can computing machines, the so-called 'electronic brains,' help lighten the prodigious planning and paper-work load of the Armed Forces' general staffs?" The author points out a number of areas in which he believes they can.

Recent developments in the field of computing machines, particularly those of the "electronic-brain" type, indicate that a new technological era is dawning. Soon machines may relieve men of the drudgery of routine mental work. When this happens, the effects on human society may be as far reaching as those of the industrial revolution, which saw the introduction of power machines to supplant tedious, low-productive hand work.

Not many years ago, no one foresaw machines capable of doing the work of a thousand hands. Yet such machines are commonplace today, and they have brought less tiring, better paying jobs, together with more and cheaper products for man's use.

Machines that can do the work of a thousand minds sound preposterous today. But are they? To a considerable extent, the answer to this question depends on our definition of the "mental work" we expect them to perform. To date, no one has envisioned a machine having the capacity and versatility of the human brain. Therefore some engineers object to the terms "brain" and "think" in discussing current computing machines. They claim that these machines only perform operations that they have been previously programmed or instructed to perform. In other words, they only do what they are told to do. However, a large proportion of man's mental work today falls into a somewhat similar cate-

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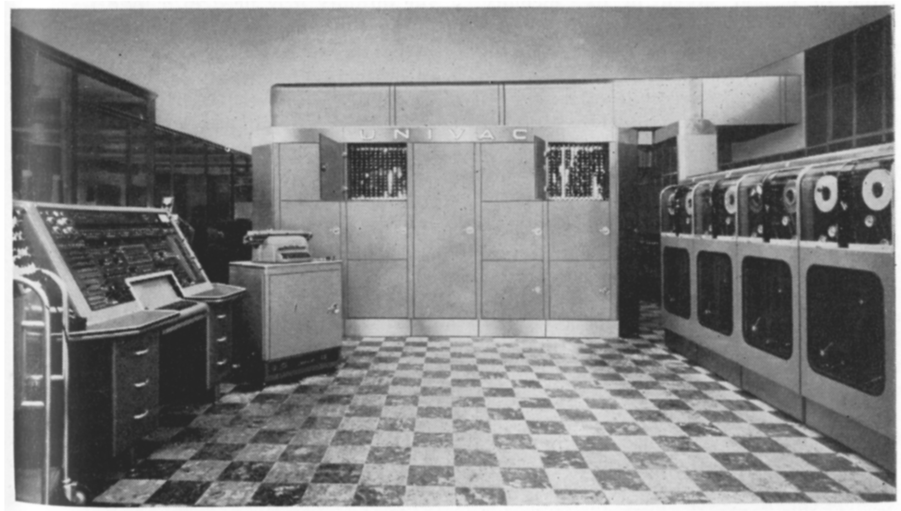

Figure 1. UNIVAC and other large digital computers have already demonstrated their capacities for the solution of complex problems. (Courtesy Remington Rand, Inc.)

gory. When a man uses his brain to recognize a situation by reading a few signs to call to mind previous instructions and then to take the indicated action, we are accustomed to call the process "thinking." At any rate, he is using his brain to perform an operation. Within limits, the same operation or similar operations can be performed by a machine which is fed certain symbols to activate previously given instructions stored in its "memory banks" and which then carries out the computation or control function desired.

Even in today's relatively early stage of development, some computing machines represent major strides toward the completely automatic control of industrial processes. One such machine is Remington Rand's new ERA 1103, an electronic computer weighing ten tons and employing 4,500 electron tubes. Its potential application to the *economic*, as well as technical, control of a petroleum refinery was discussed briefly in a recent news item announcing its development. This computer would receive data on processing through "sensing" devices located at various stages in the over-all chain of refinery-process operations. These data would be fed into the computer in accordance with instructions previously given to it and stored in its "memory." The instructions would involve such factors as temperature, pressure, contact time and composition of the feed. Given data based on the analysis of the crude oil to be processed, the computer presumably could control the processing units so that the refinery would turn out the economically optimum amounts of gasoline, Diesel oil, fuel oil, lubricating oil, etc., thus always getting the highest possible dollar return from its operations.

Industries having complex control or correlation problems undoubtedly will find countless applications for computing machines in the future, particularly as new and more versatile computers are developed. However, there is another highly complex field in which computing machines may serve most importantly, namely, in the planning that must be done by the general staffs of our Armed Forces. It is with their potential applications in that field that this article deals.

Victory in modern wars is largely a matter of inventory control. Battles are won, not by the side that "gits there fustest with mostest" men, but by the side that brings into action the right weapons and other materiel at the right time. In today's total warfare, the nation loses that lacks the proper war materiel at the crucial moment. Whether caused by enemy action, sabotage, the inability to produce or by investment of limited resources in the wrong kinds of materiel, lack of the right kinds means certain defeat. And modern battles may be lost for want of proper-size ball bearings or even dry socks.

The general staffs have the problem of investing that portion of our national resources made available to the Armed Forces in the right types and quantities of materiel. The number of men required for any conceivable military actions, the amount of training required to give these men the skills they must have, the special service activities needed to maintain their morale and numerous other considerations can also be viewed as inventory problems.

The over-all problem is almost inconceivably complex. No peace-loving nation's economy will permit supplying all the men, all the training and all the materiel that the military may need in a total war. The military catalog contains more than a million different items. The potential need of each item and its cost must be carefully weighed against the anticipated need and cost of every other item. The inter-service controversy over the relative worth of land-based planes and fixed airfields as compared with carrier-based planes and carriers has been reported at length in the press. However, the immensity of the over-all evaluation problem only becomes apparent when it is realized that it must also encompass comparisons of rifles with refrigerators, slide trombones with steam tables, etc.

If machines can be developed to assist substantially in the planning operations of the general staff, better and quicker solutions to many problems may be forthcoming. Control of the Armed Forces may be greatly simplified also. When the Korean phase of the Twentieth Century wars be-

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DETERMINING INEFFICIENCIES IN MULTIPLE-MACHINE ASSIGNMENTS

By DALE JONES*

In making multiple-machine assignments that have random servicing requirements, engineers need means for determining the optimum work loads per operator and for establishing adequate recompense for operators' idle time imposed by limitations on the work load. This article discusses the applications, mathematical basis and inherent limitations of means that have been developed at Georgia Tech for these purposes.

Today, machine interference accounts for about half of the inefficiency of multiple-machine assignments, such as those involving looms, automatic screw machines, cartoning machines, etc., that have random servicing requirements. Machine-interference idleness may be defined as the time a machine is nonproductive while awaiting servicing by its operator who is tending some other machine in his assignment.

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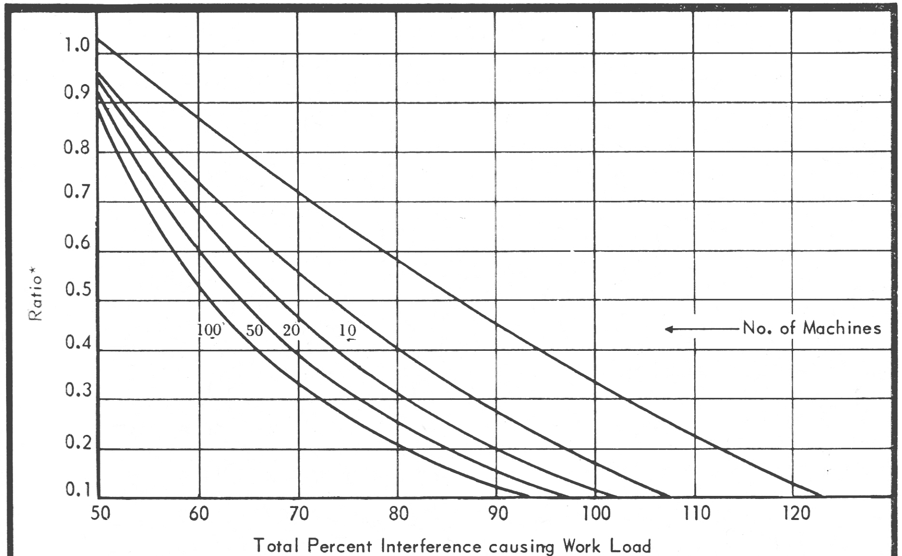
At first thought, it might seem that the most economic degree of machine-interference idleness for any multiple-machine assignment is something near zero. Realizing, however, that interference is dependent on the work load and number of machines assigned to the operator, one can see that its reduction requires the reduction of the values of these determinants. This, in turn, necessitates increasing the number of operators for any given department, causing increased unit-labor cost. On the other



* Ratio = (Margin between variable production cost and selling price for 1 hr. of production from one machine with no interference)÷(Operator's hourly pay rate for his unavoidable idle time)

Figure 1. These curves permit determination of the optimum total interference-causing work load and the number of machines to assign an operator.

hand, if the work loads or numbers of machines assigned to the operators are increased, reduced profit due to the resultant increase of interference inefficiency tends to offset and overtake the reduced unit-labor costs. It therefore follows that in any multiple-machine assignment situation, there is an optimum work load—that which will result in the least total lost profit resulting from the inherent machine interference and the expense of the operator's unavoidable idle time inherent in the work load.

Thus, engineers responsible for establishing work loads and wage-incentive standards for multiple-machine assignments that have random servicing requirements need accurate means for estimating machine-interference times. With such means they can make assignments based on the most economic degree of machine interference and then make satisfactory wage-incentive allowances for machine idleness due to interference.

Georgia Tech Work

Because the continued growth of industrial mechanization has increased the economic significance of machine interference, Georgia Tech's School of Industrial Engineering has conducted considerable research on the problem during the past five years. The development of a mathematical solution to the problem of evaluating the machine interference caused by random machine-servicing requirements where operators work independently of each other was discussed in the January, 1949, issue of this publication. That article described the application of certain laws of probability in solving machine-interference problems and also discussed the "interference computer" developed by the School of Industrial Engineering to test the validity of the proposed mathematical solution. Interference values experimentally obtained with this interference computer agreed closely with those mathematically derived for similar conditions.

Since the previous article was published, numerous practicing engineers have written for additional information on specific problems. Many have tested the validity of the mathematical solution in various multiple-machine assignments. With a single exception, they report very close agreement between the mathematically determined and the measured interference values.

The reported practical usefulness of the previous work has prompted further efforts here to provide more readily usable tools for estimating interference inefficiency. The resulting tools have been designed to accommodate the stated needs of engineers responsible for planning work loads and establishing incentive-pay rates for multiple-machine assignments which involve random servicing and in which the operators work independently of one another. These tools are presented here in the form of one set of curves and three tables. Figure 1 provides means for anticipating the relevant expenses in multiple-machine assignments and for selecting the optimum operator work loads. Having done this, the engineer must establish an incentive allowance that will offset the operator's loss of earnings otherwise resulting from machine-interference idleness. Unless these allowances are determined fairly for the various assignments, pay inequities between operators will result. However, they are virtually impossible to evaluate directly with a stop watch because of the unpredictability of multiple-servicing demands. Tables I and III are the basic tools provided for accurate setting of these allowances, depending on the incentive-pay basis used in the plant. Table II provides information for predicting machine efficiencies as an aid to production planning and scheduling.

Assuming that such will be the probable order of greatest interest to most readers, this article will discuss the applications of these tools first, then present their mathematical derivation and, finally, describe means whereby the values presented can be adjusted to accommodate certain conditions not encompassed in the situations to which the tables are directly applicable.

Applications of the Tools

The applications of the tools under discussion can best be illustrated by case examples. Let us assume a case in which the number of machines to be assigned an independent operator lies between 6 and 10. The average machine time per unit of product, R, is 9.20 minutes; the average service

time per unit of product is broken down into two components—S_d = 0.80 minute while the machine is idle and S_r = 0.20 minute while the machine is producing. Then the average work load per machine is equal to $(S_d + S_r) \div (S_d + R) = 0.10$ or 10 per cent.

Assume that the operator's earning rate during unavoidable idle time imposed by work-load limitations is set at $1.50 by company policy. Also, the margin between sales income and variable production, handling and selling cost for one hour's production of one machine, in the absence of machine interference, is $0.45. Then, the ratio between this hourly margin and the operator's hourly pay for idleness is $0.45 ÷ $1.50 or 0.30.

The most economic work load for the conditions set forth can be determined through reference to Figure 1. According to this set of curves, the 0.30 ratio warrants a total interference-causing work load of about 90-100 per cent, depending upon the number of machines assigned. Since the average work load per machine is 10 per cent, the most economical number of machines would be 9. An assignment of 9 machines, giving a work load of 90 per cent, checks quite closely with the ideal combination for a 0.30 ratio, as shown in Figure 1.

With the work load per operator determined, the next step is to evaluate the incentive allowance necessary to compensate the operator for his unavoidable idle time imposed by the limitation on work load. This allowance can be figured two ways, both of which provide the same earnings for enforced idleness under any given set of conditions.

If the incentive rates are based upon total time per piece (100 pieces, 10,000 picks, etc.), the following procedure should be employed to compensate for production lost because of interference.

(1) Determine the noninterference cycle time, i.e., $S_d + R$, per piece (100 pieces, 10,000 picks or whatever the basis for the incentive standard). In

TABLE I

AVERAGE PERCENTAGE INTERFERENCE PER MACHINE VERSUS TOTAL PERCENTAGE WORK LOAD OF ASSIGNED MACHINES

No.	Operator's Total Percentage Work Load* on Individual Attention Basis														
Machs.	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
4	3.2	4.0	4.8	5.8	6.9	8.0	9.4	10.9	12.5	14.1	15.9	17.9	19.8	21.7	23.7
5	2.8	3.5	4.2	5.1	6.1	7.2	8.5	9.9	11.4	13.0	14.8	16.7	18.6	20.5	22.6
6	2.5	3.1	3.7	4.5	5.5	6.5	7.8	9.0	10.5	12.1	13.7	15.7	17.7	19.6	21.7
7	2.2	2.7	3.3	4.1	5.0	6.0	7.1	8.3	9.7	11.3	13.0	14.8	16.8	18.8	20.9
8	1.9	2.4	3.0	3.7	4.5	5.5	6.5	7.7	9.0	10.6	12.2	14.0	16.0	18.2	20.2
9	1.7	2.2	2.8	3.4	4.2	5.1	6.0	7.2	8.4	9.9	11.5	13.4	15.4	17.6	19.7
10	1.5	2.0	2.6	3.2	3.9	4.7	5.6	6.7	7.9	9.4	10.9	12.9	14.9	17.1	19.4
11	1.4	1.9	2.4	3.0	3.7	4.4	5.3	6.3	7.5	8.9	10.5	12.4	14.4	16.7	19.0
12	1.3	1.8	2.2	2.8	3.5	4.1	5.0	5.9	7.1	8.5	10.1	12.0	14.0	16.3	18.6
13	1.3	1.7	2.1	2.6	3.2	3.9	4.7	5.6	6.8	8.1	9.7	11.6	13.6	16.0	18.3
14	1.2	1.6	2.0	2.4	3.0	3.7	4.4	5.3	6.4	7.7	9.3	11.2	13.3	15.7	18.0
15	1.2	1.5	1.9	2.2	2.8	3.5	4.2	5.1	6.1	7.4	8.9	10.8	13.0	15.4	17.8
16	1.1	1.4	1.8	2.1	2.7	3.3	4.0	4.8	5.9	7.0	8.5	10.5	12.7	15.0	17.6
17	1.1	1.3	1.7	2.0	2.5	3.1	3.8	4.6	5.6	6.7	8.2	10.2	12.4	14.8	17.4
18	1.0	1.2	1.6	1.9	2.4	3.0	3.6	4.4	5.4	6.5	7.9	9.9	12.2	14.7	17.3
19	1.0	1.1	1.5	1.9	2.3	2.9	3.5	4.2	5.2	6.2	7.7	9.6	12.0	14.6	17.2
20	0.9	1.1	1.4	1.8	2.2	2.8	3.4	4.1	5.0	6.0	7.5	9.3	11.8	14.5	17.1
25	0.8	0.9	1.2	1.5	1.8	2.3	2.8	3.4	4.2	5.2	6.6	8.4	10.8	13.7	16.9
30	0.7	0.8	1.0	1.2	1.6	2.0	2.4	2.9	3.7	4.6	5.9	7.7	10.2	13.3	16.8
40	0.5	0.6	0.8	1.0	1.2	1.5	1.8	2.3	2.9	3.7	5.0	6.8	9.4	13.2	16.6
50	0.3	0.5	0.6	0.8	0.9	1.2	1.5	2.0	2.5	3.2	4.2	6.1	9.3	13.2	16.6
75	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.3	1.7	2.2	3.3	5.2	9.1	13.1	16.5
100	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.5	1.9	2.8	5.1	9.0	13.0	16.5

*Figure the work load at incentive pace and exclude deferrable "internal" duties (those which can be performed when all machines are producing).

this example, $S_d + R = 0.80 + 9.20$ or 10.00 minutes per piece.

(2) Divide the resulting figure by [(100 per cent minus the per cent interference) ÷ 100] to determine the cycle time when the expected interference prevails. In this example, the average interference per machine for 9 machines having a 90 per cent total work load is 8.4 per cent, as determined by matching 90 with 9 machines in Table I. Dividing 10.00 minutes per piece by [(100 per cent minus 8.4 per cent interference) ÷ 100] gives 10.93 minutes per piece as the basis for the incentive standard.

If the incentive rates are based on manual time only, with separate allowance being paid for the operator's unavoidable idle time, the following procedure should be used.

(1) Determine the total manual time per piece ($S_d + S_r$). In this example, $S_d + S_r = 0.80 + 0.20$ or 1.00 minute per piece. This is the basis for the incentive standard.

(2) Estimate, through use of Table III, the percentage of over-all time the operator will be unavoidably idle when tending the number of machines assigned. In this example, his total work load is 90 per cent and he is assigned 9 machines. Matching 90 with 9 machines in Table III gives 17 per cent unavoidable operator idleness.

(3) Grant the operator an allowance equivalent to the percentage of unavoidable idle time multiplied by the hourly rate for such time. In this example, the allowance would be 0.17 times \$1.50 = \$0.255 per hour.

For purposes of production planning and scheduling, it is helpful to be able to predict machine efficiencies. Table II is designed for this use in multiple-machine assignments requiring random servicing. In our example, by matching the 90 per cent total work load with 9 machines in Table II, the average efficiency per machine is found to be 82.4 per cent. However, since part of the operator's work is performed "internally," i.e., S_r work performed while the machine serviced is producing, it is necessary to adjust the 82.4 per cent value which assumes that all work is S_d work, i.e., servicing performed while the machine is shut down. The method for making such adjustment will be described later in this article.

TABLE II

AVERAGE PERCENTAGE EFFICIENCY PER MACHINE VERSUS TOTAL PERCENTAGE WORK LOAD OF ASSIGNED MACHINES

No.	Operator's Total Percentage Work Load* on Individual Attention Basis														
Machs.	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
4	84.7	82.8	80.9	78.9	76.8	74.7	72.5	70.2	67.8	65.5	63.1	60.5	58.2	55.8	53.4
5	87.5	85.9	84.3	82.6	80.7	78.9	76.7	74.8	72.6	70.5	68.2	65.8	63.5	61.2	58.8
6	89.4	88.0	86.7	85.2	83.5	81.8	79.9	78.1	76.1	74.0	71.7	69.5	67.2	65.0	62.6
7	90.8	89.6	88.4	87.0	85.5	83.9	82.3	80.6	78.7	76.7	74.6	72.4	70.1	67.9	65.5
8	92.0	90.9	89.7	88.5	87.1	85.6	84.1	82.5	80.8	78.8	76.8	74.7	72.5	70.1	67.8
9	92.8	91.8	90.7	89.6	88.4	87.0	85.6	84.0	82.4	80.6	78.7	76.5	74.3	72.0	69.6
10	93.6	92.6	91.6	90.5	89.4	88.2	86.9	85.4	83.8	82.0	80.2	77.9	75.7	73.4	70.9
11	94.1	93.2	92.3	91.3	90.2	89.1	87.8	86.4	84.9	83.2	81.4	79.4	77.0	74.6	72.2
12	94.6	93.7	92.9	92.0	90.9	89.9	88.7	87.4	85.9	84.3	82.4	80.3	78.1	75.7	73.2
13	94.9	94.1	93.4	92.5	91.5	90.6	89.4	88.2	86.8	85.2	83.4	81.3	79.1	76.6	74.2
14	95.3	94.5	93.8	93.1	92.1	91.1	90.1	89.0	87.6	86.0	84.2	82.1	79.9	77.4	75.0
15	95.5	94.9	94.2	93.5	92.6	91.7	90.7	89.5	88.3	86.7	85.0	82.9	80.6	78.1	75.6
16	95.8	95.2	94.5	93.9	93.0	92.2	91.2	90.1	88.8	87.5	85.8	83.6	81.3	78.9	76.2
17	96.0	95.5	94.8	94.3	93.5	92.6	91.7	90.6	89.4	88.1	86.4	84.3	81.9	79.4	76.8
18	96.2	95.8	95.1	94.5	93.8	93.0	92.1	91.1	89.9	88.6	87.0	84.8	82.4	79.8	77.2
19	96.4	96.0	95.4	94.7	94.1	93.3	92.4	91.5	90.3	89.1	87.4	85.4	82.9	79.2	77.6
20	96.6	96.2	95.6	95.0	94.4	93.6	92.7	91.8	90.7	89.5	87.9	85.9	83.3	80.6	77.9
25	97.2	96.9	96.4	95.9	95.4	94.8	94.1	92.3	92.3	91.2	89.7	87.7	85.3	82.3	79.1
30	97.6	97.4	97.0	96.7	96.1	95.6	95.0	94.3	93.4	92.4	91.0	89.1	86.5	23.4	79.9
40	98.3	98.0	97.7	97.4	97.1	96.7	96.2	95.6	94.9	94.0	92.6	90.7	88.1	84.3	80.9
50	98.7	98.4	98.2	97.9	97.7	97.3	96.9	96.3	95.7	95.0	93.9	91.9	88.7	84.8	81.4
75	99.1	99.0	98.8	98.6	98.5	98.2	97.9	97.6	97.1	96.6	95.4	93.5	89.6	85.6	82.2
100	99.3	99.2	99.1	99.0	98.7	98.5	98.3	98.1	97.6	97.2	96.2	93.9	90.0	86.0	82.5

*Figure the work load at incentive pace and exclude deferrable "internal" duties (those which can be performed when all machines are producing).

Mathematical Basis of Tools

The mathematical basis for the figure and tables presented herein was rather rigorously discussed in the article, "Mathematical and Experimental Calculation of Machine Interference Time," which appeared in *The Research Engineer* for January, 1949. The following derivation is considerably simplified but equally valid. It applies to assignments where one worker (say a weaver) tends several machines (looms) which have unpredictable, random servicing requirements, with resultant simultaneous shut-downs and consequent idleness caused by machine interference.

Let S_d equal the expected "external" servicing time (operator's walking, working and any necessary relaxing time that must be taken at an expense of lost production) per unit of product on any given machine, i.e., that servicing which must be done while the machine is nonproductive.

Let S_r equal the expected "internal" servicing time (operator's walking, working and any necessary relaxing time) per unit of product on any given machine, i.e., that servicing which can be done while the machine is productive. Those internal duties which normally can be economically interrupted and/or deferred in order to avoid interference are not to be considered in this category.

The walking time in both S_d and S_r is based on the average walking that would be necessary if the number of machines in the assignment were tended together.

Let R equal the average machine's run-

TABLE III

AVERAGE PERCENTAGE OPERATOR IDLE TIME VERSUS TOTAL PERCENTAGE WORK LOAD OF ASSIGNED MACHINES

No.	Operator's Total Percentage Work Load* on Individual Attention Basis														
Machs.	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
4	52	47	43	39	35	31	28	24	21	18	16	14	12	10	8
5	52	47	43	39	34	31	26	23	20	17	15	13	11	8	7
6	51	47	42	38	34	30	26	23	20	17	14	11	10	7	6
7	51	46	42	38	34	30	26	22	19	16	13	10	8	7	5
8	51	46	42	38	33	29	25	22	18	15	12	10	8	6	4
9	51	46	42	37	33	29	25	21	17	15	12	9	7	6	4
10	51	46	42	37	33	29	25	21	17	14	11	8	6	5	3
11	51	45	42	37	33	28	24	20	16	14	11	8	6	4	3
12	51	45	42	37	33	28	24	20	16	13	10	7	5	4	2
13	51	45	42	37	32	28	24	20	16	13	10	7	5	4	2
14	51	45	41	37	32	28	23	20	16	12	9	6	5	3	2
15	51	45	41	36	32	27	23	19	16	12	9	6	4	3	1
16	50	45	41	36	31	27	23	19	15	12	9	6	4	2	1
17	50	45	41	36	31	27	23	19	15	12	8	6	3	2	1
18	50	45	41	36	31	27	22	19	15	11	8	5	3	1	—
19	50	45	41	36	31	27	22	18	14	11	7	5	3	1	—
20	50	45	40	36	31	27	22	18	14	10	7	4	2	1	—
25	50	45	40	36	30	27	22	18	13	10	7	3	2	—	—
30	50	45	40	36	30	27	22	17	13	10	7	2	1	—	—
40	50	45	40	36	30	27	21	17	12	9	6	1	1	—	—
50	50	45	40	35	30	26	21	16	12	9	5	1	—	—	—
75	50	45	40	35	30	25	20	16	11	8	4	—	—	—	—
100	50	45	40	35	30	25	20	16	11	7	3	—	—	—	—

*Figure the work load at incentive pace and exclude deferrable "internal" duties (those which can be performed when all machines are producing).

ning time per unit of product.

Then S, the portion of over-all time any machine would need servicing, if individually tended from a point involving average walking when the number of machines in the assignment are tended together, is $(S_d + S_r) \div (S_d + R)$.

When one operator tends n machines haying running cycles that cannot be coordinated, machine-interference idleness will occur. Let i equal the average portion of over-all time that each machine would be nonproductive because of machine interference if all n machines were tended by one operator. Since their average servicing ratio is S, the average portion of over-all time that each of the machines would require servicing when tended together is $S(1 - i)$.

Let d equal the average portion of overall time that one of n machines in an assignment is idle because of S duties and interference. Then,

$$d = S(1 - i) + i. \qquad (1)$$

The probability that a machine will require servicing (will be serviced or waiting for service) at any given moment is d. The probability that it will not require servicing at any given moment is $1 - d$. The probability that none of the n machines will require servicing at any given moment is $(1 - d)^n$, while the probability that one or more machines will require servicing at a given moment is $1 - (1 - d)^n$.

These statements of probability are exactly true only where the S for each machine in the group is the same as for every other machine in the group. However, the use of the average S for the machines in the group introduces only a small error, according to the interference-computer experiments and subsequent research findings.*

The average ratio of servicing time per machine to over-all time when n machines are tended together can be expressed as follows:

$$S(1 - i) = [1 - (1 - d)^n] \div n. \qquad (2)$$

Equations 1 and 2 are the basis for Table I. The values in that table were determined in the following manner. Convenient d and n values were substituted in Equation 2 in order to obtain the respective $S(1 - i)$ values. Then the respective i values were determined by substitution in Equation 1, and the respective S values were obtained in the same way. Finally, nS products versus respective i values (both expressed as percentages) were plotted graphically for various n values, thus obtaining the values presented as average percentage interference per machine (100 i) versus total percentage work load (100 nS) of assigned machines in Table I.

The values in Table II were determined from the formula:

Average Efficiency per Machine $=$ $1 - (\Sigma S \div n)\ (1 - i) - i$, where it is assumed that all servicing is S_d servicing. (See later discussion on adjusting for S_r.) The i values are taken from Table I on the basis of the respective ΣS and n values in the immediately preceding formula.

The values in Table III were determined from the formula:

Operator Idle Time Per Cent $=$ $100 - \Sigma S(1 - i)\ 100$, where it is assumed that necessary deferrable internal servicing is insignificant. The i values are taken from Table I on the basis of the ΣS and the n under consideration.

Limitations of the Tables

The tables and figure included in this article are directly valid when both of the following conditions prevail:

(1) one operator tends the machines unassisted;

(2) the servicing demands of the machines cannot be coordinated to permit a fixed servicing sequence that would minimize or eliminate machine interference.

In addition to the above conditions, Table II assumes that all of the operator's work load consists of S_d duties, i.e., servicing done while the machine is nonproductive. Table III assumes that the operator has no work other than S_d and S_r duties, i.e., no necessary but deferrable internal work to perform during his otherwise unavoidable idle time.

These limitations and assumptions give rise to several questions. Can the tables be used, with adjustment, for assignments involving two or more operators? Can they be used, with adjustment, where operators have S_r duties (nondeferrable internal work)? Can they be adjusted for assignments in which the operators have work other than S_d and S_r work, i.e., necessary deferrable internal work? Are the tables valid for use in assignments where machines produce products having nonvarying cycle times on the individual attention basis but where the cycle times vary widely from one product to another? When the servicing requirements of individual machines are significantly different, how can the interference and efficiency values of individual machines be estimated?

In assignments involving two or more operators *who work unassisted* and where the previously stipulated conditions exist, the tables can be used accurately, provided the proper adjustments are made. For example, assume that there is a second operator (B) also involved in the previously discussed assignment. Say Operator B is known to be responsible for 15 per cent inefficiency of the machines—in the form of servicing and interference down-time. In the case of the operator previously discussed (A), there was a 10 per cent work load per machine on an individual attention basis (assuming no other operator worked in the assignment). However, with Operator B now responsible for 15 per cent inefficiency, Operator A's work load per machine, on an individual attention basis, is 10 per cent multiplied by (1.00 — 0.15) or 8.5 per cent. Also, his total work load, again on an individual attention basis, is 9 machines times 8.5 per cent, or 76.5 per cent. The machine interference, machine inefficiency and operator's idle time now attributed to Operator A can be determined from the tables in the same manner as before, except that a total operator work load of 76.5 per cent should be used instead of the 90 per cent previously employed.

It will be noted that the inefficiency attributable to the other operator or operators in the assignment must be known in order to use the tables in behalf of the operator under consideration. The question will arise, "How can individual inefficiencies be attributed to individual operators in a given assignment?" An operator's percentage of unavoidable idle time can be estimated by observation and timing over a representative period. Having this percentage and knowing the number of machines in the assignment, one can use Table III to obtain the operator's total percentage work load on an individual attention basis. Having this figure, he can use Table II in the regular manner to estimate the machine efficiency attributable to the operator in question and then subtract this efficiency value from unity to determine the inefficiency.

As mentioned, Table II assumes that the operator has no S_r work, i.e., nondeferrable internal work. However, Tables I and III are directly valid regardless of S_r duties. Where the operator has S_r work, Table II is used as follows: (1) determine the value $(1 - i)\ S_r \div (S_d + R)$, where i is determined from Table I and is based on both S_d and S_r duties; (2) add this value to the efficiency determined from Table II in the regular manner.

In assignments where the operator has work other than that constituting S_d and S_r duties, i.e., deferrable internal work that does not contribute to interference, the average percentage operator idle time determined from Table III in the regular manner must be adjusted as follows: (1) determine the ratio of the deferrable internal work to $(S_d + R)$, which would be the portion of over-all time the operator would spend on such duties if the machine were individually tended; (2) multiply this value by $(1 - i)$, using Table I to determine i; (3) subtract this value from the average percentage operator idle time determined from Table III in the regular manner.

The tables have been found valid for use in assignments where the servicing requirements of individual machines are not random but are of such nonuniformity as to preclude adoption of a fixed servicing sequence designed to minimize or eliminate interference. The many experiments conducted with the interference computer have demonstrated that the tables, while based on complete randomness, are not significantly inaccurate for the nonrandom servicing condition.

So far, this discussion has been limited to multiple-machine assignments in which the machines all have about the same servicing requirements. However, it is common practice to assign an operator several

*Ashcroft, H., "The Productivity of Several Machines Under the Care of One Operator," *Journal of the Royal Statistical Society 11*, No. 1 (1950).

machines turning out different products and having significantly different servicing requirements. Although one could estimate the *average* interference and inefficiency per machine in such assignments through use of Tables I and II, the figures obtained might be of little value. When the servicing demands of individual machines in an assignment differ widely, so do the interference and over-all inefficiencies. Thus, the average values may differ greatly from the specific values. Several practicing engineers have suggested the following procedure for estimating interference and efficiency values for individual machines in such assignments. While the author cannot say how thoroughly the procedure has been tested, he will include it as it was recommended to him: (1) determine the work load for the machine (or product) under consideration; (2) multiply this figure by the total number of machines in the assignment to arrive at a work load; (3) match this work load with the number of machines in question in Table I to estimate the interference (or in Table II to estimate the efficiency) per machine or per product in question.

Before discussing the practical limitations of Figure 1, it may be of interest to explain how it was derived. The curves in this figure represent the interference-causing work loads that involve the least total machine interference and operator idleness expense for various ratios of hourly machine-interference loss of income and operator earnings during unavoidable idle time. The points for the curves were determined as follows:

(1) An operator hourly pay rate and a margin between variable production cost and selling price for one hour's production from one machine with no interference were assumed and were converted to a ratio of margin ÷ operator pay.

(2) The average percentages of interference idleness per machine for various work loads were determined from Table I and were multiplied by the number of machines under consideration to determine the total lost machine capacity due to interference for the respective work loads.

(3) The operator unavoidable idle time percentages were determined from Table III for the respective assumed work loads.

(4) For each work load, the respective value determined in (2) was multiplied by the ratio determined in (1). Then the respective value determined in (3) was added to this product.

(5) The work load that gave the lowest value determined in (4) and the assumed ratio in (1) were then taken as the abscissa and ordinate, respectively, to plot the point.

There are certain practical limitations that must be kept in mind when considering use of Figure 1. First, it assumes complete fluidity of the multiple-machine-assignment labor. That is, it assumes that if only 4.3 operators are economically justified in the department today, any excess labor presently on the payroll can be transferred to other necessary work or dismissed. If 5.5 operators are needed next week, it assumes the 4.3 can be increased with no difficulty. The validity of such assumptions is conditioned by the size of the departments in question, larger ones generally having a greater fluidity of labor. Thus, if the operators' work loads and tasks can be varied at will, as would likely be the case in departments having many operators, Figure 1 can be used effectively to select work loads.

Summary

The tools discussed in this article have been developed to permit engineers to predict the man and machine inefficiencies inherent in alternate multiple-machine-assignment work loads where the machines require random servicing. This enables the engineers to assign work loads involving the least total idleness expense. The tools can also be used to determine equitable wage-incentive allowances for operators' unavoidable idle time due to work-load limitations. Thus, these tools can assist in obtaining the most economic utilization of men and machines in multiple-machine assignments, while also serving as an equitable basis for compensating labor for the resultant variable enforced idleness.

TELEMETERING BY TELEVISION

Continued from Page 4

general-purpose telemetering system, a careful study of the problem indicated that a considerable amount of superflous information is transmitted by the television system. Basic communication principles show that if a reduction in transmitted information can be tolerated, a reduced bandwidth of frequencies will suffice to transmit the information, with a consequent simplification in equipment.

To transmit a meter reading by television means, it is clear that it is not necessary to reproduce a facsimile of the meter face: it is necessary only to indicate the position of the meter pointer with respect to a pair of meter-dial calibration marks. This can be achieved by application of very simple television principles.

Consider Figures 1 and 2 which show two meters with transparent scales mounted close to the screen of a cathode-ray tube. If sinusoidal voltages of equal magnitude and quadrature phase relationship are connected to the vertical and horizontal deflection plates, or coils, of the cathode-ray tube, the luminous cathode-ray spot will trace a circle on the fluorescent screen. Furthermore, the spot will trace a complete circle for each cycle of the applied voltage. When the spot passes beneath one of the opaque meter calibration lines, or under the meter pointer, the spot is momentarily hidden from view. If a phototube is placed in front of the meters, it is apparent that the phototube will receive light of constant intensity when the spot is in direct view, but the intensity of this light will momentarily drop each time the spot travels behind the calibration marks and the meter pointer. At the output of the phototube, the amplitude of the signal voltage generated varies in perfect synchronism with the variations in light intensity. In general, no optical system of lenses is required with this type of scanning.

Figure 3 is a photograph of the signal

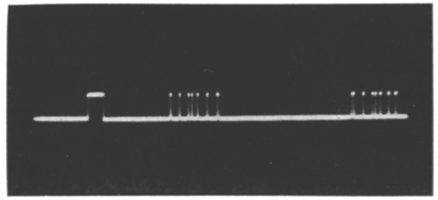


Figure 3. The large reference pip identifies left- and right-hand meters; the pointers appear between the graduations.

voltage developed as displayed in a conventional manner on a cathode-ray tube. The phototube circuit and its associated amplifier were arranged to produce positive pulses for decreases in light intensity. The broad pip is a reference mark used to identify the meters and to provide a well-defined synchronizing pulse at the receiving indicator.

If the pulse signal is connected to the control grid of a second cathode-ray tube so arranged that the cathode-ray spot is also sweeping a circle on the screen of the tube, the brightness of this circle can be caused to either increase or decrease depending on the polarity of the pulses. In view of the fact that the spots on the two cathode-ray tubes are travelling around in synchronism, the receiving cathode-ray tube will repro-

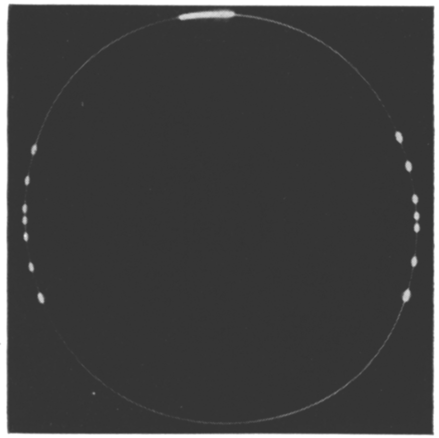


Figure 4. In this circular trace the reference marker (top), meter graduations and pointer positions appear as bright spots.

duce a true image of the light trace picked up by the phototube. It has been found more desirable to reproduce a negative of the transmitted picture as shown in Figure 4. The bright spots in this photograph correspond to the decreases in brightness picked up by the phototube. The reference marker and the pointer positions are clearly indicated in their correct relative positions in this figure.

The telemetering system which was constructed to investigate the above basic principles is shown in block diagram form in Figure 5. The phototube employed is a 931-A electron-multiplier tube followed by a conventional two-tube amplifier connected to the receiving cathode-ray tube through a shielded cable. The circular sweep voltage is obtained directly from the 60-cycle power line through a low-voltage transformer connected to a resistor-capacitor quadrature circuit.

Although only two meters were employed in this particular system, it is clear that a large number of meters can be grouped on the face of the transmitting cathode-ray tube. Moreover, these meters need not be of the electric type, but may be pressure indicators, temperature indicators, etc.

The telemetering system shown in Figure 5 is basically a single-line-scan television system. This fact is brought out quite clearly if the amplitude of the circular sweep voltages at the transmitting and receiving ends are synchronously modulated, or varied, in amplitude. This will cause the radii of the circular traces to vary continuously between predetermined limits and sweep tight spirals on the screens of the cathode-ray tubes. The image reproduced at the receiving end is then a complete shadow image of the meter calibrations and pointers. This type of presentation is shown in the cover photograph. Although the aesthetic quality of this image is better than that of Figure 4, the latter image contains all of the information required to obtain the meter readings.

The signal generated by this telemetering system is of the pulse-position-modulation type employing time-division multiplexing. That is, the pulse generated by each individual meter pointer is varied in position with respect to a calibration reference mark, and each of the separate meter readings is transmitted sequentially in time. This type of signal can be made highly immune to interfering noise voltages by employing a process known as full-wave signal clipping. In fact, the pulses shown in expanded form in Figure 6 were originally triangular in shape, and both the peaks and the base line were "sliced off" electronically to remove noise voltages generated by the phototube.

The type of image presentation shown in Figure 4 reveals all of the meter readings in their proper positions with respect to the reference marker at the top of the image. This is generally satisfactory for the rapid observation of all the meter indications. For increased accuracy of reading, a section of

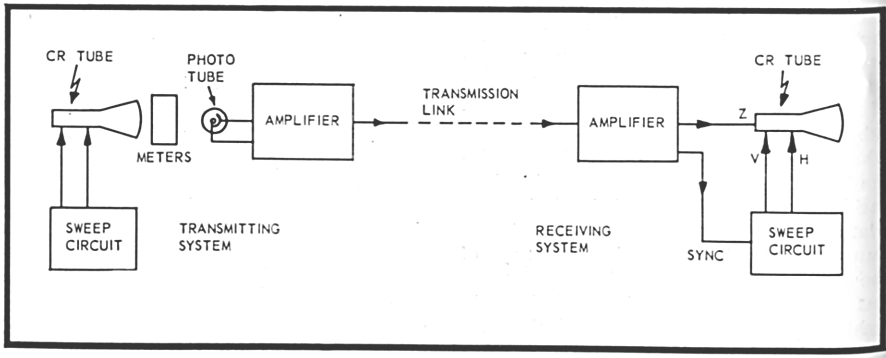


Figure 5. Schematic diagram of Georgia Tech's television telemeter. In practice, the signal could be carried along with a standard FM broadcast.

the trace may be expanded so that one meter scale occupies the full diameter of the screen. A further expansion of the trace will produce a magnified image showing the meter pointer between two scale calibration marks.

Although it is very convenient to use circular oscilloscope traces, other types of traces particularly suited to different meter groupings may be employed. For example, a trace consisting of several horizontal lines provides space for many meters to be grouped on the screen of a large rectangular cathode-ray tube.

For a given system, the bandwidth required to transmit the triangular telemetering pulses is determined by the scanning frequency and the size of the scanning spot at the transmitting end. If a scanning, or sampling, rate of one cycle per second is adequate, a long-persistence cathode-ray tube may be employed at the receiver to reduce flicker. The necessary bandwidth will then be approximately 1000 cycles for acceptable reproduction. Greater scanning rates require correspondingly greater bandwidths.

The problems of stability, resolution of detail and accuracy of reading are identical to the similar problems in television, radar and loran. Suffice it to say that great accuracy is available if complexity of associated equipment can be tolerated. However, this telemetering system becomes less attractive as more refinements are added.

Conclusions

Since the telemetering system described herein is fundamentally a single-line-scan television system, all scanning and reproducing arrangements employed in television and facsimile systems are directly applicable. It is obvious that simple devices like the Nipkow scanning disc may be employed for pick-up or for reproduction. Electronic scanning may be employed with mechanical recording, or vice versa. The received signal may be recorded on a magnetic tape recorder, or a facsimile recorder or on a Morse code recorder. Moreover, it is possible to use a flying-spot scanning arrangement in which the light from the cathode-ray tube is focused on a standard meter dial and the resultant reflected light is picked up by the phototube. This latter arrangement, of course, necessitates the use of lenses.

It is believed that the Station-developed telemetering system offers the features of simplicity, flexibility and reliability in applications where it is desired to transmit several meter readings for direct instantaneous viewing. Now that any seven-year-old child can be taught to operate a television receiver, it is believed that inexperienced personnel can easily adjust and use a telemetering system employing cathode-ray tubes.

A typical potential application of this telemetering system is to permit a control operator at the studio of a radio broadcasting station to read the meters of an unattended frequency-modulation transmitter on a mountain peak. A conventional form of telemetering has already been tried experimentally for such use.

There are many potential applications of this telemetering system. For example, on a steamship important indications of engine speed, temperature, etc., could be conveniently presented on the bridge as well as in the chief engineer's and the captain's quarters for immediate observation.

Another unexploited application is in connection with FM radio broadcasting installations at points remote from the studio such as Georgia Tech's station WGST-FM which is on top of Burnt Mountain, 50

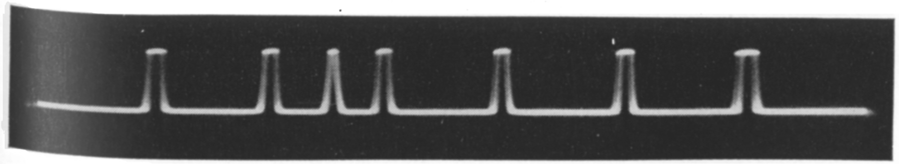


Figure 6. Expanded trace of a televised meter reading showing the pointer between the second and third graduations (reading left to right).

miles north of Atlanta. Due to the expense of keeping a crew of radio operators at this remote point and the difficulty of driving up the mountain during winter snows, WGST is considering operating the station by electronic control from the studios in Atlanta. Such remote operation would necessitate the telemetering of three measurements. The Federal Communications Commission requires that meter readings of power input to the transmitter, antenna current and frequency be taken every half hour.

A conventional form of telemetering has already been tried experimentally by one FM station for such use. However, this installation permitted only one meter reading at a time to be recorded at the control studio, because it required a switching signal to be transmitted over a microwave link in order to switch the metering circuits at the transmitter.

The single-line-scan telemetering system would make it possible for the maintenance man and the chief engineer to have a simple telemetering indicator connected to their FM receivers in their homes for the continuous monitoring of the important meter indications. The telemetering signals would modulate an inaudible sub-carrier transmitted simultaneously with the musical programs on the FM broadcasting station.

Numerous additional applications of the Station-developed telemetering system will no doubt arise in the mind of the reader.

COMPUTERS

Continued from Page 6

gan, our Armed Services personnel in that area was considerable, yet the number of men that could be put in the field to fight was pitifully small. Even now, with full-scale forces in Korea, the men actually fighting are outnumbered by the officers, men and clerks required to maintain and control them.

High-Speed Computing Machines

Before discussing how computing machines might serve the Armed Services, we should consider briefly the capabilities and limitations of existing models. Today's high-speed computers fall into one of two classes—the analogue computers or the digital computers.

As their name implies, the analogue computers solve a problem by setting up a physical analogy of that problem rather than by direct mathematical solution. The familiar Wheatstone bridge might be considered an exceedingly simple analogue computer, since it can be used to determine an unknown resistance by setting up an electrical balance with known resistances. If one wished, he could set up a complex network of Wheatstone bridges to represent the known and unknown factors in some physical problem, such as a study of fluid flow, and then, by balancing the electrical system, determine the values of the unknown physical factors by analogy. This is the basic principle of network calculators, such as that at Georgia Tech, which enable electrical power companies to determine the effects of changes and extensions in their transmission systems. A direct-current network calculator reportedly is now in use by the Institute of Gas Technology to solve the transmission and distribution problems of gas companies, enabling them to determine the optimum size of pipelines and gas mains, transmission and distribution pressures, etc.

Because they depend upon setting up a balanced relationship between knowns and unknowns, analogue computers can give only an approximate answer. However, the approximation can be made so close that, to all intents and purposes, it represents the desired solution. The differential analyzer built at Massachusetts Institute of Technology in 1942 works complicated problems in calculus. The "Typhoon," a large machine recently built by RCA, simulates the flight performance of guided missiles. Today's gun computers are of the analogue type. Such computers are used not only to control guns but also to pilot airplanes, to steer guided missiles and to perform other complicated control functions. However, despite their great usefulness, analogue computers lack the versatility needed to handle many general staff problems.

Fortunately, digital computers are as versatile as mathematics itself. With their complex array of electron tubes, memory banks, sensing and correcting devices, etc., they are much more than high-speed counting machines. A digital computer can control itself to follow detailed instructions in carrying out involved calculations.

To date, digital computers have been used primarily as high-speed mathematicians, performing in hours or days series of calculations that would require months or years of a man's time. However, these machines are capable of a much greater variety of work. They have been used for mechanized inventory control, to control milling machines and to prepare operating reports for large business enterprises. Digital computers are even being developed as translating machines.

Thus, the term "computer" is inadequate to describe the digital machines. A better name for them might be "information machines," since they can take raw information, process it in accordance with established logical rules and produce consolidated information for guidance and control. They can calculate their own criteria, make comparisons and exercise "judgment." In a sense, they can "think." Some of the advanced digital machines can handle very complicated problems involving mathematics, logic and probabilities more rapidly, more reliably and more economically than can human minds—and with apparently equal ingenuity.

Characteristics of Information

Since information is both the raw material and the product of computing machines, to understand them, we should know something of the characteristics of information. This is an elusive subject, and theories concerning it are still in a quite formative stage. Recent communication theory has demonstrated that information can be measured and treated mathematically.

Information appears to display the properties of entropy which, in thermodynamics, gives a measure of unavailable energy. In statistical physics, entropy is related to the number of alternatives that remain possible to a physical system after all of the macroscopically observable data have been recorded. In communication theory, the properties of entropy are introduced by the fact that the amount of information conveyed by a message is determined by the amount of choice available to the sender in formulating it. If the sender has no choice, that is, if the receiver knows what the message will be before he gets it, no information is conveyed.

If the sender has a choice between two messages, one "bit" of information is conveyed. It matters not what the two messages are. They may be 0 and 1 of the binary scale; the famous "One if by land, two if by sea" that started Paul Revere on his ride; or any other two messages. The length of the two messages is immaterial—one could be "no" and the other could be an operational plan the size of an encyclopedia. However, if the sender has only one choice between messages, his message conveys only a single bit of information. If there are many choices, the amount of information, measured in bits, is the logarithm on the base 2 of the available choices. This is a typical entropy formula.

In any physical system, information is never available without some distortion and error known as "noise." In telephony, it is low fidelity; in radio, it is static; in television, it is "snow"; in language, it is semantic disagreement. To convey information and accomplish the desired result in spite of noise is a problem.

Determining the best means of coding information so that the maximum amount can be handled by existing channels and so that the effects of noise are minimized also poses problems. Studies are needed to determine more clearly what happens when the information supplied exceeds the capacity of the channels to handle it.

At some stage, much of the information for control of the Armed Forces must be in the form of written English. Therefore, computing machines for general staff use should be able to write. If we regard writers as geniuses inspired by the Muses, a machine that writes seems unbelievable. However, most writing is certainly not the work of geniuses. Is it not, for the most part, simply the rewording, according to fixed rules, of what has been written down before? Is it not, for the most part, primaily mechanical, i.e., performed by rote.

Information from a mass spectrometer has already been translated into readable language by the "Charactron." It is a kind of electronic picture tube that employs an inch-square, very thin copper matrix with stencil-like character openings to shape an electron beam into letters. The picture on the screen can be put into printed form by Xerography, a new type of reproduction that uses dry materials instead of wet chemicals for developing. The printing equipment, mounted in front of the screen, turns out printed copy as the image appears on the screen. The combination of mass spectrometer, electronic computer and translating tube reportedly enables Atlantic Refining Company to make complete molecular analyses of hydrocarbon mixtures in ten minutes.

It seems likely that some highly refined approach to the problem will eventually result in a machine that can convey its information in passably well-written English messages of whatever length required. Such a machine could greatly lighten the paper-work problems of our Armed Forces.

The Paper-Work Problem

Let's look at the Armed Forces' paper-work problem and how it has grown over the years to its present awesome proportions.

The fighting forces of the Thirty Years' War had practically no staffs and very little paper work. Prior to the Seventeenth Century, military affairs were handled almost exclusively by fighting men. Then under the great planners, Richelieu, Louvois and Vauban, civilian administration was introduced, bringing increased central control and consequent improvements in organization and discipline.

As the magnitude and complexity of military operations have grown, so have grown the armies of clerks, the printing and mimeographing establishments, the regulations, correspondence, reports, paper work and "red tape." The great variety of weapons, including guided missiles and atom bombs, the expansion of sea power and the introduction of air power, the vast forces involved in vast areas and the ramifications of economic and psychological warfare all make the problems of Twentieth Century war too complex for an individual human mind to handle. Large staffs have become a necessity.

Unfortunately, the inevitable result of large staffs is red tape. Any officer who has tangled with red tape, and all have, will welcome any hope of liberation. One frequently mentioned Army shoulder patch is described as a blue general in a fog, completely surrounded by red tape. This description is not entirely facetious. A Seventeenth Century captain of the gendarmerie, though his weapons were ludicrous by our standards, was a grander, freer person than a modern-day Army post commander who is burdened with reports and bound by regulations.

The regulations, directives and guides problem of the Armed Forces stems from the necessity for translating the will of the nation and the strategy of the planners into action by the personnel. The will of the nation is expressed through laws by Congress, orders by the Executive Branch and decisions by the Courts. It is intricate, with many conflicts and compromises. Today's war plans are extremely involved. The task of formulating directives is broken down and divided among various staff sections in an effort to put a number of minds to work on the problem. This necessitates regulations to regulate the making of regulations.

Directives and guides are issued from the top down through the various echelons of command, with each adding explanations and additional directives. This is necessary because the human minds at the top cannot visualize all the ramifications of their directives and anticipate all of the questions that will arise. However, the net result is that those at the bottom, who must do the work, are buried under a mass of regulations and guides. For example, a recent Department of the Army letter to re-emphasize cost consciousness invited attention to a message from the Secretary of the Army, two Army Regulations, a Vice Chief of Staff letter, a Deputy Chief of Staff memorandum, two Department of the Army pamphlets, two Department of the Army circulars, three Department of the Army letters, a technical bulletin, two Chief of Army Field Forces

letters, an Armed Forces Talk, an Officers Call Talk and, finally, a "Management Improvement Material Packet."

In addition, inspections are necessary to determine compliance with regulations. These inspections are reported, and correspondence regarding the reports develops. More paper work.

Time consuming as it is, Armed Forces paper work is not the principal area in which computing machines could serve the military. As mentioned, the primary job of the general staffs is keeping inventory of the means for waging war. Whether the Armed Forces are fighting a total war, are preparing for the defense of the nation in the event of war or are engaged in an intermediate stage, as today, the staffs have a vast, highly complicated problem of inventory control.

Can Computing Machines Help?

In attempting to determine whether computing machines can help lighten the prodigious load of the Armed Forces' general staffs, first let us see what they might do with the paper-work problem.

While its development would be by no means simple, it seems likely that a machine could be devised to translate verbose English into a logical code, to analyze written messages for their meanings, to summarize, to compare, to pass judgment and to write the results in concise English. Such a machine could be given the herculean task of clarifying the existing mass of regulations, directives and guides.

In legal matters, it is customary to speak of "the intent of the law." In the same sense, there is an over-all intent in the Armed Forces' directives. However, they are so voluminous that they conflict with one another and their intent is largely obscured.

The computing machine would analyze existing directives and guides for their over-all intent, eliminate conflicts and inconsistencies, complete deficiencies and produce a revised body of regulations. The machine would determine what regulations and guides are needed by the various echelons and classes of personnel, and it would write special ones for each group. These regulations would be so formulated that the lowest echelon, which has the most work, would be burdened with the minimum of regulations. The higher echelons, with broader responsibilities and larger staffs, would be provided with the additional regulations they require. The pyramid would be reversed, with the least regulations at the bottom and the accumulation of regulations at the top. The staffs of the higher echelons would be provided with computing machines to keep track of the regulations, so that, at every level, individual minds would no longer be crowded with more regulations than they can assimilate. This would make unnecessary the large volume of paper work that emphasizes and re-emphasizes existing regulations.

Besides rewriting regulations, computing machines might handle many other tasks faster, better and with fewer people. They could write specifications, contracts and most correspondence. However, their principal job would be inventory control.

Inventory machines recently developed are taking their places in business and military establishments. So far, these machines are dealing only with the simpler forms of the problem. They keep track of stocks, subtract items as they are withdrawn and, when stocks are reduced to established levels, automatically signal for their replenishment. In addition, the military maintains tabulating-machine reports of items of materiel as compared with authorized quotas.

This is only a small beginning. To approach a solution of the over-all problem of the general staffs, all items of materiel should be covered. The factors of personnel, training and morale would have to be added. Perishability, training obsolescence, wear and tear, expected life, repairs and maintenance are all factors to be considered. The probabilities of various needs produced by the various possibilities of war must be weighed.

Consider the factor of morale. Perhaps no single factor is as important to a fighting unit. While battles can be lost for the want of proper materiel at the right time, an army can have all the materiel it needs and still go down in defeat if its morale is low. How much of a factor morale was in the speedy defeat of the French and the stubborn resistance of the British may never be fully known. Certainly Spitfires, the English Channel and radar proved a better defense than the vaunted Maginot Line. However, the morale of the governments and the people also seems to have been markedly different.

Considerable money is spent on morale, but it is difficult to buy. Much materiel of war was given to the Chinese, but their morale, in general, deteriorated. As a result, not only the equipment but most of the soldiers, themselves, have been turned against us.

Instances of victory won on morale alone are rife in the annals of American history. Take the morning of October 25, 1944, for example. The U. S. Third Fleet had been drawn out of position by a Japanese feint from the mainland. MacArthur's landing on the Philippines was exposed to a powerful Japanese battleship fleet steaming south unopposed except for an insignificant anti-submarine force of "baby carriers" and destroyer escorts. Ships of other navies, when faced with similar odds, have often run. The men in the American ships attacked, fought and died. The little fleet was virtually destroyed. But it fought to the last with such courage and ferocity that the Japanese thought they had tangled with the powerful Third Fleet. With victory in its hands, the Japanese fleet turned and ran. The Philippine landing was saved—a victory of American morale. Whatever this morale cost in terms of mail service, ice-cream machines, movies on the hangar decks, U. S. O. shows, beach parties with cans of beer and the like was money well spent.

Yet, money spent for morale building cannot purchase guns. Too much ice cream and too few weapons can lose the battle, just as plenty of guns and no morale can. The problem is to maintain a proper balance. Could computing machines help? Can morale be measured?

Perhaps morale cannot be measured, but it certainly can be indicated. Much data now being collected indicate the state of morale. For example, various reports show AWOL rates, arrests, trials, VD cases, property losses, complaints, suggestions, study courses being taken, sales of savings bonds and re-enlistments. However, for the most part, these data are served up raw. It is like giving a businessman a mile or so of ticker tape instead of the Dow-Jones averages. Better indices are needed—indices for the state of morale, proficiency in training, materiel condition, probability of victory, etc. Also needed are measures of the probable error in any indices developed.

Practically speaking, the needed indices are not available manually. However, computing machines, which are ideally suited to making statistical calculations, could readily calculate them. After a period of trial and adjustment, these indices could give a much clearer picture of the Armed Forces' progress in attaining their objectives.

Let's consider a case where an index could have decided a decision that, without one, had to be arbitrary. The staff of an Army commander recently set aside a sum for air-conditioning a dozen theaters. The suggestion was immediately made to air-condition service clubs instead. There was no morale index to say, "At Location X the service club was air-conditioned and the index of morale rose two points, while at Location Y the theater was air-conditioned and morale rose five points. Therefore, air-conditioning of theaters appears to be the best buy."

Since some decision had to be made, it was decided to air-condition the theaters. This decision raised the question of how much air-conditioning. Minimum installations would have cost the equivalent of 2,000 M-1 rifles; standard installations, 3,000 rifles; and deluxe installations, 4,500 rifles. Here again, no indices of comparative value were available, and the middle road was arbitrarily chosen.

Decisions such as the above are part of the day's work of a staff officer. Many of them are routine, but many are also relatively important to the over-all objectives. If computing machines can help make better decisions, shouldn't increased use be made of them? Their application to the more important decisions facing our general staffs may greatly increase our chances for victory. In the future, ultimate victory may go to the forces that make the best use of computing machines.

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Editor's Note: The author, a 1932 graduate of Georgia Tech, is now studying as a special student in the Graduate Division, his field of specialization being automatic computation and control. Besides being a professional engineer, and having studied also at Massachusetts Institute of Technology, he is a Commander in the Naval Reserve and, during World War II, commanded a division of 1,200-ton destroyers. He has asked that the following statement be appended to his article. "The opinions expressed herein are solely those of the author and are not to be construed as reflecting the views of the military services."

OUR STAKE IN RESEARCH

Continued from Page 2

half of the nation's working population earns its living producing things unknown fifty years ago.

In considering how research has benefited the average man, we can say it has given him a longer life, a healthier life, a greater range of job opportunities and more leisure time. Also, some of the products of research have made leisure time more enjoyable. Travel can be accomplished by private car, busses, speedy trains, ships or airplanes. Or far-away sights and events can be viewed on moving picture or television screens. Material developments though they are, radio and television can bring us the inspiration of a great preacher, a fine composer or a talented playwright.

When we realize that research has already brought us a longer, more bountiful life, we can readily perceive the advantage of continuing and extending our research efforts. Commercial enterprises may be expected to exert their utmost efforts to develop new products, since therein lie profits. However, we must not rely upon them exclusively for all of our research. In general, commercial enterprises are more interested in immediate salable applications than in basic contributions to scientific knowledge. Yet it is to new fundamental discoveries that we must look for continued progress toward longer life and better living. The sulfa drugs, antibiotics, X-rays, electronics, etc., stemmed primarily from pure research —the search for knowledge without particular regard to specific use. Moreover, many of today's products of research took years of patient applied research before their potentialities intrigued large companies to invest substantially in their further development, manufacture and sale.

Much, if not most, of today's pure research is conducted in our institutions of higher learning, and an increasing amount of applied research is being done in their experiment stations and research foundations, close to the pure research fountainhead. Many of these institutions, Georgia Tech for one, utilize their own funds to finance more basic research.

Research-conducting universities contribute more than the sum total of tangible results from their pure and applied research. They also provide an atmosphere in which students' minds are inculcated with the spirit and methods of research at the same time they are educated in the existing knowledge of science. Thus. on-campus research produces not only new discoveries but new researchers.

Knowing all this, progressive educators have fostered the growth of research on their campuses. Here at Georgia Tech, the Engineering Experiment Station is prepared to undertake research and development programs for any organization or individual whose problem is of scientific importance and involves work likely to advance the educational objectives of the Georgia Institute of Technology. It also undertakes programs of pure research and applied research on problems too broad for consideration by a single company. All this work combines to give the well-rounded research program needed to stimulate the minds of student and teacher alike.

Harking back to the title of this editorial, "Our Stake in Research," it is intentionally ambiguous. It could read "The Average Man's Stake in Research," or it might read "Georgia Tech's Stake in Research." As a non-profit institution, Georgia Tech's ends are those of the people. Within the limits of available funds and the fields of its competence, it will continue its efforts to bring the fruits of technological progress to our state and nation.

PRESIDENT'S STATEMENT

Continued from Page 2

These figures should give us fair warning that we can, through inaction, lose the technical manpower advantage we have long relied upon to balance Russia's great advantage in controlled populations. The value of advanced degrees in research work has been proved beyond question. What we sorely need are many more fellowships, adequate in stipend, to insure that all our potentially able students continue their studies to the highest degrees they can attain. Patriotic individuals and enterprises, recognizing the importance of such action to our national security, are beginning to provide such fellowships. Industrial companies now have established fourteen graduate fellowships at Georgia Tech. Many more—in fact, at least 200 more—are needed.

BLAKE R. VAN LEER

President, Georgia Institute of Technology

NEW ACTING HEAD CHEMICAL SCIENCES DIVISION

Dr. Frederick Bellinger has been appointed Acting Head of the Station's Chemical Sciences Division to succeed Dr. Herschel H. Cudd who recently became Acting Director of the Engineering Experiment Station.

Dr. Bellinger's education and professional experience constitute fine qualifications for his new position. He received his B.S. in Engineering Chemistry from Georgia Tech in 1926, an M.S. in Chemistry from Emory University in 1935 and the degree of Doctor of Engineering from Yale University in 1940. He also has taken graduate courses in the night schools of the University of Maryland, Brooklyn Polytechnic Institute and Johns-Hopkins University.

Dr. Bellinger's professional experience includes service in industrial companies, educational institutions, government departments and military establishments. From 1926 to 1928 he worked for the Chemical Warfare Service on the design and operation of chemical plants. He then joined Roessler and Hasslacher Chemical Company where he served in the Development Department and in development of a peroxygen plant process until 1932. In 1933 he joined an Atlanta firm of construction engineers to do design work on the production of sweet-potato starch. During 1934 he served as chief computer and chief of party for an aerial mapping project of Georgia conducted for the U. S. Geologic Survey.

In 1935 Dr. Bellinger joined the faculty of Yale University where he taught chemical engineering subjects until 1937. Next he worked on the development of cellulosic plastics for Hercules Powder Company until 1940. In the period 1940-42, he served first as Senior and Principal Chemical Engineer for the Chemical Warfare Service at Edgewood, Maryland, then as Chief Chemical Engineer at Huntsville Arsenal, Alabama.

During the war years, Dr. Bellinger served as a Lieutenant Colonel in the Chemical Corps both at Huntsville and in Washington on development and production of chemical warfare agents, smokes and charcoals. He came to Georgia Tech in 1945 as an Associate Professor of Chemical Engineering and was appointed a Professor of Chemical Engineering in 1948. Until he took leave from Tech in 1950 to serve again with the Chemical Corps, Dr. Bellinger also directed several Station research projects. In 1952, he was relieved from duties as Chief of the Plants Division of the Chemical and Radiological Laboratories, Army Chemical Center, Maryland, to return to Georgia Tech.

Dr. Bellinger is the author of numerous papers and articles on the design and operation of chemical-plant equipment, on chemical propellents such as hydrogen peroxide, fuming nitric acid, etc., and on the preservation of food by freezing.