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SIMULATION AND DISPLAY OF FOUR INTER-RELATED VEHICULAR TRAFFIC INTERSECTIONS

by

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INTRODUCTION

In this paper we are concerned with the development of a computational tool to aid the vehicular traffic engineer in the solution of some of his problems. In particular, we are concerned with the problems of the urban traffic engineer. Investigation of the state of the art in traffic engineering quickly leads to the conclusion that the practitioner is able to handle single intersections with a reasonable assurance of success. However, if he is concerned with the relationship among two or more intersections in an urban area (or a rural area, for that matter) he is without an adequate tool for the solution of the problem.

This paper is the second of a series which will be associated with the development of a computer model for urban traffic engineering. The first paper was Reference 1. Other attempts at the creation of such models are contained in References 2-5.

The steps in the creation of the computational tool with which we are concerned should run as follows:

1. Development of a "reasonable" mathematical model of a single intersection, programming of the model for a digital computer, and subsequent runs on a computer to test it for consistency.

2. Development of a four intersection model to introduce the first complications of multiple intersections, programming and subsequent running on a digital computer to check out its consistency.

3. The creation of a more complex and perhaps more realistic model still with four intersections but with a multiplicity of lanes, varied types of traffic, etc., as complications.

4. The design of an experiment in connection with real traffic to measure the parameters governing some specific traffic situation.

5. The comparison of the results of this experiment with similar efforts applied to a computer model.

6. If the experimental results do not agree with those of the computer model, the necessary modifications to the computer model and repetition of experiment until a check is obtained.

7. A change in the computer model with a consequent prediction of outcome for real traffic.

8. An experiment to test the validity of the prediction.

With the accomplishment of these steps, a useful version of a computational tool for traffic engineering will have evolved. This paper is concerned with step 2. The results in the case of step 2 will be gone into after a summary of step 1 has been given.

Summary of the One Intersection Case and Results

In Reference 1, the fundamental unit in terms of an intersection for simulation was chosen. It consisted of a single intersection and the lanes approaching it. Such a combination was called a cross block and is illustrated in Figures 1 and 2. The cross block can be considered a building block from which the network of streets of a city can, in many cases, be constructed. A simple combination of two cross blocks is shown in Figure 3.

After the general characteristics of the cross block had been de-

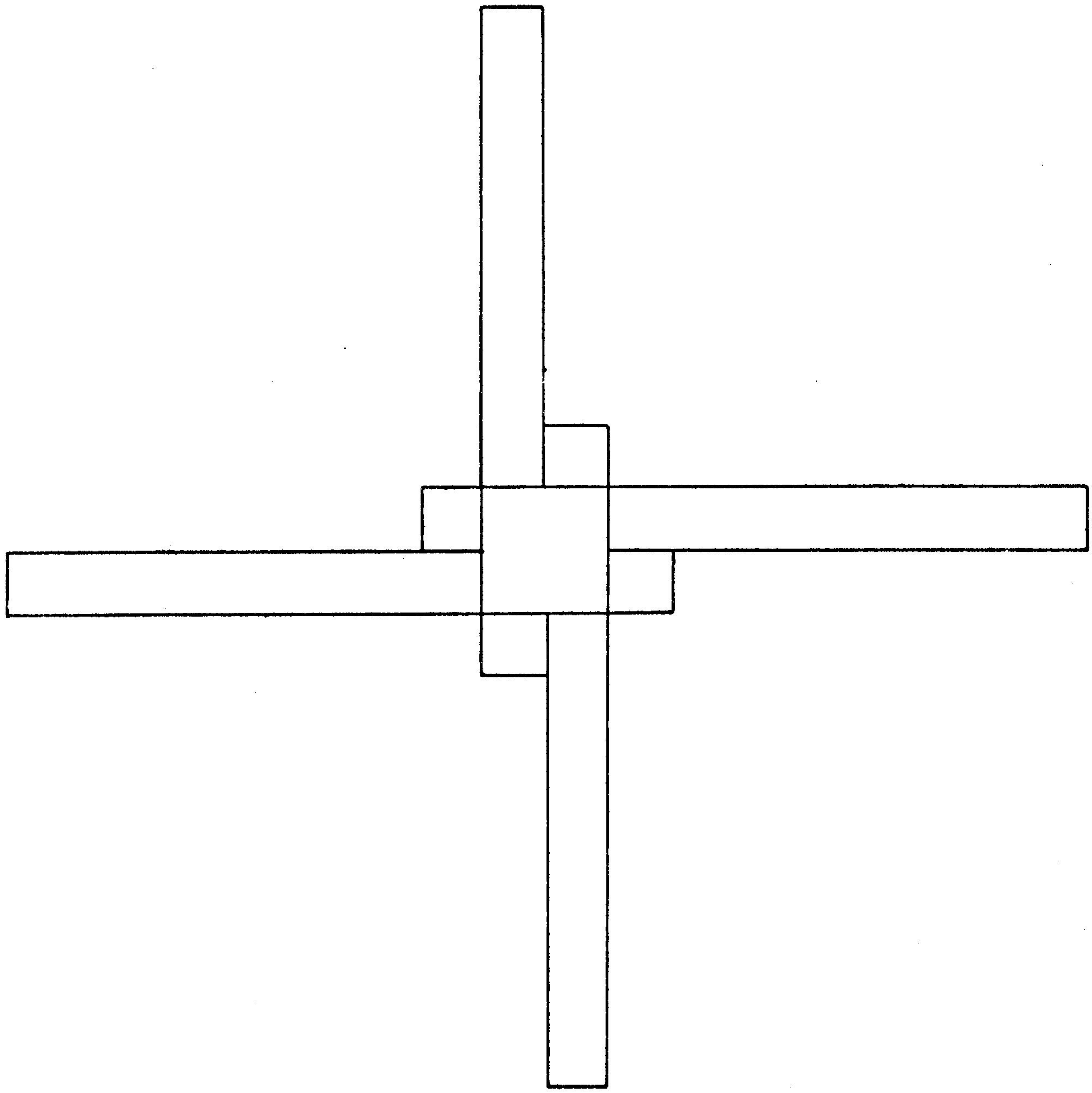

FIG. 1

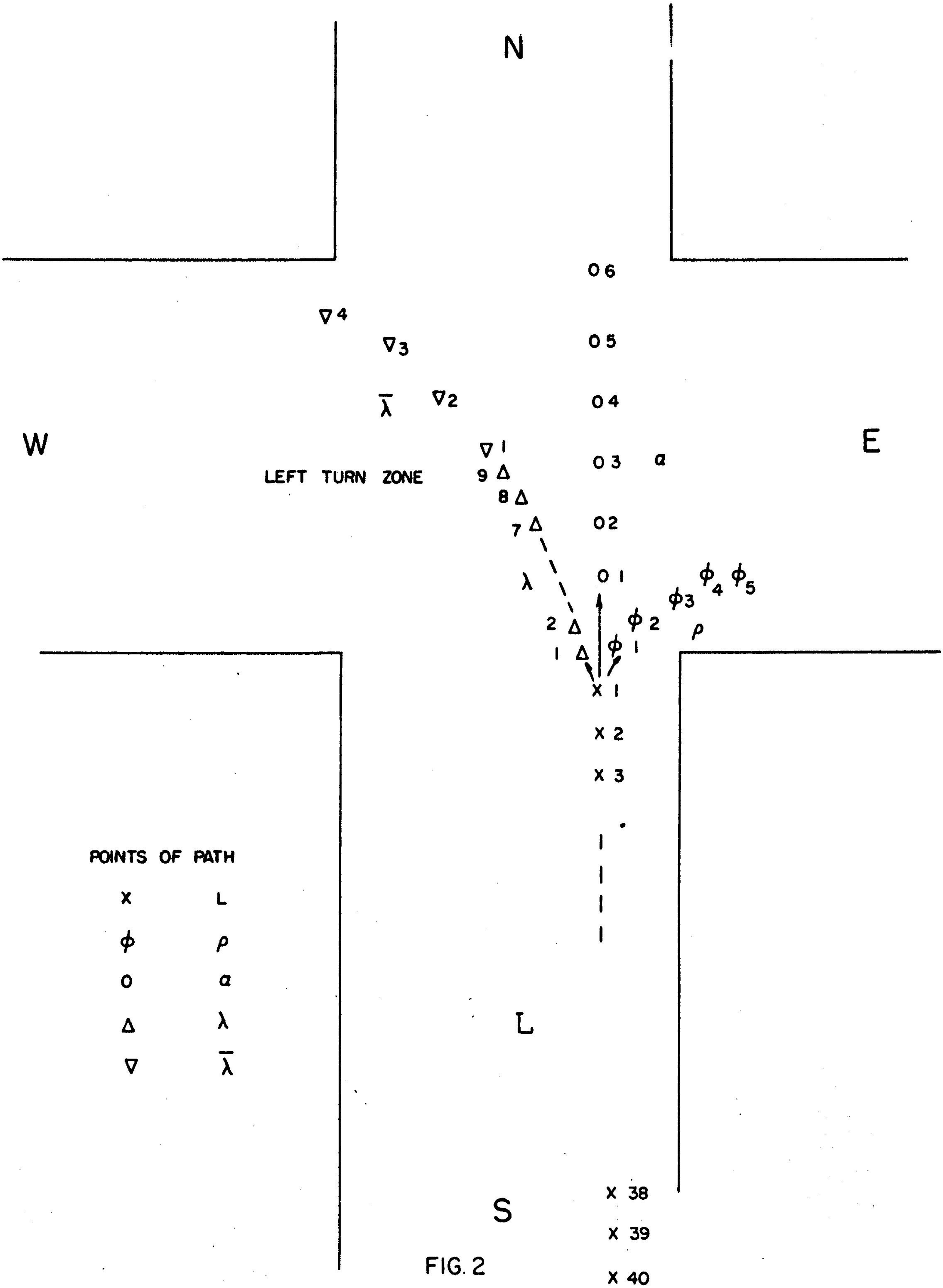
N
W
E
S
L
LEFT TURN ZONE
POINTS OF PATH
X L
ϕ ρ
O a
Δ λ
∇ λ̄
X 1
X 2
X 3
X 38
X 39
X 40

FIG. 2

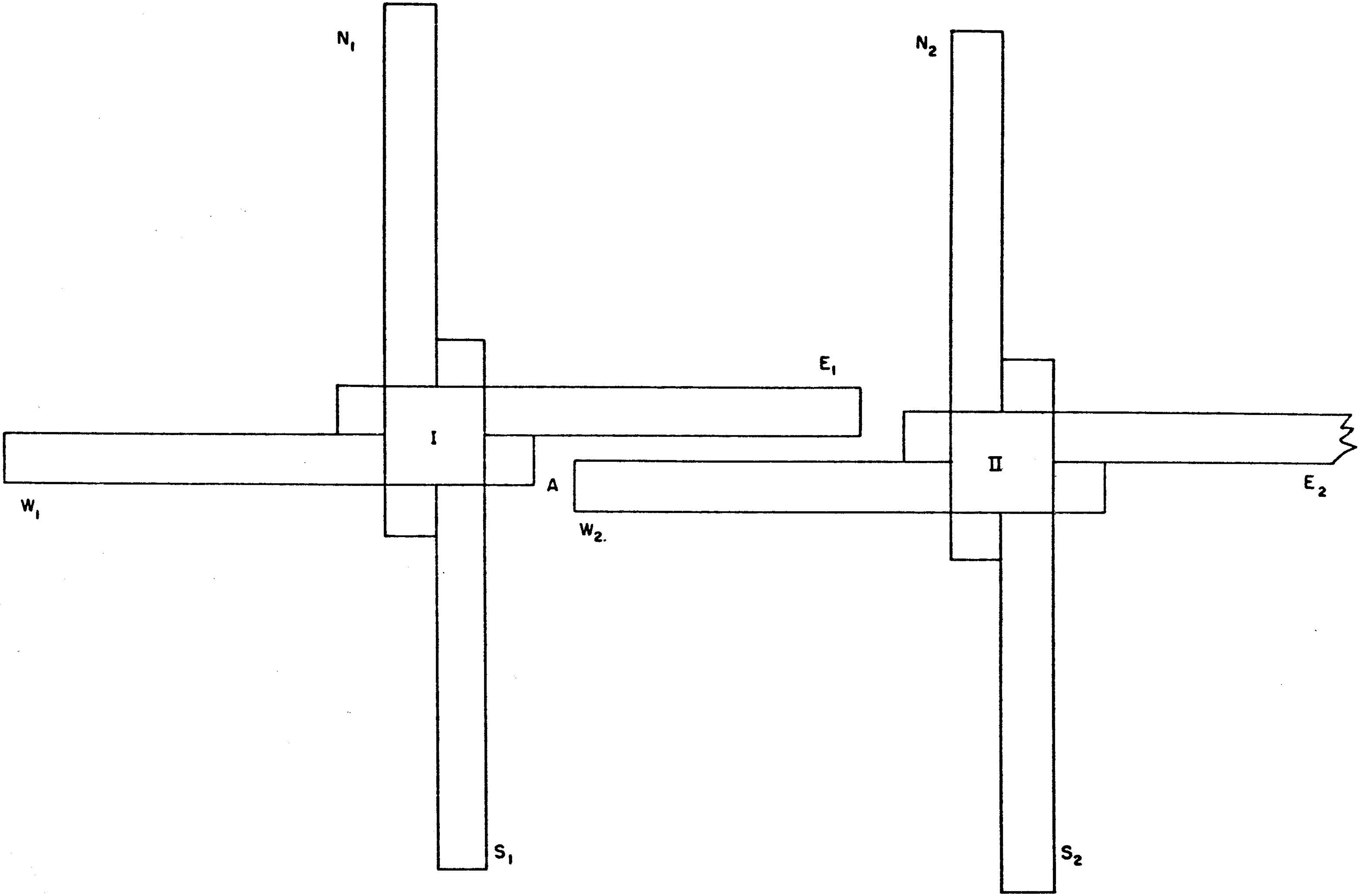

FIG. 3

cided upon, a method was devised for representing the position of every car in the cross block at any particular instant of time. This was extended, in the light of the operations available on the digital computer being used, to a method for simulating traffic flow. The method required the computer to determine the motion of, and to move, each car in the cross block individually.

Once the over-all picture had been sketched, the detailed development of the rules according to which the computer determines the movement of the cars, their introduction into the lanes, and so on, were developed. The formulation of these rules concluded the first phase in the construction of the computer model. The final phase was the writing of the computer program to realize the model on the computer and its subsequent execution in terms of computer runs.

Characteristics of the Cross Block for the Single Intersection

For the single intersection, the cross block was assumed to have streets twenty-two feet wide, and lanes in the neighborhood of four hundred feet long. The vehicles travelling through it were assumed to average eighteen feet in length, being in any case more than eleven feet and less than twenty-two feet long. They travelled in the lanes at thirty miles per hour when not obstructed, passed through the intersection under the control of a three-phase traffic light, and turned right, left, or went straight ahead according to the "desires of the driver" which were embodied in a random mechanism. The position of a car in the block was given by the position of the mid-point of the front bumper. To avoid complications, cars were not allowed to pass one another, and interference from parked cars and pedestrians was assumed to be negligible.

The two-dimensional strip was idealized to a line and the position of the car in the lane to a corresponding point on the line. A lane was then a sequence of forty points in which a car jumped from point to point.

In this model, there were four lanes. With each lane were associated four segments of paths lying within the intersection, one traversed by right turning cars, one by cars going straight, and two traversed in succession by cars turning left. These paths were called ρ, α, λ and $\bar{\lambda}$, respectively. The paths, also, were considered to be a set of points and are shown for a single lane in Figure 2. The end point of λ (point 9) is of special importance and is called the left turn zone.

Cars moved down the idealized lanes and paths by jumping from one point to the next. When a car was moved, it jumped, and thereby covered the distance between two adjacent points, every quarter second.

In the computer, each lane was represented by a register. The points of the lane, or intersection path, were associated one-to-one with digit positions in the corresponding registers. To represent the distribution of cars in the model at a particular instant of time, it was only necessary to specify the presence or absence of a car for each point of the model. This was done by having ones in the digit position corresponding to points at which there was a car, and zeros otherwise. The computer simulated the flow of traffic by constructing a sequence of car distributions for successive moments of time. To move a car from one point to the next, the digit concerned was extracted to determine whether a car was present; if one was present, then the set of logical rules governing its position were examined; and then steps were taken to move the car according to its position in the scheme of things.

It is necessary to specify the rules governing the construction of a car distribution. To do this procedures were employed for entering cars in the lanes, for determining the direction of cars entering the intersection, for cycling the traffic signal, and for taking account of traffic conditions. All of this follows:

Cars enter the four lanes at point forty (Figure 2). They are generated by a process making use of psuedo-random numbers. At the end of each quarter second interval, a random number sub-routine generates a number between 0 and 1 for lane S, say. This number is then compared to the number m. If it is less than m, a car is generated for lane S. If it is greater than m, no car is generated. Thus by changing the value of m, the average number of cars per hour entering the lane can be controlled. The resulting distribution approximates the Poisson.

In order to avoid piling cars on top of one another, which would occur whenever cars are generated at successive quarter second intervals, cars are first put in a register known as the backlog. In this register, cars are merely counted and not put in relative positions. The contents of the register indicate the number of cars waiting to enter the lane at a point remote from the lane. As space becomes available, cars are moved from the backlog into the lane S. Similar procedures are carried out for the other three lanes

When cars leave the end-point of a path in the intersection, they are dropped from consideration in the single intersection model.

At an actual intersection, an observer of traffic cannot tell which way a particular car will turn. However, he may know the probabilities for a right turn, left turn, or for going straight ahead. This characteristic of traffic is simulated by associating a turn register with each lane. It can be thought of as representing the turn indicator of the car nearest the intersection in that lane. If the turn register contains a 1, then the car nearest the intersection will turn right. A 0 indicates straight ahead, and a 2, a turn left. After the car has made its turn, the turn register must be set to indicate the next turn. A similar mode to that of generating cars is used to generate the random numbers which decide whether turns take place.

The three-phase traffic light is simulated in the computer by a light register. The register contains a 0 if the light is red, a 1 if the light is green, and a 2 if the light is amber. The duration of each phase of the light is controlled by counting the number of quarter seconds during which it has been continuously in that phase, and changing to the next phase when the counter has reached the specified value. The duration of red and green for the north south and east west lanes are parameters of the program and can be set to anything desired. The duration of amber, however, is fixed. It is long enough to enable all cars entering the intersection on green to pass through before the light turns red.

Behind the specific rules the computer obeyed were the following general principles:

1. Cars approaching the intersection give the right of way to cars which are in the intersection, but not in the left turn zone.

2. Cars in the left turn zone give right of way to cars which will cross their paths.

The cars on α, ρ, $\bar{\lambda}$ (Figure 2) are first considered and are moved up one point. This can be done without any consideration of the light or traffic because cars are not allowed to enter these paths until the way is clear for their complete negotiation.

A car approaching the left turn zone is likewise automatically moved up. If there is a car, C, in the left turn zone, the light is checked. If it is red, C completes the turn. If it is green or amber, the computer examines the right and straight ahead paths of the opposing lane (e.g., lane N if C is turning left from lane S). If these paths contain a car, C remains where it is. If they are empty, the traffic in the opposing lane is examined. If there isn't any car within 55 feet of the intersection (i.e., if there are zeros corresponding to the first five points), the car continues its left turn. If there is a car within 55 feet, the turn register for that car's lane is examined. If it indicates that the nearest car is to turn left, C completes the turn; otherwise, it remains in the left turn zone.

If the car is at point one (i.e., is about to enter the intersection) the light is checked. If it is red, the car remains at point one. If it is green, the computer examines the turn register. If a right turn is indicated, the right turn path and the paths intersecting it are examined, and if clear, the right turn path is entered. The digit corresponding to point one is made zero and the digit corresponding to the first point of the right turn path is made 1, (i.e., the car turns right). If a left turn is specified, the left turn path and the paths intersecting it are examined. If empty, the car proceeds; otherwise, it remains at point one. Similar treatment is given to the "straight ahead" direction.

A car at point two of a lane always moves to point one and a car at point three advances unless there is a car at point one or a car entering the intersection from this lane. These facts are determined by checking to see if zeros or ones are associated with the points of these intersection paths.

Cars further back in the lanes follow rules designed to maintain a distance of at least 55 feet between the front bumpers of moving cars. This was deemed a reasonable minimum distance for cars travelling at thirty miles per hour. A moving car will, of course, approach a stopped car until there is a distance of 22 feet between their front bumpers.

A measure of effectiveness used in the one intersection model was the average delay experienced by cars at the intersection. Since the minimum time for negotiating the course was known, the average delay for cars in a given lane is obtained by finding the average actual time needed to go from the far end of the lane (point 40) through the intersection, and subtracting the minimum time for negotiating the course. The average time needed to pass through the lane and intersection is approximated by counting the 1's, that is, the cars, in the lane and its associated intersection path every quarter second, accumulating this count and dividing by the number of cars leaving the lane's intersection paths. From here on, parameters were varied to study the average delay as it was affected by increase in right or left turns, changes in the light cycle, and changes in the rate of cars being generated.

Four Intersections -- Additional Logical Rules

In this paper, we are concerned with the extension of this one intersection model to a model containing four intersections. In our cross block (Figure 4), as before, there are again four incoming lanes Each lane, because of a change in computer, consisted of 35, instead of 40, possible car bumper positions. With each lane is associated four paths within the intersection and one "exit" position (really an entrance posi-

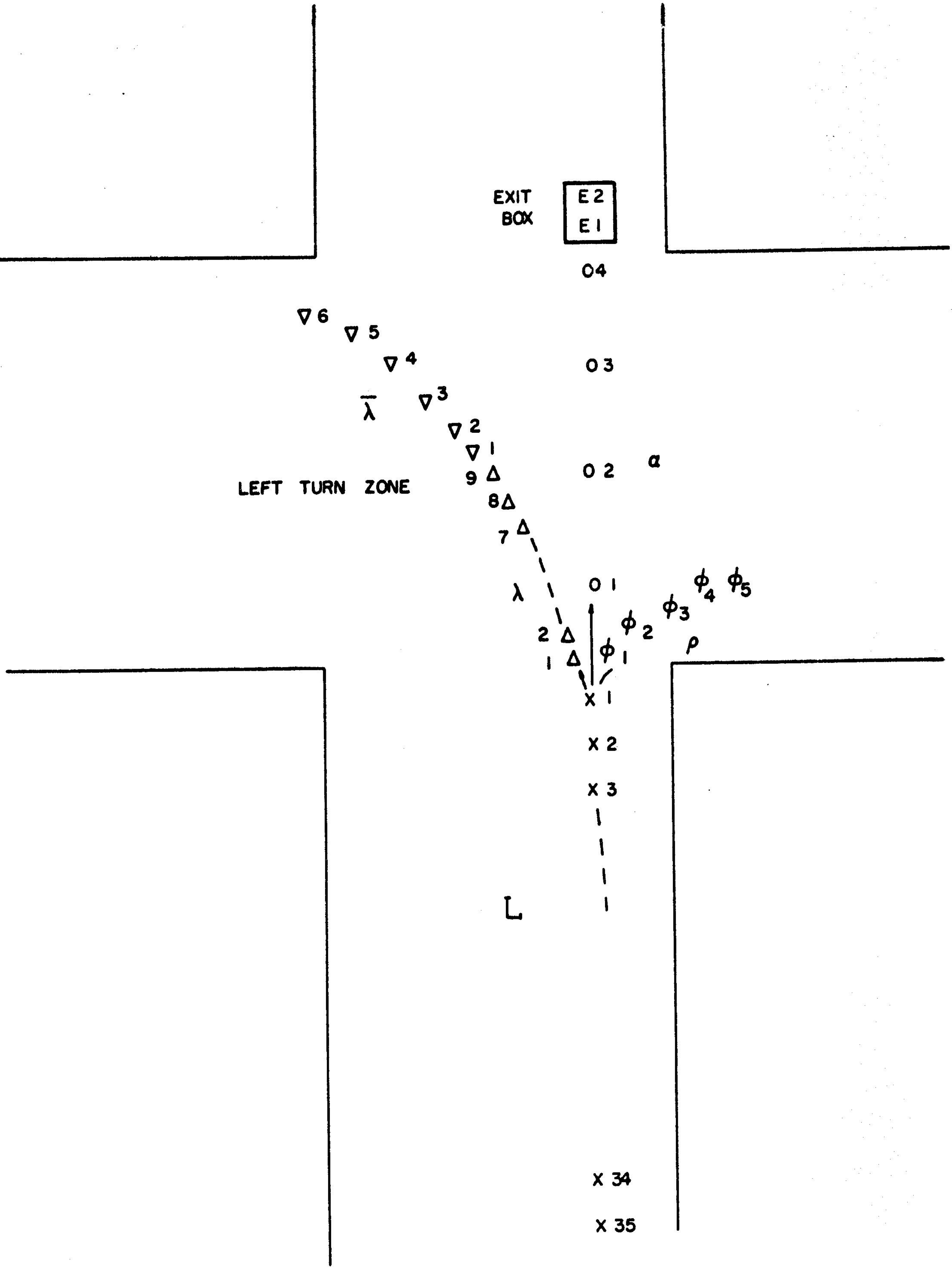

FIG. 4

tion relative to the lane, as will be seen). One of the four paths lying within the intersection is followed by right-turning cars, one by cars going straight ahead, and two by cars turning left. As before, these are called ρ, α, λ, and $\bar{\lambda}$, respectively.

In order to interconnect cross blocks as indicated in Figure 3, we have added an exit box to each "straight ahead" path out of the cross block. This exit box consists of the first two points that are attained by a car leaving the intersection on the straight ahead path. Right and left turners into the exit box are also deposited in it as they leave the intersection. These exit boxes allow the programming of the computer to arrange for the connection of any given cross block with any other cross blocks. If, for example, it is intended that crossblock 2 connect to crossblock 1 on the latter's east side, say, the two points of the exit box on the west side of crossblock 2 are made to coincide with points 34 and 35 of the lane entering crossblock 1 from the east. (See Figure 5). On the other hand, if no intersection is to be connected to crossblock 1, the exit box stands alone and cars drop out of the model after leaving it.

For each crossblock there now corresponds a storage register to each lane, to each intersection path, and to each exit box—24 in all, since there are four lanes, sixteen paths, and four exit boxes. Four crossblocks, interconnected, made up the model under discussion in this paper.

As in one intersection operation, when a car reached point 1 of any lane, the light is checked. If it is red or in the last ten quarterseconds of the amber period, the car remains at point one. If it is green or in the first 15 quarterseconds of the amber period, the computer examines the turn register. If a right turn is indicated, the right

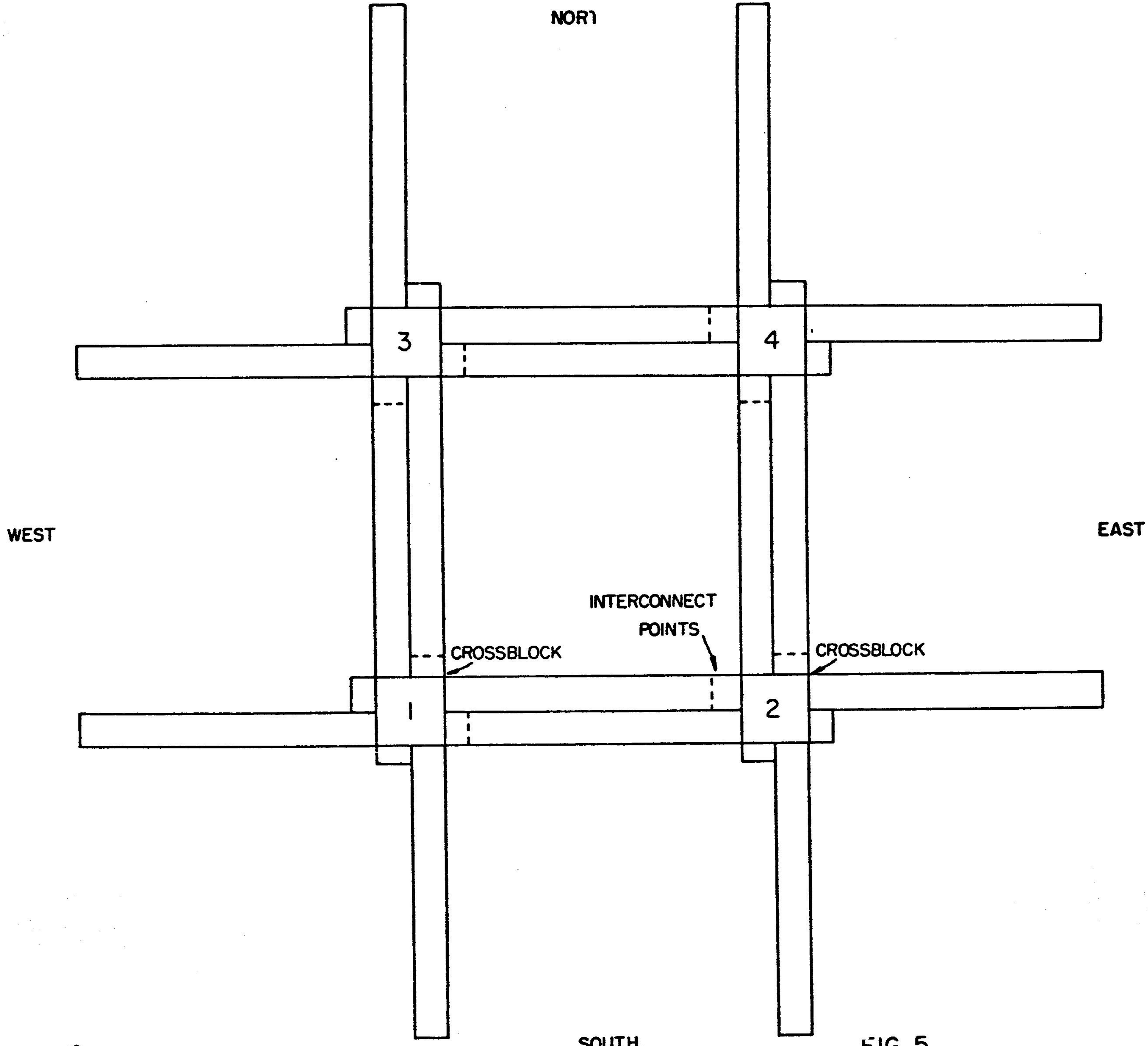
NORT
WEST
EAST
3
4
1
2
INTERCONNECT
POINTS
CROSSBLOCK
CROSSBLOCK
SOUTH

FIG. 5

turn path is considered. If it is empty, the car proceeds (i.e., a zero is placed in the first bit position of the lane and a 1 is placed in the first point of the right turn path); otherwise the car remains at point one. If a left turn is indicated, the left turn path is examined. If it is empty, the car proceeds; otherwise it remains at point one. The same procedure is followed if a straight path is indicated.

Since in our model, we have four crossblocks joined together to give a sample city block, there are eight entrances into the model (i.e., S_1, S_2, E_2, E_4, N_4, N_3, W_3, and W_1), and the eight exits as shown in Figure 5. Other lanes and exit boxes are joined to some other crossblock beside their own. We apply the rules of this model in the following order. First the four intersections are worked on, then the lanes are worked on, starting at point 35 and progressing up the lane to point one. We then proceed around the model and connect the appropriate exit boxes to their lanes. Having done this, the unconnected exit boxes are attended to. Next, the lights are examined and changed if necessary. This brings up the next quarter of a second which repeats the routine.

Note that if the exit box were not introduced, as a car left an intersection the crossblock and lane it was entering would have to be found and investigated to determine whether 34 and 35 were free. The exit box makes operation on each crossblock self contained until the connection is made.

The use of the exit box permits work on the intersection and lanes of one crossblock for the entire quarter second without consulting any of the information concerned with the other crossblocks. Since 34 and 35 of the next lane are synonymous with the exit box, they can only be filled if the exit box is. Thus, after all the intersections and lanes of the crossblocks have been worked on, then a short routine transfers the content of the exit boxes to the 34 and 35 boxes of the appropriate lanes.

Computers

The computer used in connection with the one intersection model was the MIDAC (Michigan Digital Automatic Computer) which contained 40 bits and a sign in each word. For the four intersection case, a computer put at the disposal of the authors by the General Motors Corporation Research Center*—an IBM 704—was used. Each register of the 704 contains 35 bits which coincides with the 35 point lane.

As described above, to move a car in MIDAC it was necessary to perform an extract operation at the bit in question to determine a car's presence and proceed from there through a subroutine. In the 704, instead of having to go through the extract operation, the following operation was used to examine a possible car position (a bit in a register) and to take the required actions. A given lane register's contents were placed in the accumulator. Then the lower order bit test was used on each bit in succession, starting at the light. This order gives one instruction if a bit is in the digit's position and another instruction if there is no bit present. The first instruction will lead to a course of action which is the execution of the car movement. The second instruction, which occurs when no car is present, leads to the examination of the next digit position by shifting the accumulated contents to the right one digit position.

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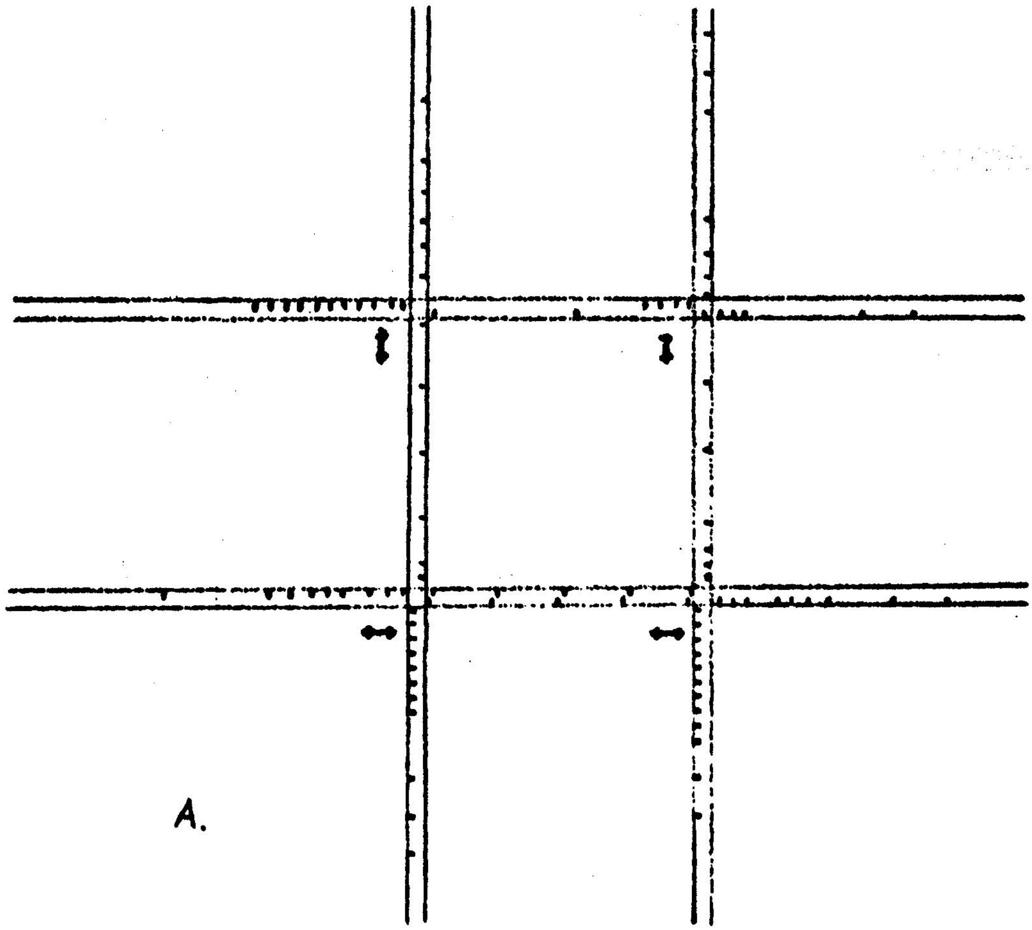
* The authors are grateful to the General Motors Corporation Research personnel for their assistance in making the computer available and in aiding us in its use, particularly in coding for oscilloscopic output. In particular, Mr. Morrison was extremely helpful.

Display and Parameters Used

In Reference 1 it was proposed that in order to allow the traffic engineer to examine traffic flow without forcing him to consider the reduced amount of information provided by the use of single measures of effectiveness such as average delay, etc., it would be desirable to have the computer situation at every moment fed out to an oscilloscope which would represent the positions of cars in their proper geographical location. Since the General Motors computer which was used had an oscilloscopic output available, and since the engineering group there was kind enough to aid in the programming of the output of the model onto the scope, and to provide equipment for making a film of the resulting pictures, the four intersection model was so arranged that every quarter of a second of problem time the contents of the computer were scanned and points on an oscilloscope intensified at locations corresponding to those of cars within the computer model. A useful inversion of the negative with the positive film provided black cars on a white background instead of white on black, which would have been the output if the film had been printed negatively. In addition, the scope was made to paint the bounding lines of the four intersections, resulting in frames of film such as the ones reproduced in Figures 6A and 6B. The resulting film made by the General Motors people provided an animated cartoon-like version of the flow of traffic within the computer. Such a film was made for three separate cases with sets of parameters as in Table I.



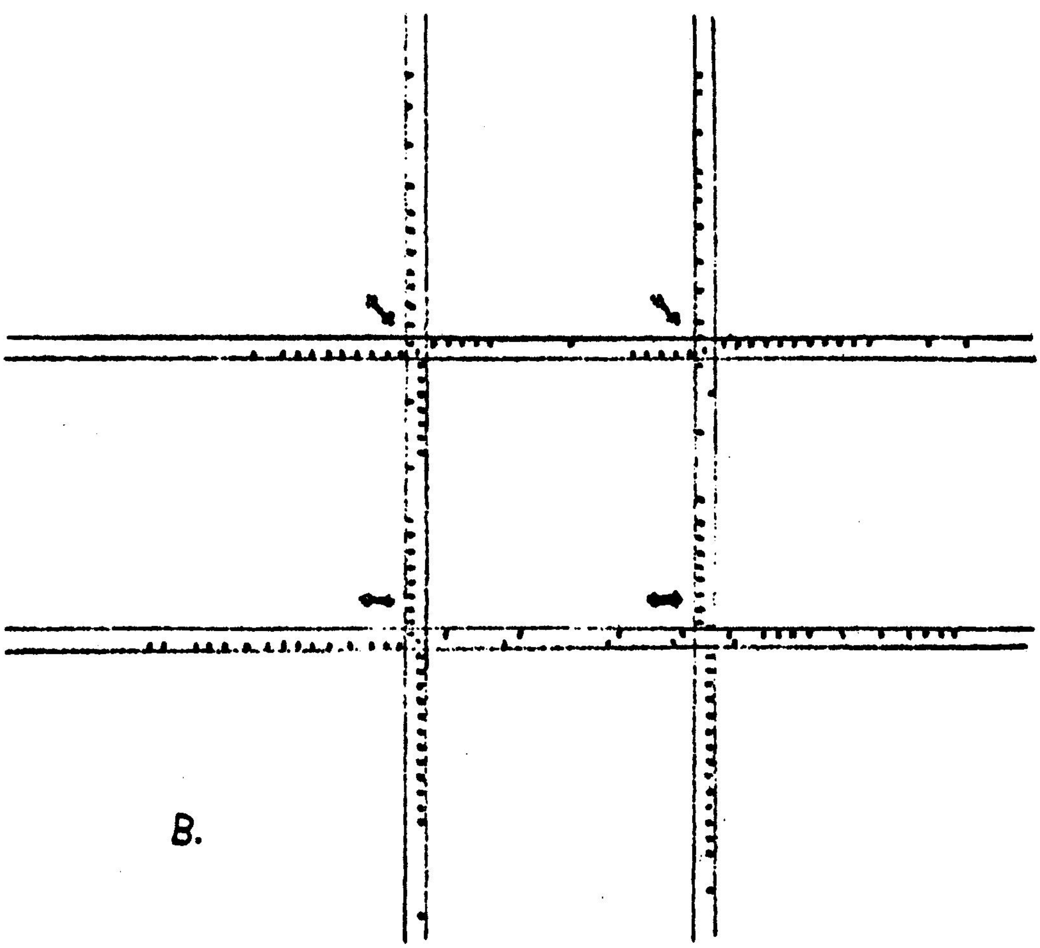


FIG. 6

TABLE I — PARAMETERS USED

	Case I Single Inter-section	Case II Four Inter-sections—All turns	Case III Four Inter-sections—No left turns
1. Cars per hour entering at each entrance.	300	576	576
2. Fraction turns			
Left	10%	10%	0%
Right	10%	10%	30%
Straight Ahead	80%	80%	70%
3. Cycle	60 sec.	60 sec.	60 sec.
Green	25 sec.	25 sec.	25 sec.
Red	30 sec.	30 sec.	30 sec.
Amber	5 sec.	5 sec.	5 sec.

Results of the Four Intersection Runs

In Reference 6, in which some of the results of the simulation of a single intersection were reported for a different purpose from the development of the model, the extrapolation diagram shown in Figure 7 was reproduced. It will be noted that the extrapolation shown indicated that approximately ten intersections could be run on the 704 with the computing time being about three times problem time. The actual results on the 704, which are discussed in this paper, used one-half of the available computer speed to do four intersections of problem time. A pretty safe extrapolation is that the computer could do about eight to ten intersections at a real time rate (i.e., one second of computational time required for one second

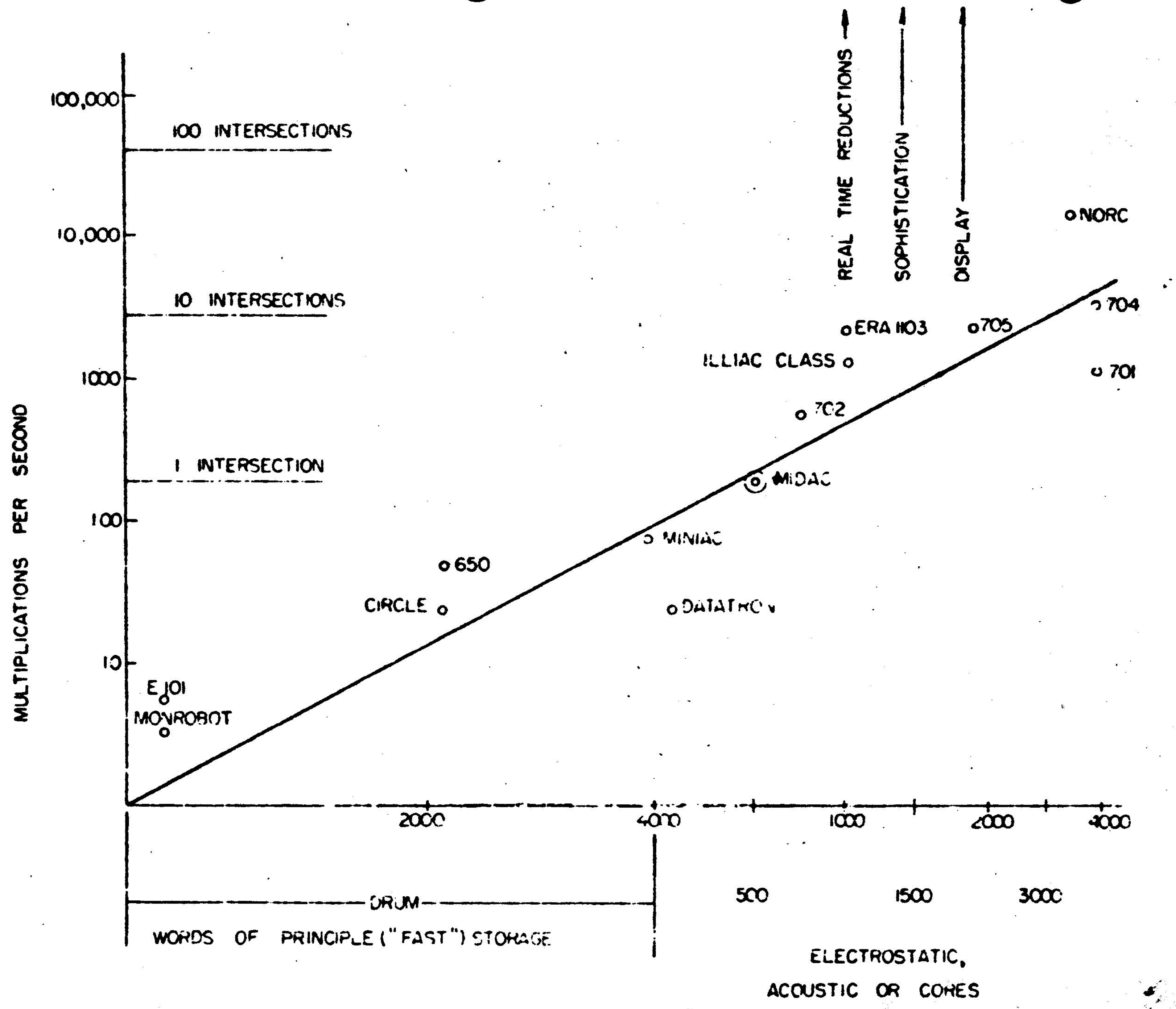


FIG. 7 COMPARISON OF COMPUTERS FOR TRAFFIC PROBLEM

of traffic flow). However, since a film can be made, and since scaling time is no obstacle, even if the computer takes ten or twenty times real time, no difficulties are envisioned in producing for the traffic engineer a version of what real traffic flow would look like. Moreover, ten intersections in any city, with attention being paid to the important intersections, is a fair representation of the flow of traffic during the busy periods at essential points. The model thus far indicates that at this level of sophistication, a reasonably adequate real time version of traffic flow can be produced.

The storage absorbed in the computer was not of much consequence, since of the 8192 words of fast storage available, only 1000 were used. The addition of a single crossblock entails approximately 50 additional registers.

One unfortunate choice in connection with the film was that which allowed cars to disappear out of the block immediately after leaving the model. Traffic engineers who viewed the film subsequently, reported that they would have been better able to make judgments on the basis of traffic flowing out of the exits from the model, rather than just watching the flow of traffic inside the model.

To date the most important point in the development of a computational tool, that is, an experiment to verify the comparability of the computer model and real traffic flow, has not been forthcoming. No support has thus far been available for such a comparison.

Projected Developments

We have now undertaken the development of an expanded model with characteristics different from the one described above at the following points:

1. To represent two lanes of traffic flowing in the same direction, in which a car in the one lane may attempt the passing of the car in front by going over into the lane, speeding up, and then pulling back into the original lane, requires several conditions not present in this model. In the first place, the driver must want to pass, that is, his actual speed must be lower than some speed at which he desires to travel, and secondly, on a city street, he must have in mind an idea of which direction he will try to proceed in when he reaches the end of the lane. In the model discussed above, neither of these elements, driver speed desire nor turn desire, is present. Therefore, two lanes of traffic in a single direction could not be simulated. In the model which is to be developed, a complete register will represent a car, with the number of the register representing the geographical position of the car. In this fashion, a desired and an actual speed may be recorded. Futher, to give purpose to passing, the decision concerning a right, left, or straight ahead intention will be made on entering the lane rather than on leaving it. These two factors will allow a proper simulation.

2. Since many extra bits will now be available, each car will be given a character (bus, passenger, truck, etc.) on a random number (but fixed average) basis. This character will be carried with the car and may be used on display. That is, if a colored scope were available, the character could be used to indicate bus traffic by green, passenger by blue, truck by red, etc.

3. Also, the desired speed will be assigned on a distributed basis (average $\underline{a}$ miles per hour, ranging from $\underline{a} - k$ to $\underline{a} + h$ with

known probabilities) and subsequently carried with the car.

4. Since storage is not at a premium, 210 registers, each representing a possible car space, will make up the lane. Thus car movement will be smoother (although it is not objectionably jerky at present).

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"A PAPER TAPE ACCOUNTING SYSTEM"
·PRESENTED BY PETER G. MUNDY
ASC TABULATING CORPORATION
AT THE G-15 USER'S CONFERENCE

As an introduction to the subject of Paper Tape Accounting, I wish to read from a manual prepared by the Burroughs Corporation, subject, Tape Punch Adding Machine for Accountants....

> "This area, in which adding machines with punched tape have been most successful, is one with exceptional promise for the future. Small business accounting--the processing of raw transaction data into monthly profit and loss statements and balance sheets is commonly being handled by accountants for their clients, instead of the business maintaining its own general bookkeeping system.
>
> The punched tape adding machine enables the accountant to record clients transactions in a minimum of time, and to employ a service bureau for the routine work ending with the monthly statements. Many service bureaus are actively promoting this kind of business among accountants."

We, the ASC Tabulating Corporation, are a service bureau and we are doing this kind of work. I have prepared for distribution, samples of the three basic reports we make from paper tape, the Ledger, the Profit and Loss statement, and the Balance sheet. There is also available for distribution a mimeographed article which explains in detail the way inwhich this system works.

I will briefly state the mechanics of this system. A paper tape is received which has been made on any one of a number of business machines that can punch paper tape. On the first pass, the photo reader, at the rate of 400 characters per second, reads this data, digests it, and sends it to the CA-2 and then to an IBM punch, where individual cards are punched at the rate of approximately 100 cards per minute. Also, the totals of debits and credits by journal are typed out. An additional card is made for payroll entries for later use. If the typeout says the debits equal the credits, the detail cards are merely re-entered into an IBM machine followed by the previously punched balance forward cards. On the next pass the detail cards are read in, stored on memory and then updated card for card from the balance forward cards. They are now complete and ready to be listed for the two statements. This is the new updated output. It carries current and year to date information and the two percentages of cost to sales if it is needed. The input can then be sorted at 1000 cards a minute and listed to make the ledger.

That is the system in a nutshell. Auxiliary reports such as Quarterly Earnings statements, Check Registers, Sales Analysis reports, etc., can be drawn from the original detail cards at no trouble at all. Branch accounting is also possible under this system.

Of interest to engineers is the fact that budgeting and comparison of completed work to budget can be done with this simple system. An engineer can merely estimate percentage of completion on each budgeted phase of construction and get these weekly reports showing actual versus estimated, for the percentage of the job finished.

I would like to give you at this time the advantages to the public accountants in using this system over traditional methods. First, it cuts write-up time as much as 90%. This means the accountant can handle more business. Second, it provides current monthly statements complete with percentages, even during tax season. Third, it eliminates necessity of a highly trained accounting machine operator. It allows the accountant to control input within their office where personnel are familiar with the source. Next, it provides with a minimum investment, a key to special data processing, such as inventories and sales analyses. Lastly, entries can be made at about the time it would take to code them, and they can be made at random. The reports prepared by the service bureau are uniform, accurate and economical.

Users who are unfamiliar with the photo reader and the CA-2 will find the equipment is very reliable and outstanding in its speed and ease of operation.

I would give this word of caution to proposed users of paper tape. Be sure to devote some time to the accuracy of the input because at the present time, the paper tape could be in error and this, of course, causes processing delay.

Also, caution accountants against making entries to account numbers reserved for headings or for totals. The Bendix knows if such an entry has been made, but again, it causes delay in report preparation. The versatility of the G-15 enables all the special characters such as %, $ signs, commas and periods to be used in account descriptions. These special characters will not summarize on the type 407 machine, but of course, are handled by the Bendix automatically.

The future of business data processing seems to be largely with paper tape and I feel that this application, as simple as it is,may provoke thinking along other lines in your data handling problems.

LINEAR PROGRAMMING APPLICATIONS IN THE CHEMICAL INDUSTRIES

PRESENTED AT THE

5TH NATIONAL G-15 USERS CONFERENCE

PITTSBURGH, PA.

BY

MRS. ANNE W. PUSTERHOFER

THE STANDARD OIL CO. (OHIO)

LINEAR PROGRAMMING APPLICATIONS IN THE CHEMICAL INDUSTRIES

One of the best definitions of scientific programming I have come across is that of Andrew Vazsonyi in his book Scientific Programming in Business and Industry. He gives "the allocation of limited means in order to reach specific goals in the best fashion" as his definition of scientific programming. If we examine this definition we see that it can be broken down into three concepts, first, "allocating limited means", second, "to reach specific goals", and third, "in the best fashion."

We in the petroleum industry are not unfamiliary with the problem of limited means. If every unit gave 100% yields of a desired product that met all product specifications and if we could run unlimited amounts of raw material through these units with an unlimited sales market, we would have little need for scientific programming. This, however, is not the case so we must look for a method which will allow us to make best use of the available facilities.

In deciding how to make optimum use of the facilities we must set up a specific goal. In defining a problem we have to decide whether we are to satisfy customer demand, minimize production or inventory costs, or stabilize the labor force - in the case of refining, this could be thought of as avoiding shutdowns on the units. These goals are not necessarily compatible and, in many instances, may be conflicting ones. Once a goal has been formulated it may turn out to be a poor choice. Take, for example, the case of the fat mathematician who was told by his doctor to go on a diet. This mathematician liked to eat, so he formulated a linear program that would decide what foods would satisfy his minimum daily requirements and yet maximize the bulk of these foods. He ran the program through a computer and the answer came out "drink eighty gallons of vinegar a day". With a poor choice of goals, some of the answers we get from refinery linear programs may be just as unpalatable.

The third and perhaps the most important concept in Vazsonyi's definition is reaching these goals in the best fashion. It is not enough to look at a problem and say "this is perfectly suited to linear programming; we will apply this technique and come up with the optimum answer." The way in which a problem is solved should also be optimized. If it appears that the application of rigorous mathematical techniques will be so time-consuming as to more than offset the savings realized, then the solution to the problem is not, in the larger sense, optimum. When it is anticipated that only small savings may be realized, then perhaps the application of several approximation methods may be adequate. Often, too, once the preliminary investigations of the application of linear porgramming to a problem are finished, the answer to a problem may become intuitively obvious. So go ahead at this point would be folly. Keeping these concepts in mind, let us now turn to the areas in which linear programming has proved to be of great use in the chemical and petroleum industries.

At this point I should like to indicate some of the basic assumptions in the application of linear programming. First, a decision problem exists, that is, we have several alternate courses of action available and wish to select the best course of action, second, we can express the variables involved as a set of linear equations or inequalities, third, the answers to the linear programming will be positive quantities, fourth, we can assign factors such as cost or profit to each variable in order to provide a yardstick for the optimum solution. I will hereafter refer to the equation representing these factors as the objective function.

The problem of blending components to meet product requirements and specifications has proved to be especially well-suited to the application of linear programming. Again, however, we must assume that all components will blend linearly to each specification. Once we have set up the matrix describing the properties of each component and the maximum or minimum specifications on the finished blend, we may study various blends depending upon our choice of the objective function. One choice of an objective function may be to maximize the octane number of the blend or set of blends. The results of such a program may indicate whether or not current facilities are adequate to meet future octane number requirements. A decision may then be made as to whether or not current facilities should be expanded for future needs. Another choice of objective function may be to minimize the overall cost of the blends. With this choice we can minimize costs on daily blending operations. At the same time, a thorough examination of the final answers will show the cost of maintaining rigid specifications on the finished product. This may, in turn, lead to an investigation of the feasibility of relaxing certain restrictions on the blends for further savings. A third choice of objective function might be to maximize use of available stocks either to satisfy customer demand or to reduce inventories. We see then, that even in a simple blending problem, the choice of goals will determine the usefulness of the final answers.

Production planning is another fertile area for the application of linear programming. Once we have expressed the yields and limitations in the refinery as linear equations and inequalities, we may again study the effects of various policies by the application of different objective functions. Several objective functions may be:

1. Minimize production costs

2. Maximize production

3. Maximize utilization

4. Maximize customer delivery where demand exceeds supply.

These objectives will likely be in conflict, for instance minimum production costs might lead to incomplete utilization of the facilities or maximum production could produce great quantities of unsalable material and thus not satisfy customer demand. We must therefore choose one objective function to be optimized and, if desired, build the others into the matrix as limitations. One common example is to set maximum restrictions on inventory, minimum limits on demand and then use minimum production costs as the criterion.

Inventory control is another problem well-suited to linear programming, especially where seasonal demand is a factor to be considered. Perhaps the most useful application of the inventory control problem is found in conjunction with the production problem. Too often the cry is heard "How can we reduce our inventory?" A thorough analysis of the problem, including production and demand limitations, will often show that the question posed should be, "What is the <u>best</u> level at which to maintain our inventory?" It could very well turn out that an increase in inventory with additional storage facilities is called for.

The shipping or distribution problem is one which is often mentioned in conjunction with linear programming. By studying the total distribution picture we can determine answers to such questions as whether to ship by pipeline, tank truck, or rail in order to minimize overall costs. The various alternate routes may also be studied. Again, however, the total problem should be considered. One company realized a savings of shipping costs by stocking outlying warehouses with purchased parts. If the total picture of shipping costs, production facilities and purchase costs had been taken into account, the profits realized from this program would have been six times the savings in shipping costs. The beauty of linear programming is that with the aid of large high speed computers we can study many more factors in the problem than would otherwise be possible.

Another area for the application of linear programming is in market research and site planning. In this application we can study the weights of the effects of various factors on the rating we have assigned to existing facilities. For example, in planning a site for a new refinery we might take into consideration such factors as available market, nearness to shipping facilities, available labor force, etc. We would collect these data on current installations and then rate them according to (probably) a profitability factor. The answers to a linear program run on these data would then indicate the relative weight of each factor on the profitability. This method is preferable to correlation analysis in that one of the assumptions in linear programming is that all answers will be positive numbers. This insures that a factor such as market potential will not turn out to have a negative relationship with profitability.

I hope that in this short time I have been able to at least indicate a number of areas for the application of linear programming. Again let me emphasize that linear programming is not the cure-all solution in all areas of optimizing. Perhaps its greatest value, as in all areas of scientific programming, is found in forcing a realistic evaluation of the total problem and a thorough analysis of the variables involved.

I have prepared a bibliography for those interested in a more detailed analysis of linear programming. If you have any questions - time permitting, I will try to answer them now.

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PROGRAMMING INPUT/OUTPUT FOR THE G-15

I. Description of Operation.

A. Standard Numeric Input.

The standard numeric input for the G-15 is initiated by a command with C = 0-3 and S = 12-15. The selected input unit (typewriter, photoreader, magnetic tape unit, etc.) sends characters to the computer each consisting of five bits which enter five flip-flops known as the OB's. Four of these bits go to a set of four flip-flops known as the OA's and the fifth bit determines whether the character is to be considered numeric or nonnumeric (sign, tab, reload, stop, etc.). If the character is numeric, Line 23 is recirculated through the OA's, which has the effect of storing the four bits in the OA's in bits T1-T4 of 23.00 and shifting the rest of line 23 by four bits.

Nonnumeric characters are interpreted by special circuitry. A minus sign character causes a single one bit to be stored in the OS flip-flop. A tab or carriage return character causes Line 23 to be recirculated through OS, so that the sign bit is placed in T1 of 23.00 and the rest of Line 23 is shifted by one bit.

A reload character causes Line 23 to be copied into a special buffer line known as MZ. At the beginning of the next drum revolution. Line 19 is recirculated through MZ for one revolution, which has the effect of storing the four words of MZ in 19.00-03 and shifting the rest of Line 19 by four words. A stop character from the typewriter merely terminates the input by setting the Ready indicator, but a stop code from any other input unit also causes a reload, and the Ready indicator is set at the end of the precession of Line 19.

B. Automatic Input.

The automatic input mode is initiated by a command with C = 4-7 and is used with the alphanumeric typewriter and the PR-2 high speed photoreader. It permits the filling of Line 19 without the necessity of supplying reload characters. When the command is executed, Line 23 is cleared and a marker bit is placed in T1 of 23.00. When an eight bit character is entered from the typewriter, the first four bits enter the OA's and the second four bits are held in a four-bit buffer. Line 23 is recirculated through the OA's to enter the first four bits and then the second four bits are sent to the OA's and then to Line 23. If the marker bit is recirculated out of Line 23, Line 23 is copied to MZ and the reload occurs automatically. A stop character from the typewriter causes Line 23 to be precessed until the marker bit is removed and a reload occurs.

C. Slow Output - Numeric.

This mode of output takes place under control of a format which determines the type of character to be transmitted to the output unit (typewriter or paper tape punch). For AR typeouts, the format is obtained from 03.00-03 and for Line 19 output, the format is obtained from 02.00-03. When the output command is executed, the format is first copied into MZ at the beginning of the next drum revolution. MZ is then recirculated through a set of three flip-flops to pick up and interpret one three bit format character at a time.

If a digit is to be typed, Line 19 is recirculated through the OA's on the next drum revolution, which has the effect of shifting the line by four bits and moving the last four bits of 19.u7 into the OA's. The OA's are cleared before the recirculation begins, so zeroes are entered into 19.00. At the end of the recirculation the character in the OA's is sent to the selected output unit to be typed or punched.

When a sequence of digits are being typed, recirculation through the OA's occurs once every four drum revolutions with the numeric typewriter (3 revolutions for wait characters), once every three revolutions with the alphanumeric typewriter in the numeric mode, and once every two revolutions with the tape punch.

D. Slow Output - Alphanumeric.

With alphanumeric output, no format is involved since all possible typewriter characters are stored as eight bit characters. Line 19 is recirculated through the OA's to pick up four bits, which are then transmitted to the four-bit buffer in the typewriter. After an interval of one revolution between recirculations, Line 19 is again recirculated through the OA's to get the second four bits. If the first bit of the eight-bit character is a zero, the output is terminated. Typeout occurs at an average rate of one character per five drum revolutions.

E. Fast Output.

The fast output mode is used with magnetic tape or the high speed paper tape punch and no format is involved. When the output command is given, MZ is cleared beginning at word .u4. During the next drum revolution, Line 19 is recirculated through MZ, which is then copied to Line 23. Line 23 is recirculated through the OA's and on the first recirculation a marker bit is inserted in 23.00. The output character is sent from the OA's to the tape and Line 23 is recirculated through the OA's again. This continues until the marker bit is shifted out of Line 23, at which time a reload character is written on the tape. Meanwhile, Line 19 has been recirculated through MZ again so four more words are available in MZ. The process continues until Line 19 is zero.

F. Set Ready.

If the Set Ready command (0.00.31) is given while an output operation is in progress, a four word precession of Line 19 occurs. Beginning at word .u4 of the same drum revolution in which the Set Ready command occurs, line MZ is cleared. Line 19 is then recirculated through MZ on the next revolution. The "Type AR - Set Ready" sequence is a convenient method of programming a four-word precession of Line 19.

During the drum revolution in which the precession is occurring, if Line 19 is used as a source of information, the information comes from the unshifted locations and does not pass through MZ. If information is copied into Line 19 during this time, it goes into the specified address without passing through MZ, but the information from MZ is also written into Line 19 simultaneously, so the result is the logical union of the two sources. In fact, if information is copied into Line 19 at any time it is being shifted, whether by four words (Set Ready, reload from typewriter or tape, or writing on magnetic tape), four bits (typing or punching digit or wait character), or one bit (typing tab or carriage return), the shifted information is combined with the new information rather than replaced by it.

G. Reversing Paper Tape.

The input/output system goes through three distinct phases during the operation of reversing paper tape by one block. These are indicated by the configuration of the input/output lights on the front of the computer and operate as follows:

1. Configuration 06. This is initiated by executing the 0.06.31 command. The photoreader light turns on, the tape moves in the reverse direction, and no information enters the computer except that a stop code on the tape sets up the 07 configuration.

2. Configuration 07. This results from passing a stop code in the 06 configuration or may be initiated by executing the 0.07.31 command. The photoreader light is on, the tape moves in the reverse direction, and no information enters the computer except that a stop code on the tape sets up the 15 configuration.

3. Configuration 15. This results from passing a stop code in the 07 configuration or may be initiated by executing the 0.15.31 command (normal read tape command). The photoreader light is on and each character passed on tape enters Line 23. A stop code causes the light to turn off, the tape to stop moving, and a reload from Line 23 into Line 19. If entered from the 07 configuration with the tape moving in reverse, the tape moves a distance of two or three words past the photoreader, depending on the speed of tape motion, comes to a halt, then moves in a forward direction past the stop code.

II. Programming Methods.

A. Monitoring Typewriter Input.

Inspection of the contents of Line 23 by the computer during typewriter input permits a wide variety of formats for type-ins and may be used to terminate input by means other than the s key if this is desirable. Input may be terminated by the tab key by distinguishing between a one bit shift and a four bit shift. One way this might be done would be by clearing 23.03 and loading -.8888888 into 23.02. As long as digits are typed, the sign bit of 23.03 is clear, but a one bit shift resulting from a tab will move a 1 bit into it. The program will continually copy 23.03 into AR and test the sign. As soon as it is negative, a tab has occurred and the computer executes a Set Ready and obtains the typed information from 23.00

Other routines are also possible: clear 23.00 and test for any nonzero input; clear 23.01 and set a marker bit in 23.00 positioned so that it will move into 23.01 after n digits have been typed, and then test 23.01 for nonzero; test 19.00-03 so as to detect a slash or reload; and so forth. If input is to be terminated when a digit is typed, it must be remembered that the last bit of the digit is in the sign positon of 23.00 and the program must make provision for recovering this bit if the number is odd.

Similar tests may be used to monitor input with the alphanumeric typewriter. For instance, the input may be monitored for a specific character by setting an extractor in 20.00 and continually copying 23.00 into 21.00, extracting 31.00 into AR, and subtracting the desired character configuration from AR. This procedure has been used to answer questions by "yes" or "no" by continually inspecting the input for the letters "s" or "o". It has also been used to terminate input by means of the tab kep if the input is correct or the space bar if a typing error has been made. It must be remembered that the characters are loaded into Line 23 four bits at a time, not eight, so the character tested for must not coincide with another combination resulting from the last four bits of one character and the first four bits of another. Line 19 may also be monitored for automatic reloads in order to store information away in memory as it is typed in.

B. Monitoring Paper Tape Input.

In previous Users Conferences a routine has been described in which a paper tape of decimal integers is read into the computer and the entire line is converted to binary integers. In the first version, this routine required 324 drum revolutions to do the required conversion after the tape had been read in. Subsequent revisions of this routine have reduced the required time to 216, then 135, and then (U. P. No. 377) 54 drum revolutions, all after the tape has been read. The over-all program may be accelerated still more by converting the numbers to binary as fast as they are read from tape, so that the conversion is finished as soon as the tape-reading is finished. Example I shows the flow sheet for monitoring the input to accomplish this. The decimal-to-binary conversion routine is not shown because it has been described elsewhere, but it converts two words at a time using both halves of the two-word registers and requires most of one drum revolution. The method involves storing a non-decimal flag (.wxywxyz) in 19.00 and testing to determine whether a reload has occurred. The routine can handle tape reading speeds up to one reload per three drum revolutions (390 characters per second if tape is punched with four words (7 digits, tab) between reloads).

Another example of monitoring input during tape motion is found in fast rewind routines. The objective here is to rewind the tape with the tape moving continuously in the reverse direction rather than crossing each stop code three times. The tape may be monitored to determine whether it is moving across information by setting the 15 configuration for a fraction of a revolution, then setting Ready and returning to a rewind configuration (06 or 07). If information is passing the photoreader, Line 23 will be shifted and this can be detected by placing a marker bit in Line 23 and testing its position. Stop codes on the tape may be detected by rewinding in the 07 configuration, so that stop code will set up the 15 configuration and shift Line 23. A rewinding subroutine for Intercom 1000 is shown in Example II.

C. Typewriter Output.

The commonest example of loading Line 19 while a typeout is in progress is the standard typeout of double-precision numbers. In order for the sign to be typed correctly, it must be loaded into the sign position of 19.u7 and the type command is executed. After a delay of three drum revolutions the sign has been picked up for typing, so the double precision number may be copied into 19.u6,u7 and it will be typed. To save time, the binary-to-decimal conversion may be carried out during this three revolution interval.

A method of typing double precision numbers from AR is given in Technical Applications Memorandum No. 55. The method consists of first copying the sign of the number into AR and beginning the typeout. After a three revolution delay, the first seven digits are copied into AR along with a marker bit in T1. An extractor (.8000000) is then copied into Line 20 and the corresponding word in Line 21 is cleared. When a test of Source 27 indicates zero, the marker bit has been shifted into T29 of AR and the last seven digits of the number are then loaded into AR for typeout.

Typing of trailing zeroes in a number may be suppressed by testing 19.u7 for zero. When the word is zero, a Set Ready command may be given after a delay of about three revolutions to permit the last nonzero digit to be typed.

A further example of monitoring Line 19 during typeout occurs in an alphanumeric input/output routine (U. P. No. 485). In this routine, Line 19 is filled with alphanumeric information for typeout and when the end of the information is signalled by the occurrence of zeroes in the last eight bits of a two-word group, a typeout of Line 19 is initiated. However, if Line 19 is filled before the end of the information is reached, a typeout is started and Line 19 is filled with more information while the output is in progress. A flow sheet showing the method of testing Line 19 is shown in Example III.

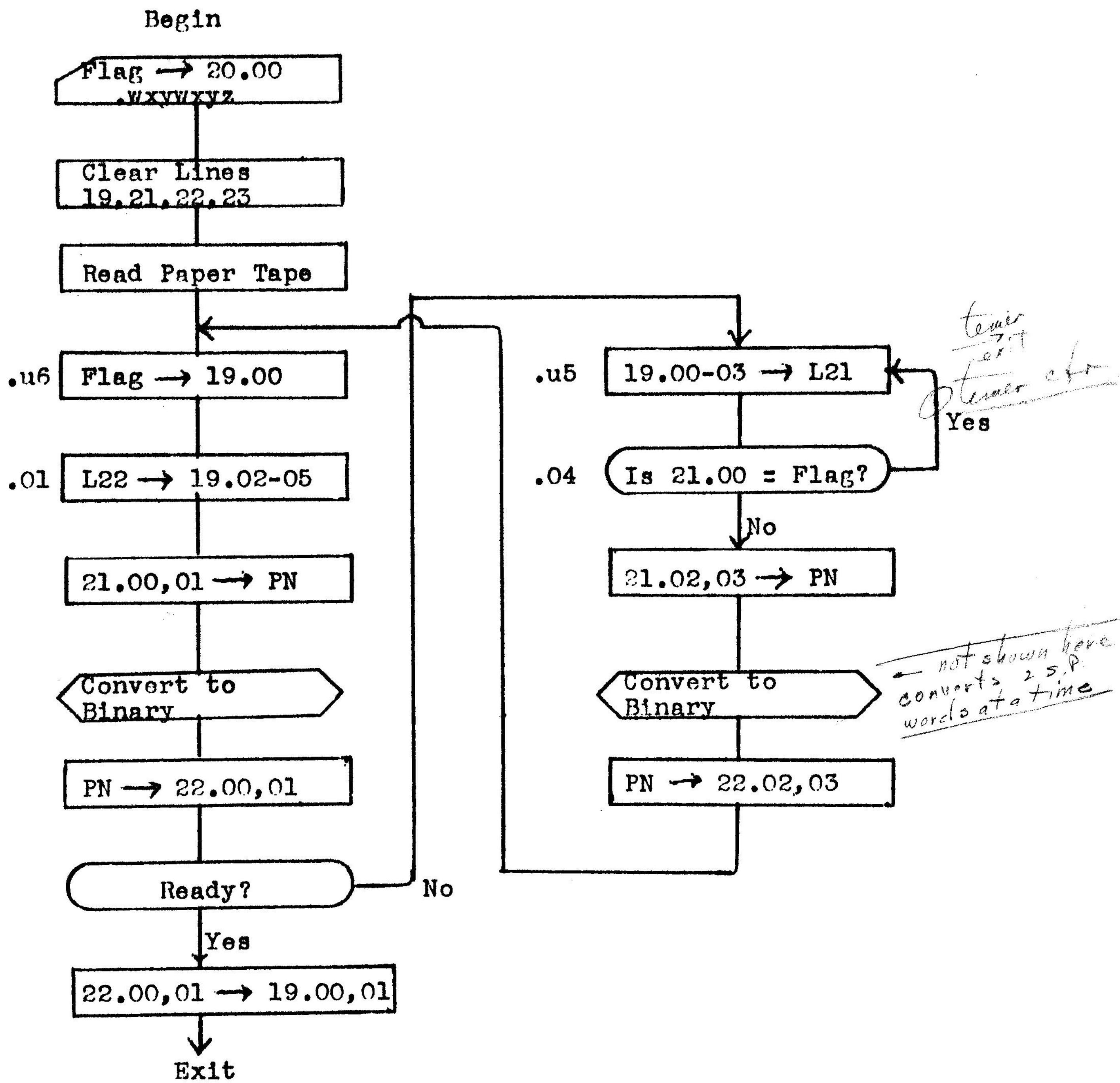
III. Other Coding Tricks

Frequently a programmer is faced with the problem of squeezing a few more commands into a line of coding that is already full. There are various techniques which may be used to make the same operation be carried out with fewer commands. Good use may frequently be made of the 2 characteristic, with which the contents of AR can be stored and a new number picked up in AR with one command. The contents of AR may be changed in the least significant digit in one command without storing the value of the increment by using the 7.28.28 command for decrementing positive numbers or the 0.26.31 command for incrementing numbers (providing that shifts in ID and MQ are immaterial). If the same operation is performed several times, the same coding should be used each time if possible, with exit from the loop being made by a return to mark place command or by executing a previously stored return command in AR. It is frequently unnecessary to have more than one 0.31.31 command (Next command from AR) in a line of coding.

Example IV shows an illustration of accomplishing as much work as possible in as few commands as possible. It is a routine to clear the entire memory including all long and short lines, two-word registers and AR, and turn off the overflow light. The entire routine requires only four commands. While this example is academic from a practical point of view, it shows some of the things which can be accomplished by the multiple use of commands.

EXAMPLE I

Decimal-to-Binary Conversion during Paper Tape Input



Program Tape rewinding routine Sum .yw95&xx Line 05

Prepared by A. L. Squyres Date February 29, 1960 Page 1 Of 2

L		T	N	C	S	D	NOTES
							INTERCOM 1000 (D.P.) Version
							Store routine in Channel CH. Enter with 02CH00 (tab)s
							to rewind entire tape reel.
.00		.00	.00	.0	.28	.31	Wait for Ready
.01		.03	.12	.0	.07	.31	Reverse tape to first stop code.
.12		.14	.14	.5	.21	.31	Mark .13. Go to .14.
.14		.16	.19	.4	.05	.23	Load flag to 23.00,01 (23.00 ≠ 0, 23.01 = 0)
.19		.23	.25	.0	.05	.28	Delay counter → AR. (.0000023)
.25		.13	.15	.0	.23	.27	Test for stop code (23.01 ≠ 0)
							Stop code changes light pattern to 0●●●● and reads tape into Line 23. If stop code is reached, skip to .16.
.15		.20	.22	.7	.28	.28	Decrement AR
.22		.23	.24	.0	.28	.27	Test AR for zero. Return to .25 if ≠ 0.
							AR ≠ 0, One second delay finished.
.24		.26	.02	.0	.15	.31	Read tape.
.02		.04	.04	.0	.00	.31	Set Ready.
.04		.06	.07	.0	.07	.31	Reverse tape to first stop code.
.07		.09	.11	.0	.23	.27	Test 23.01 for presence of characters on tape.
							Return to .12 if characters are found on tape. If tape is empty, (leader or end of reel) go to .11.
.11		.13	.12	.5	.20	.31	Return to mark. (.13 on first blank space, .18 on second.)
							Skip to here from .25 if stop code encountered on tape.
.16	w	.18	.01	.0	.00	.31	Set ready, return to .01.
							Return to here on first blank space
.13	w	.18	.14	.5	.21	.31	Mark .18, go to .14.
							Return to here on second consecutive blank space without
.18		.20	.20	.0	.00	.31	intervening stop codes. Set Ready.
.20		.01	.01	.0	.21	.31	Return control to INTERCOM 1000 (D.P.) For INTERCOM 500,
							change this command to u.21.u7.0.06.05

G-15 COMPUTER PROGRAM

Program Tape rewinding routine Sum .yw958wz Line 05

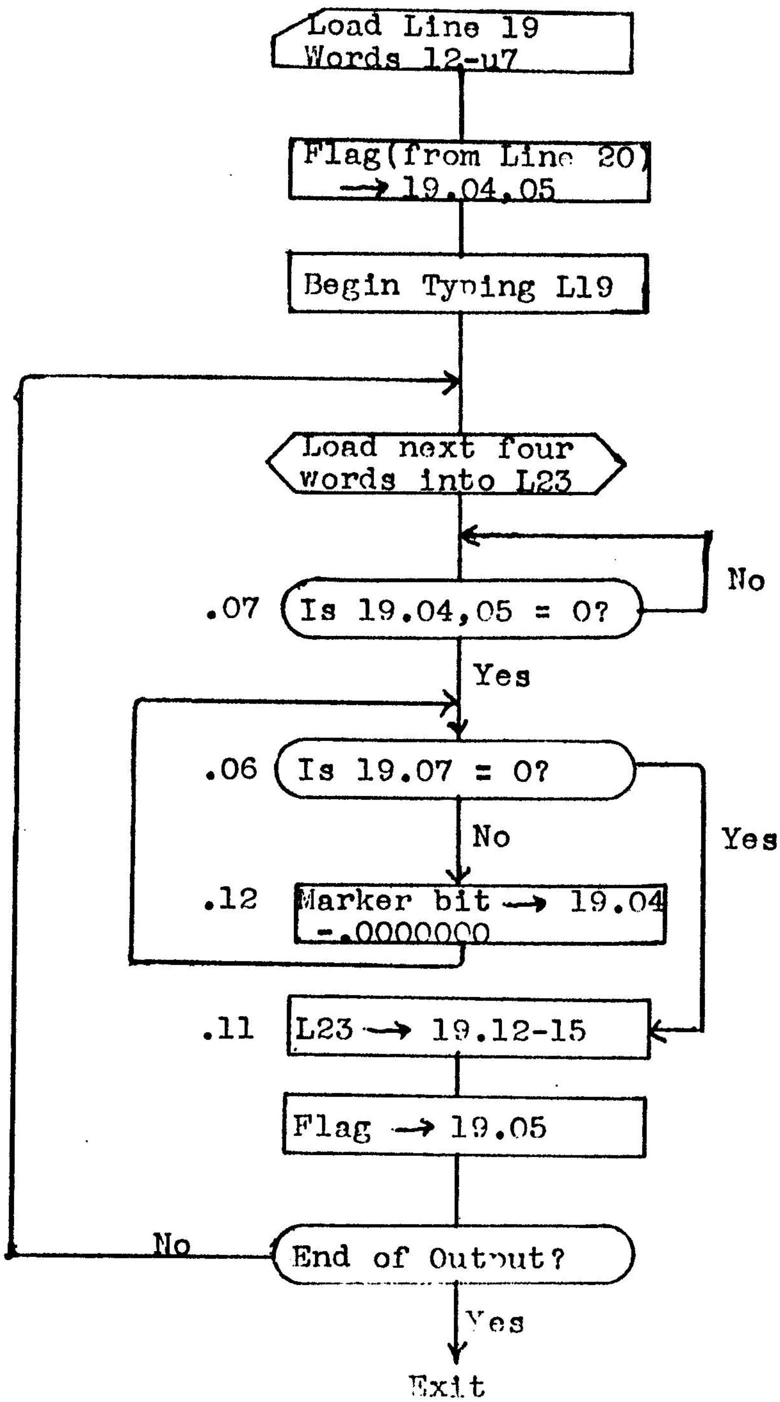
Prepared by A. L. Squyres Date February 29, 1960 Page 2 Of 2

L		T	N	C	S	D		NOTES
								To rewind n blocks, set B_{wd} in same line as this routine;
								that is, execute K70000n, where K = CH - 8
								Enter routine with 02CH10.
.10		u4	26	0	05	28		B register → AR
.26		26	26	0	28	31		Wait for Ready
.27		29	03	0	07	31		Reverse tape to first stop code.
.03		05	20	0	28	27		Test counter. Exit if zero.
								Counter not zero
.21		05	06	3	05	29		Subtract .0100000 from AR
.06		16	08	4	05	23		Load flag to 23.00,01 (23.00 ≠ 0, 23.01 = 0)
.08		05	08	0	23	27		Wait until stop code is passed (23.01 ≠ 0)
.09		11	27	0	00	31		Set ready. Return to .27 above.
-								CONSTANTS
.05	u	01	00	0	00	00		.0100000 Decrementer for counter (See .21)
.17	u	00	00	0	00	00		.0000000 Zero flag for L23. (See .06 and .14)
.23	u	00	00	0	01	03		.0000023 Counter for one-second delay (See .19)

EXAMPLE III

Filling Line 19 during Typeout.

(From U.P. No. 485, Alphanumeric Input/Output Routine)



EXAMPLE IV

Routine for Clearing Memory

Object: Clear memory, including 20 long lines, 4 short lines, MQ, ID, and PN registers, IP flip-flop, AR, and overflow indicator.

Also, use compact coding to make program as short as possible.

Operation: Read program tape with p, then Compute to GO. Program operates in Line 23. Execution time is 2.5 seconds.

Coding:

.00	.02.05.0.29.28	Clear AR
.01	u.12.15.2.23.23	Executed at .05. Line 23 is precessed by one word to the form shown below. Also AR is exchanged with 23.03.
.02	u.16.10.0.27.29	
.03	.06.10.0.26.31	

Revised form of Line 23 after precession.

.00	.06.10.0.26.31	Add 3 to destination of command in AR by means of 3-bit shift tally.
.01	.02.05.0.29.28	No longer used.
.10 (.02)	u.12.15.2.23.23	Exchange AR with 23.03, then execute 23.03 at word .15.
.15 (.03)	u.00.00.0.00.00	Skip to .00
	or	
	u.16.10.0.SS.DD	Copy SS to Line DD

The SS.DD combination in .03 takes on the following values:

28.00	Clear Line 00 (AR is clear)	29.13	
28.03		29.16	
28.06		29.19	
28.09		29.22	
28.12		29.25	ID and PN, IP
28.15		29.28	
28.18		29.31	Turn off overflow indicator
28.21		30.02	Line 21 has been cleared
28.24	MQ	30.05	so Source 30 = 0
28.27	AR = 0, no test	30.08	
28.30		30.11	
29.01	Source 29 = 0	30.14	
29.04		30.17	
29.07		30.20	
29.10		30.23	Clear out program.

INTERCOM WORKSHOP

The Intercom Workshop was conducted as a discussion group. About fifty persons were in attendance, of whom at least half contributed to the discussions.

The interests of the group could be roughly classified as follows:

- 1/6 have had their G-15 installations for less than one year
- 2/3 use more than one Intercom
- 1/10 use Daisy 201 as a double precision system
- 1/3 have devised machine language subroutines for Intercoms
- 1/3 use Intercom 1000 in connection with accessory equipment.

The nature of the machine language subroutines were described briefly by their authors; they appeared to reflect the diversity of individual interests rather than duplication of effort on common problems. A discussion of off-line data preparation showed that predominant interest lay in Flexowriter tape preparation, but prominent mention was made of other optical tape devices. Card preparation interests seemed to involve principally CA-2 equipment.

A discussion of teaching procedures indicated a three to one preference for use of the students own elementary program as the basis for instruction in operations as opposed to imposed or standardized programs for instruction.

The only suggestion for pseudocode interconversion was to provide a translator for Intercom 101 programs to convert them into Intercom 500X form; the suggestion of the Intercom 1000S to Intercom 500X converter was well received.

Since this workshop was devoted to the diffusion of ideas, no occasion arose to consider organizational matters; the meeting adjourned at 3:30 p.m.

Robert U. Bonnar
Chairman

MTA WORKSHOP

The workshop session was well attended by over fifty people. The first topic of discussion was a report by Don Hassell of Bendix Computer, on the magnetic tape systems in existence. He pointed out that the Bendix Magnetic Tape Service Routine and the General Mills Magnetic Tape System imbodied in PPROMPT, were not compatible.

Harvey Chiat of General Mills, Inc., Mechanical Division, then presented a discussion on the PPROMPT (PPR on Magnetic Program Tape) Routine.

It was decided on the basis of a motion by M. Rohr of E. I. duPont Company, seconded by R. Noel, North American Aviation, Missile Division, that the magnetic tape users should seek recognition of the Steering Committee in the form of an ad hoc committee. The purpose of this ad hoc committee would be to keep all magnetic tape users informed of latest developments in magnetic tape programs as well as to seek a means of standardizing the various magnetic tape systems.

Harvey Chiat
Chairman

PURPOSE

The purpose of placing the Program Preparation Routine on Magnetic Program Tape (PPROMPT) is to incorporate into PPR the speed and versatility afforded by magnetic tape.

Since PPR is rapidly loaded from the Magnetic Program Tape (MPT) after an auxiliary routine has been executed, the necessity of retaining it in memory is eliminated. Hence, lines 11, 12, and 13 and made available to the programmer.

In addition to the standard PPR auxiliary routines, two magnetic tape routines are included in PPROMPT. These are the Magnetic Tape Preparation Routine and the Magnetic Tape Search Routine.

ADVANTAGE OF USING MAGNETIC TAPE

Some of the advantages in using magnetic tape for operating programs and for code checking purposes are:

1. Programs are quickly and easily recorded on magnetic tape for future use by simple coded instructions.

2. Programs are rapidly located and easily loaded by simple coded instructions.

3. Magnetic tape provides a more permanent and accessible record than paper tape.

EXPANSION

PPROMPT is written so that it can be expanded indefinitely. This feature allows an installation to record frequently used programs on the MPT for quick and easy access. For detailed instructions on expanding PPROMPT, see Part V of PPROMPT writeup (U.P. No. 431).

MAGNETIC TAPE SYSTEM

The Magnetic Tape System outlined herein is proposed to facilitate usage of the Magnetic Tape Units. The basic philosophy of these routines is to make "housekeeping" on magnetic tape as automatic as possible and under computer control. We have tried to include as many of the suggestions of the Advisory Committee on Magnetic Tape (report of June 11, 1958, meeting) as were practicable. If the basic specifications outlined below are adopted, we feel this "package" will provide a comprehensive Magnetic Tape System for the User.

Scope

The package provides for a fairly flexible tape format which should be applicable to a wide variety of uses. Error-detection where practical is included. Familiarity with actual mechanisms of handling magnetic tape is not necessary for the person operating the package. However, prudence must be exercised in recording on magnetic tape to insure that previously recorded data is not overwritten. For this purpose, it is suggested that Magnetic Tape Logs be maintained for each magnetic tape in use.

Files

For proper identification with the Magnetic Tape System, the leading block, and only the leading block, must have a Check Sum which identifies it. This identification block may or may not be the loader for the rest of the file. The check sum of the leading block must be the decimal identification code:

TT BBB DD

where "TT" is the magnetic tape number
"BBB" is the file identification number
"DD" is available for the programmer's use.

The file identification number, digits "BBB" of the check sum, must be numbered sequentially in decimal, i.e., the identification number for file number 1 would be 001; the identification number for file number 150 would be 150.

Blocks

Each file on the magnetic tape will contain a variable number of blocks as fits the needs of the situation. The check sum, in general, of any block within a file, with the exception of the leading block, can be as the programmer desires. Only the leading block is used for identification. Blocks of information on the magnetic tape can also be variable in length as zeros are processed out before writing on magnetic tape.

File Codes

In order to insure proper operation with this Magnetic Tape System, it is recommended that all recording on the Magnetic Tapes be done with MTPR. Where this is not feasible, it is recommended that blank space be left in front of and following each FILE CODE. In MTPR, this space is generated by allowing the Magnetic Tape Unit to read forward for 5 drum revolutions before and after writing a FILE CODE.

Magnetic Program Tape

Magnetic Tape No. 1 has been designated as the Magnetic Program Tape. This tape will operate from Magnetic Tape Unit No. 1 and hence certain restrictions are included in the MTPR for reading and writing on Unit No. 1. Whenever Unit No. 1 is detected, a characteristic signal is given and the computer will halt before obeying the instruction. It is hoped that this innovation will somewhat alleviate the danger of overwriting the Magnetic Program Tape.

Magnetic Tape Service Routines

Two Magnetic Tape Service Routines are included within the PPROMPT package. These routines are the Magnetic Tape Preparation Routine and the Magnetic Tape Search Routine. Both of these routines, which have been previously issued as Users Projects (at least in part), are modified for operation from Magnetic Tape.

LIST OF MTPR INSTRUCTIONS

All instructions are to be followed by "tab s." N = Magnetic Tape Unit Number (1, 2, 3, 4). "de" is line of computer, where indicated

	N 1	Search Magnetic Tape, Forward, Type Check Sum
	N 2	Search Magnetic Tape, Reverse, Type Check Sum
	N 3	Read Magnetic Tape, Type Check Sum
de	N 4	Read Magnetic Tape, Type Check Sum, Transfer Contents to line "de"
	N 5	Read Magnetic Tape, Type Check Sum, Punch Paper Tape
	N 7	Read Paper Tape, Type Check Sum, Write Magnetic Tape
de	N 8	Type Check Sum line "de", Write Magnetic Tape
	N U	Write FILE CODE on Magnetic Tape
	N V	Initialize Magnetic Tape
	N W	Locate Clear File
	Y	Locate File Indicated
	Z	Return to PPR

MAGNETIC TAPE NO. LOG

Page ______

ID NO.	PROGRAM	PROGRAMMER	BLOCKS

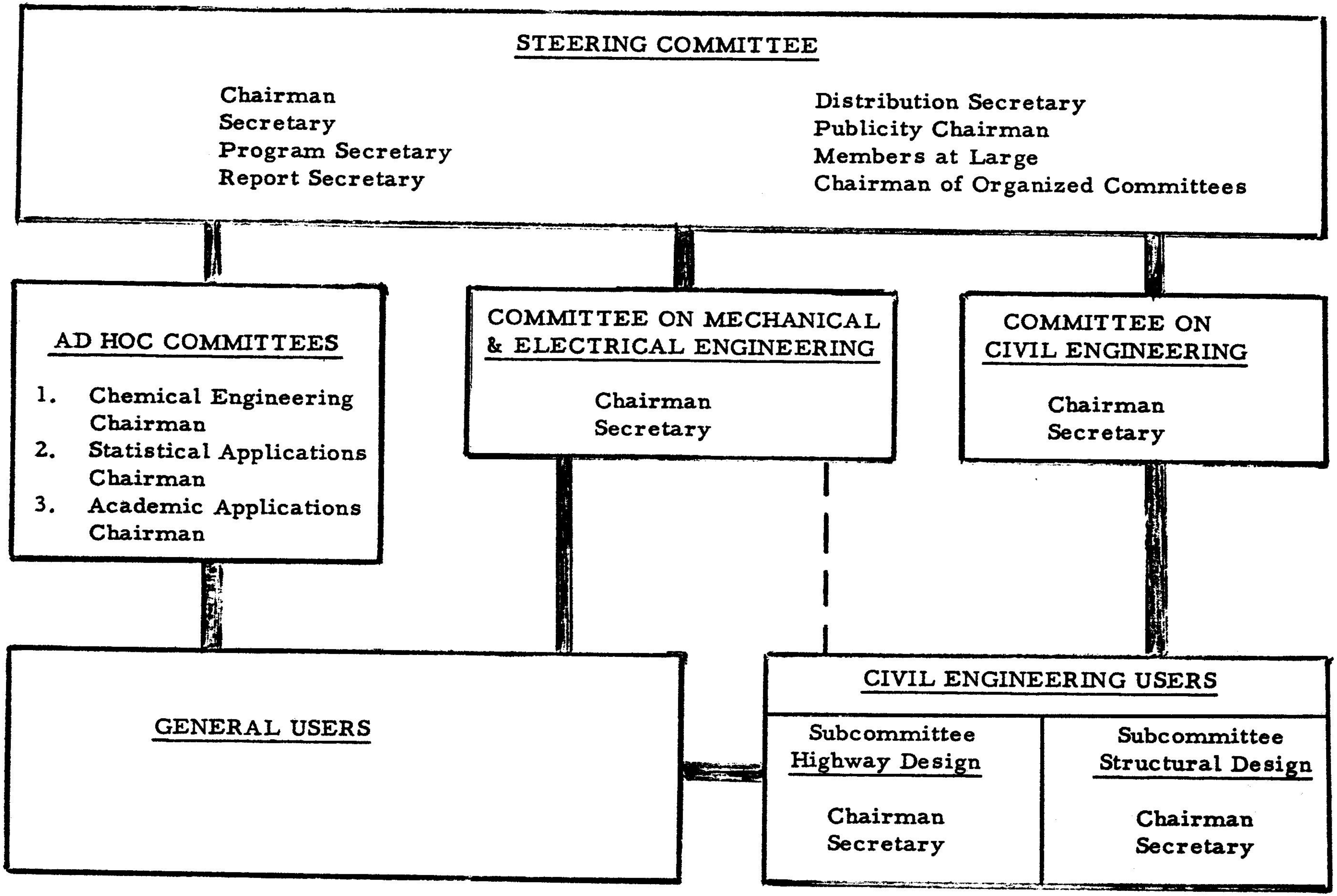
G-15 MAGNETIC TAPE FILE ALLOCATION CHART

TAPE NUMBER: ____________ PROGRAM ______________________________

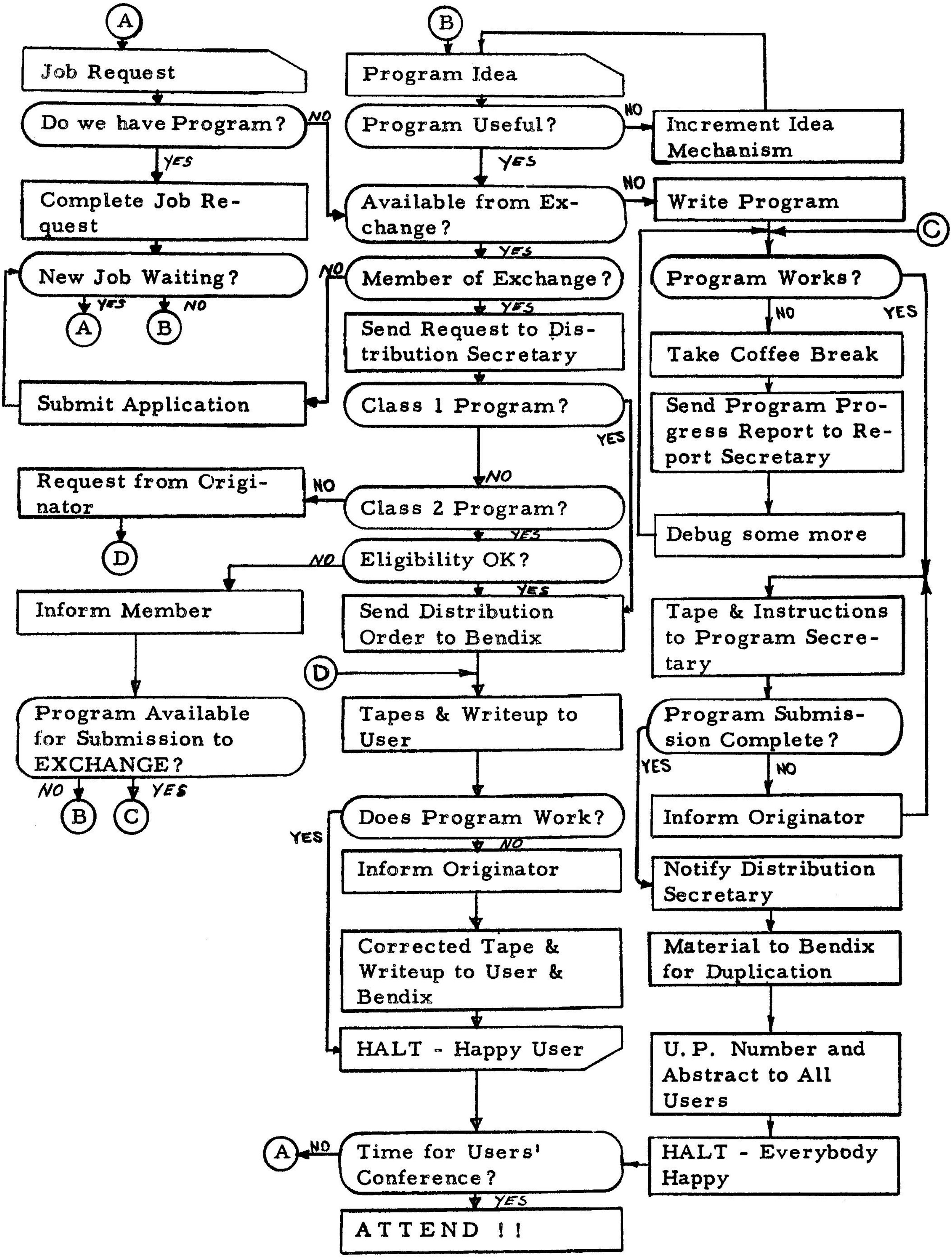
FILE NUMBER: ____________ PROGRAM NO. ____________ DATE ____________

BLOCK NO.	LINE NO.	CHECK SUM	CHK. SUM LOCATION	REMARKS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

EXCHANGE ORGANIZATIONAL CHART



EXCHANGE ORGANIZATION FLOW SHEET



G-15 USERS EXCHANGE
NEWSLETTER

Volume I Issue 6 August 1960

CONFERENCE ISSUE

FIFTH NATIONAL BENDIX G-15
USERS EXCHANGE CONFERENCE

AUGUST 10 - 12, 1960

THE PITTSBURGH HILTON
PITTSBURGH, PENNSYLVANIA

AGENDA FOR THE VARIOUS WORKSHOP SESSIONS WILL BE FOUND THROUGHOUT THIS ISSUE.

Dear G-15 Member:

Your Publicity Chairman, Mr. Harvey Chiat, has asked me to say a few words as the outgoing Chairman.

First of all, I am very pleased that our NEWSLETTER has achieved full status in the past year. It has done what it is supposed to do, that is, to inform you with minimum delay on important developments related to the Exchange and and the G-15. This issue is a good example. Much credit should go to Harvey for a job well done.

It would indeed be most difficult for the Exchange to operate without the backing of the Bendix Computer Division. The Steering Committee has also received full cooperation from them in carrying out our policies. On behalf of the Exchange, I wish to express our appreciation to Bendix and in particular to Mr. Tak Yamashita.

Tak not only has been an excellent liaison and secretary, but has contributed many sound ideas in furthering Exchange.

This conference has been planned by the program committee made up of Bonnar, Yamashita, Salter, Fedde, and Davis with Bob Bonnar as its Chairman. Our thanks to the committee.

I would be the last one to say that everything is rosy. There are still many things that should be done to improve the functions of Exchange. I am very glad that your Steering Committee has elected Mr. Paul Fedde as its Chairman. As you know, Paul has already contributed much to us, and is well qualified for this job. With your support, I am certain he will lead us to new heights.

I am grateful for the opportunity to serve on your Steering Committee, and I shall long remember my association with the Exchange.

Sincerely yours,

Jerry C. L. Chang, Chairman
Steering Committee

PAUL FEDDE ELECTED NEW STEERING COMMITTEE CHAIRMAN

The Steering Committee has elected Mr. Paul Fedde the Chairman of the G-15 Users Exchange Organization for the 1960-1961 year. Mr. Fedde is a Senior Research Engineer in the Planning and Research Department of the Texas Gas Transmission Company.

Mr. Fedde holds B.S. and M.S. Degrees in Chemical Engineering and a M.S. Degree in Gas Technology. He is a member of the American Gas Association Subcommittee on Computer Applications. He has been associated with the Bendix G-15 Computer since January 1957.

The G-15 Users Exchange NEWSLETTER is the official publication of the G-15 Users Exchange Organization. The opinions expressed are those of the contributors and not necessarily the opinions of the G-15 Users Exchange Organization, the Steering Committee, or the Bendix Computer Division.

NEW STEERING COMMITTEE OFFICERS NAMED

✓Chairman:

Paul Fedde
Texas Gas Transmission
416 West Third Street
Owensboro, Kentucky

Report Secretary:

Jack Russell
The Ohio Oil Company
Refining Division
Robinson, Illinois

Program Secretary:

Arthur Squyres
E. I. duPont de Nemours & Co., Inc.
Eastern Laboratory
Gibbstown, New Jersey

Distribution Secretary:

Albert K. Spaulding
Tippetts-Abbett-McCarthy-Stratton
375 Park Avenue
New York 22, New York

✓Publicity Chairman:

William Davis
Applied Mathematics Division
Hercules Powder Company
Wilmington 99, Delaware

General Secretary:

Tak Yamashita
Applications Section
5630 Arbor Vitae Street
Los Angeles 45, California

Members-at-Large:

Andrew R. Barkocy
Vogt, Ivers, Seaman & Asso.
34 West Sixth Street
Cincinnati 2,Ohio

D. C. Baxter
Computation and Simulation Group
Mechanical Engineering Division
National Research Council of Canada
Building M2, Montreal Road
Ottawa, Ontario, Canada

John B. Cox
The Chemstrand Corporation
Decatur, Alabama

Robert L. Watson
Department 465
Bendix Radio Division
Baltimore 4, Maryland

NEW EXECUTIVE COMMITTEE MEMBERS, COMMITTEE ON CIVIL ENGINEERING APPLICATIONS

Chairman:

Lewis Crawford
Wilson and Company
631 East Crawford Avenue
P. O. Box 28
Salina, Kansas

General Secretary:

Basil Mikhalkin
Applications Section
Bendix Computer Division
5630 Arbor Vitae Street
Los Angeles 45, California

Subcommittee on Structural Design

✓ Chairman:

Albert K. Spaulding
Tippetts-Abbett-McCarthy-Stratton
375 Park Avenue
New York 22, New York

Secretary:

John T. Potts, Jr.
Reynolds, Smith, and Hills
227 Park Street
Jacksonville 1, Florida

Members-at-Large:

John Cail Crane
Dept. of Highways
County of Cook
130 North Wells Street
Chicago 6, Illinois

David B. Martin
Palmer and Baker Engineers, Inc.
P. O. Box 346
Mobile, Alabama

Subcommittee on Highway Design

Chairman:

Andrew R. Barkocy
Vogt, Ivers, Seaman & Associates
34 West Sixth Street
Cincinnati 2, Ohio

Secretary:

Oliver Landry
John F. Meissner Engineers, Inc.
300 West Washington Street
Chicago 6, Illinois

New Executive Committee Members, Committee on
Electrical and Mechanical Engineering Applications

✓ Chairman:

Eugene Cristofano
International Engineering Co., Inc.
74 New Montgomery Street
San Francisco, California

General Secretary:

Tak Yamashita
Bendix Computer Division
Los Angeles 45, California

Members-at-Large:

Benjamin Bloomfield
Computer Division
Fellows Gear Shaper Company
Springfield, Vermont

Richard Dobrovolny
Stanley Engineering Company
Hershey Building
Muscatine, Iowa

A third member-at-large will be elected during the Electrical and Mechanical Engineering Workshop.

BASIC EXCHANGE WORKSHOP AGENDA

3:45 P.M. - 5:00 P.M., August 11, 1960

Ballroom 3
Pittsburgh Hilton
Paul A. Fedde, Chairman

The program for this session will include a complete description of the operation of the G-15 Users Exchange Organization. Mr. Fedde, as the new Chairman of Exchange, is a well qualified speaker on this subject.

THIS SESSION IS A MUST FOR ALL NEW MEMBERS OF THE G-15 USERS EXCHANGE ORGANIZATION.

MTA WORKSHOP AGENDA

3:45 P.M. - 5:00 P.M., August 11, 1960

Brigade G
Pittsburgh Hilton

Discussion of Magnetic Tape Service Routines by Don E. Hassell

Discussion of PPROMPT Routine by Harvey J. Chiat

Discussion of Magnetic Tape Programming Techniques

ANNIVERSARY CONGRATULATIONS

Congratulations to the following Users who celebrated anniversaries of G-15 installations during July and August.

The Chemstrand Corporation
Hercules Powder Company
Charles W. Cole & Son
University of Arkansas
Stanley Engineering Company
Allied Research
Shell Development Company
Continental Oil Company
E. I. duPont de Nemours
Portland Cement Association
John F. Meissner Engineering
B. F. Goodrich Company
North American Aviation, Missile Division
The Mead Corporation
Texas Research Association
Lumnus Company

WELCOME TO NEW USERS EXCHANGE MEMBERSHIP

On behalf of the Steering Committee, we would like to welcome the following installations to membership in the G-15 Users Exchange Organization:

Amalgamated Wireless (Australasia), Ltd.	Sydney, N.S.W., Australia
Corn Products Co.	Argo, Illinois
Dow Chemical Co., Rocky Flats Plant	Denver, Colorado
Dow Chemical Co.	Pittsburgh, California
E. I. duPont de Nemours & Co. Inc., Film Dept.	Wilmington, Delaware
Ebasco Services, Inc.	New York, New York
Fordham University, Physics Dept.	New York, New York
General Electric Co., Flight Prop. Div.	Cincinnati, Ohio
Jones and Laughlin Steel Corp.	Pittsburgh, Pennsylvania
Ledex, Inc.	Dayton, Ohio
Panhandle Eastern Pipeline Co.	Kansas City, Missouri
Research, Inc.	Minneapolis, Minnesota
Sacramento Peak Observatory	Sunspot, New Mexico
Systems Development Corp.	Lodi, New Jersey
Systems Development Corp.	Santa Monica, California
Institute of Geophysics, UCLA	Los Angeles, California
USA Signal Eng. Research and Dev. Lab.	Belmar, New Jersey

REVIEWERS NEEDED FOR "COMPUTING REVIEWS"

A new journal entitled, COMPUTING REVIEWS, is now being published by the Association for Computing Machinery. It will appear within the covers of COMMUNICATIONS OF THE ACM. The primary purpose of the journal is to provide critical information on what is being published of significance in the broad area of computers, anywhere in the world, in any language.

There is a need for competant people in the various computer fields to participate in reviewing books and papers for the journal. Each reviewer will be asked to review from five to ten papers (fewer books) and evaluate them for publication.

Those who are interested in participating in this endeavor are urged to contact Mr. John W. Carr, III, Editor, ACM Computing Reviews, P. O. Box 1184, Chapel Hill, North Carolina.

NEW PROJECT NUMBERING SYSTEM ADOPTED

In order to make the numbering of both Applications Section and Users Projects more uniform, the following plan has been adopted for numbering the projects:

> The project number will be followed by a dash, class number, and revision letter. For example, Project No. 494, a Class I program, Second Revision, would be numbered 494-1B.

POGO WORKSHOP AGENDA

3:45 P.M. - 5:00 P.M., August 11, 1960

Ballroom 4
Pittsburgh Hilton
J. Myers, Chairman

1. The New Pogo Tapes and Their Functions
2. Use of Region 80
3. Special Commands (including Line 19 Precession)
4. Special Accumulators
5. Milling Coding
6. Commands to be Used with Care
7. Ways to save time and memory space

CATEGORIZED PROGRAM INDEX

A Cross-Index of the programs in the Exchange Library, arranged in categories of application, has recently been issued. The index is designed to aid in finding programs to meet specific requirements, with ease.

The Cross-Index was prepared by the Applications Section of the Bendix Computer Division, for which they deserve a vote of thanks for a job well done.

INTERCARD AND CA-2 WORKSHOP AGENDA

9:00 A.M. - 12:00, August 12, 1960

Chartiers B
Pittsburgh Hilton
Robert Noel, Chairman

1. Presentation of double precision Intercard system
2. Review of single precision Intercard system
3. The presentation of an off-line monitor system for Intercard
4. Discussion of commercial Autocard system
5. Discussion of CA-2 Programming Techniques

INTERCOM WORKSHOP AGENDA

2:00 P.M. - 3:30 P.M., August 11, 1960

Ballroom 4
Pittsburgh Hilton
Robert U. Bonnar, Chairman

1. Survey of interests of those present.
2. Discussion of Scope of Application of the various Intercoms
3. Discussion of subroutine developments
4. Interconvertibility of Pseudocodes
5. Role of accessories of Intercom programming, especially the alphanumeric typewriter

Items 2, 3, 4, and 5 will be developed in accordance with the interests of the workshop participants.

NOTICE TO USERS ENGAGED IN CLASSIFIED MILITARY WORK

Various members of the G-15 Users Exchange Organization may be interested in applications of the G-15 to classified military work. Those persons who would be interested in forming a committee for such applications are requested to contact Dr. William Sollfrey of General Mills, Inc., during this conference.

ELECTRICAL AND MECHANICAL ENGINEERING WORKSHOP AGENDA

9:00 A.M. - 12:00, August 12, 1960

Ballroom 4
Pittsburgh Hilton

9:00 - 10:30	Introductory remarks - W. Sollfrey Papers by: Dr. D. Baxter, "2 x 2 Complex Matrix Program" E. Cristofano, "Penstock Speed and Pressure Rise Problems" H. Van Gerpen, "Machinery Applications of the G-15D" J. Potts, "Flexibility Analysis"
10:30 - 10:45	Coffee break
10:45 - 12:00	General discussion of E. & M. Applications Presentation of new officers

STRUCTURAL ENGINEERING WORKSHOP AGENDA

9:00 A.M. - 12:00, August 12, 1960

Chartiers A
Pittsburgh Hilton

9:00 - 9:30	Discussion of the two structural papers presented on the main program, Committee on Civil Engineering Applications
9:30 - 10:00	Presentation of "Beam Deflections Program" by Lew Crawford, Wilson and Company
10:00 - 10:30	Discussion of progress by Civil Engineering Users since the last conference
10:30 - 10:45	Coffee break

APPLICATION OF MATRICES TO STRUCTURES

10:45 - 12:00	This period will be devoted to a short paper on the application of matrices to simple structures and other presentations and comments by various Users. (It is planned that those taking part in this discussion will speak from rough notes on the application of matrices that they have made or expect to make to various structures, or how matrix algebra could be used on programs already written.)

INTERSECTION OF LINES AND CIRCLES PROGRAMS

The Cook County Highway Department has recently issued two Intersection Programs through the Exchange Library.

Users Project No. 476, entitled "Multiple Intersections of Circles and Lines," will solve up to 18 different line and circle intersection problems. The program is written in Intercom 1000-D and contains an automatic P loader and data entry routine. Output includes the original data, two points of intersection, distance from these points to the point given on the line, and the azimuth from the center of the circle to these points. The running time is approximately one minute per problem.

Users Project No. 486, "Intersection of Two Lines-Multiple Input," will solve up to 15 different intersection of two line problems. The program which contains an automatic P loader and data entry routine, is written in Intercom 1000-D. The output gives the complete geometry of the triangle formed by the two given points and the intersection. Running time is approximately one minute.

Both of these projects are Class I and are available through the Exchange Library.

WATER DISTRIBUTION SYSTEM ANALYSIS PROGRAM

Reynolds, Smith and Hills have announced a revision to the Water Distribution System Analysis Program written in Intercom 500x. This program is a rewrite, in Intercom 500x, of the original program which was written in Intercom 101 by Midwest Computer Service. The program is a Class II project.

This program is available through the Exchange Library by requesting Users Project No. 215, Intercom 500x Revision.

ALPHANUMERIC TYPEWRITER PROGRAMS

The Exchange Library has recently received a number of programs for control of the Alphanumeric Typewriter. Since there are now a number of these programs available through the Exchange Library, it is suggested that Users investigate these before writing their own.

BENDIX COMPUTER DIVISION ACCESSORIES

9:00 A.M. - 12:00, August 12, 1960

Ballroom 3
Pittsburgh Hilton
Roger Mattson, Chairman

The capabilities of each accessory in the G-15 product line will be discussed. The discussion will be based on the use of the various accessories in given applications.

INTERCOM 500X LISTING

A method has been found whereby Intercom 500x programs may be started and stopped while listing without halting computation.

The method for doing this is first to set up the lister as specified by the Intercom 500x Manual while the routine is in the manual mode. Then do not type the starting command, 69CHWD; instead type 620000. Hereafter, listing will start when an 080803 command is given and listing will stop with a 080860 command. During the time the program is not being listed, computation willproceed at the normal operating speed.

G-15 USERS EXCHANGE
NEWSLETTER

CODERS' CORNER

The items included in this section have been submitted by various Users as an aid to programming. If you have any questions regarding any of these items, please communicate with the Editor of the NEWSLETTER.

INTERCOM 500x DOCUMENTOR

In order to produce a satisfactory documentation of an Intercom 500x program, the format for typeout of commands, located within the system at 0408 and 0409 (currently 10000000 and 8w00001- respectively) must be set to 0120088 1240249. After making this replacement, set Word Base K to the location of the initial command of the program, Word Difference K to 1, and Word Limit K to the location of the final command of the program. The execution of the following program will produce quite satisfactory results.

```
    K 31 0000
    K 35 0000
LOC K 76 LOC-2
      67 0000
```

If it is desired to document on Intercom coding forms, set the left typewriter margins at the position for the first digit of location output and a tab stop in the K column of the form.

One method of inserting the necessary format changes is by the execution of the following sequence, with the computer in the manual mode.

```
Type   0120088 tab 0422301 tab s
                    420408 tab s

       1240249 tab 0422301 tab s
                    420409 tab s
```

CORRECTION

In the Article entitled "1000D Incrementation Beyond Word 99," on page 5 of the July NEWSLETTER (Issue 5), an error has been noted. The first line indicated in the changes should read:

Machine Language Command		Intercom Form	Location in Intercom
u.10.20.1.22.29	=	046xxul	01.07

CODERS' CORNER (Cont'd)

MACHINE LANGUARE P LOADER FOR INTERCOM 1000 PROGRAMS

The usual method for entering an Intercom 1000 program prior to computation calls for the read-in of a loading routine by a manual command of the form 055CH00 followed by another manual command of the form 069CHWD. This routine allows the loader to be read into line 19 with the P key, and when the compute switch is moved to go, allows for the transfer of the loader to the desired channel and the initiation of Intercom computation at the desired word position in this channel. This routine uses word positions 00 and u0 through u6 in the loading channel; the actual Intercom program in this channel can be put into locations 01 through 99.

Intercom 1000 S - P Loader

Location	Decimal Command	Notes
.00	.01.u0.6.21.31	Next command from 19.u0
.u0	u.u1.u1.0.19.CH	Transfer line 19 to line CH
.u1	w.64.u2.0.00.20	Transfer the contents of 00.64 to 20.00
.u2	w.87.u3.0.03.00	Transfer the contents of 03.87 to 00.87
.u3	w.u4.u5.0.19.22	Transfer the contents of 19.u4 to 22.00
.u5	.u6.87.0.21.31	Next command from 00.87
.u4	.NN.17.0.CH.28	Command for initiation of Intercom computations at CH.NN+1

Intercom 1000 D - P Loader

Location	Decimal Command	Notes
.00	.01.u0.6.21.31	Next command from 19.u0
.u0	u.u1.u1.0.19.CH	Transfer line 19 to line CH
.u1	w.u2.u4.0.19.28	Transfer the contents of 19.u2 to AR
.u4	w.01.u5.0.28.00	Transfer the contents of AR to 00.01
.u5	w.u3.u6.0.19.22	Transfer the contents of 19.u3 to 22.03
.u6	.u7.01.0.21.31	Next command from 00.01
.u2	w.03.04.0.22.26	Commands for initiation of Intercom
.u3	.NN.19.0.CH.28	computation at CH.NN+1

Preparation and use of P loaders:

1. Prepare P loader with PPR and punch tape.
2. Read in Intercom magazine.
3. Read in P loader with a 055CH00 Intercom command.
4. Type in Intercom loader starting at CH.NN+1.
5. Punch channel CH. (Note: Since the P loader uses locations u0 to u6, care must be taken in reproducing tapes if between read-in and punch-out, the index register in channel CH has been used.)
6. Loader will now operate, after reading in Intercom, by typing P with enable on and then moving enable to off and compute to go.

CODERS' CORNER

The items included in this section have been submitted by various Users as an aid to programming. If you have any questions regarding any of these items, please communicate with the Editor of the NEWSLETTER.

INTERCOM 103 PUNCH ROUTINE MODIFICATION

If paper tape is punched from a section of Intercom 103 interpretive memory in which some of the numbers were left from earlier (non-Intercom 103) operations, an erroneous end-of-record signal may be generated. If at least one number is in the range zzzzz00≤N≤zzzzzzy, it will be taken by the Intercom tape read routine (code 09) as the end-of-record signal. This may result in incomplete loading of the tape. To ensure that only zzzzz00 will be taken as the end-of-record signal, make the following modifications.

Block	Check Sum	Location	Hex Number
B.S. #1	-.vxy6983	.26	.7v4zz8w
		.31	.4zx3w64
		.45	.889w825
B.S. #2	-.wwy6983	.25	.72z417y
		.30	.u82uzxy

Block	Check Sum Old	Check Sum New	Location	Decimal Command
Line 02	-.v02v7w0	-.v02w39w	.53	.54.56.3.28.27
			.56	w.58.98.1.21.31
			.57	.58.75.0.31.28
Interpreter Line 04	.7y54uw3	-.8x0vy82	.05	.44.99.0.26.31
			.37	u.39.85.0.00.00
			.38	.40.37.0.29.31
			.99	.u3.40.0.25.21
Line 16	-.84xz074	-.84v0074	.u4	u.u5.38.0.04.01

CODERS' CORNER

The items included in this section have been submitted by various Users as an aid to programming. If you have any questions regarding any of these items, please communicate with the Editor of the NEWSLETTER.

CORRECTION

A typographical error has been noted in the "Intercom 103 Punch Routine Modification" item in the May NEWSLETTER, Issue 5. The first location after Block B.S. #2 should be .23 not .25.

1000D INCREMENTATION BEYOND WORD 99

In some cases it may be desirable to increment an index register to words u0 thru u7. The Standard Intercom 1000D gives an error signal if this is attempted. It can be changed to permit incrementation beyond word 99 by making the following changes:

Machine Language Command		Intercom Form	Location in Intercom
u.10.20.1.22.29	=	0826180	01.07
u.00.07.2.21.28	=	07uvw00	01.u6

These changes can be made with a Machine Language Subroutine, such as in a P Loader, or in Intercom. To make them as part of an Intercom Program, proceed as follows:

Store Intercom Commands

Even Location = CH(XX) = 098xy80
CH(XX+1) = 0826180

Even Location = CH(YY) = 07uvw00
CH(YY+1) = 152vz51

Program Steps

1. 042CHXX
2. 0490106
3. 042CHYY
4. 04901u6

G-15 USERS EXCHANGE
NEWSLETTER

CODERS' CORNER

The items included in this section have been submitted by various Users as an aid to programming. If you have any questions regarding any of these suggestions, please communicate with the Editor of the NEWSLETTER.

Decrement AR by 1×2^{-28}

The command

T.N.7.28.28

as a deferred command with decrement the contents of AR by 1×2^{-28} provided AR is positive. As a block command it must start at even word time and will subtract 1×2^{-28} from AR for each two word times of execution.

Modifications of Intercom 1000 for use of Clary Add-Punch

The Intercom 1000 S.P. and D.P. Flexowriter Input Subroutines may be modified for operation with a Clary single-precision adding-machine tape punch by changing the subroutines as follows:

INTERCOM 1000 S.P.

(for off line data or program tapes)

Change Word	from	to
05	wwwwwww	8888888
10	3333333	1111111
u6	xv9u709	9xzz291

INTERCOM 1000 D.P.

(for off line program tapes)

Change Word	from	to
18	wwwwwww	8888888
24	3333333	1111111
u6	xvu69y1	245961z

When the above changes are made, the code 8888888 indicates the end of a block of tape. All other specifications for the Flexowriter Input Subroutines remain the same as published.

Note: The check sums of both subroutines must remain unchanged for correct loader operation.

Use of "Select Command Line and Return" Command

In the command

L_k.N.C.20.31

In order to facilitate single-cycle operation during debugging, it is recommended that this command be written with N = n7, whenever it is desired to return to mark. With the command written in this manner, the next location will be the marked location, whether in single-cycle or continuous operation.

A restriction on this is that the location of the mark must be equal to or greater than L_k. There does not appear to be any way to avoid difficulty in single-cycle operation, when this command is used as an unconditional transfer.

CODERS' CORNER

The items included in this section have been submitted by various Users as an aid to programming. If you have any questions regarding these methods or if you find they do not work on your computer, please communicate with the Editor of the Newsletter.

Rewind Magnetic Tape by Blocks

A good method for rewinding Magnetic Tape on block is to give the following commands:

(1) Search Magnetic Tape Reverse

(2) Set Type In

(3) Test Ready

Note: The "Set Type In" should follow immediately after "Search Magnetic Tape Reverse."

Normalize and Shift Commands

The normalize and shift commands may be given in even word locations. They operate for an even or odd number of word times. The odd half of the register is shifted during the odd word time and the even half during the even word time. The 1 bit is added to AR during the odd word time and on the normalize command, tests during the odd word time. The even word will not be shifted the last bit. This permits shifting either the odd or even word 1 bit more than the other. This method must be used with caution on double precision numbers.

Negative Zero as a Sentinel

A negative zero will not be confused with a number or command. A zero resulting from computation (+ or -) will have a + sign (i.e., it will be a true machine zero). A single command which tests whether the contents of AR is not -0 is:

T.N.3.28.27
If (AR) = -0, go to N+1.

NEWS FROM THE COMPUTER DIVISION

ALGO ROUTINE

Master tapes and the programming manual for the ALGO system have been completed. It is anticipated that reproduction of the tapes and programming manual for use will be completed by the end of August. This system will be described during the Users Conference in Pittsburgh.

INTERMAP

The Intermap Routine has been completed and will be presented at the Users Conference. Demonstration of this system will be given upon request by those attending the Exchange Conference.

ALPHABETIC ROUTINE

This routine has just been completed. It allows for continuous input of alphabetic information.

ALPHABETIC CORRECTION ROUTINE

This routine allows for the up-dating of portions of information on the drum without having to retype all the data.

PA-3 PLOTTING ROUTINE

This routine is being written for the purpose of plotting highway cross section.

G-20 USERS GROUP MAKES PLANS FOR FORMAL ORGANIZATION

Plans to establish a formal organization were made when the second G-20 Users Conference was held recently in South Bend, Indiana with 50 persons in attendance. The Bendix Products Division was host.

The next conference will be held in Los Angeles during the latter part of this year. Meantime, ballots are being sent to members who will vote to fill the offices of chairman and secretary.

Three committees were established at the conference. These are: standards, with Robert Noel of North American Aviation, Inc., as chairman; by-laws and nomination, William Anderson, Bendix Mishawaka Division, chairman; and data processing, Max Waggoner, Bendix Products, chairman. Tak Yamashita, applications manager, represents the Computer Division on each committee.

FOPEANO NAMED EASTERN REGION MANAGER

Robert P. Fopeano has been named eastern regional manager. He has been New York district manager for the past two and a half years.

Dear G-15 Member:

With this issue, my term as Editor of the NEWSLETTER comes to an end. I would like to thank all of you for your contributions and words of encouragement. Without your contributions, especially to the "Coders' Corner," this publication could not have been a success.

A word of thanks goes to all of the Steering Committee Members, whose help is getting news items has been a great help. Special thanks goes to the Bendix Computer Division Applications Section headed by Mr. Tak Yamashita who has been responsible for reproducing, collating, and distributing the NEWSLETTER.

Sincerely yours,

Harvey J. Chiat
Editor

MINUTES OF THE POGO WORKSHOP
Fifth Users' Conference

The POGO workshop was opened by Chairman Joe Myers of Bendix Computer with a brief history of POGO and a statement of the capabilities of the present system.

Since a majority of the 25 persons present had not used POGO, an explanation of its structure and use was given. The following topics were then discussed:

Regional Programming
Use of Region 80
Special Commands
Milli-coding
How to Compile Faster Programs.

The problem of repeated long assembly and compiling times during debugging was to the group's attention. Regional programming and debugging was recommended as a solution.

The meeting concluded with a discussion of the relative speeds and ease of programming of POGO, Intercom and Machine Language.

ELECTRICAL AND MECHANICAL ENGINEERING WORKSHOP

The meeting was opened with a talk by Dr. William Sollfrey of General Mills telling the members of this section of the past year's activities. Mr. Sollfrey mentioned a meeting held in Detroit during April, 1960, where members of the Mechanical and Electrical Section discussed particular problems concerning machine design. Mr. Sollfrey also announced the results of a recent ballot electing Mr. E. A. Cristofano of International Engineering as the chairman of the section for the coming year and Mr. Dobrovolny of Stanley Engineering Company as the secretary.

Mr. Sollfrey then introduced the first speaker, Dr. Don Baxter of National Research , who presented a talk concerning a program he has designed to solve a 2 x 2 complex matrix. Mr. Baxter explained his program with two examples of problems found in electrical engineering. Mr. Baxter's program was found quite interesting among those in attendance.

Upon conclusion of Mr. Baxter's talk, Mr. Sollfrey introduced Mr. Cristofano as the next speaker. Mr. Cristofano told of using the Bendix Computer for the solution of the many problems found in the field of hydro-electric development. He explained the steps which are usually followed from the initial planning to final design of the integral features of the hydro-electric development. He also pointed out in brief, the areas where specific use had been made of the computer to solve problems in the electrical and mechanical engineering fields related to the overall design of the hydro-electric development.

The next speaker introduced by Mr. Sollfrey was Mr. C. R. Reese of the John Deere Tractor Company who gave a talk concerning the many programs his company has developed in the field of mechanical engineering. Mr. Reese's talk concerned many programs written for gear and cam design. His talk was enlightening, and his programs generated qhite an interest among the members present in the meeting. Mr. Reese informed the section that he intends to make some of the programs his company has written available to the users group.

Mr. H. B. Ellis was introduced as the next speaker and he presented an excellent talk concerning the mechanical engineering aspects of the design of multiple anchors. Mr. Ellis told how the program developed for this particular application was used and how the addition of each anchor could be handled within the program.

Thirty-five members attended this meeting and the interest seemed to be equally divided among the mechanical, electrical and electronic fields.

Mr. Harvey Chiat of General Mills nominated Mr. Don Baxter as the fourth member of the Electrical and Mechanical Engineering Applications Committee. Mr. Baxter was then elected as the fourth member by a voice vote.

Dr. Sollfrey then introduced Mr. E. Cristofano as the next year's chairman and Mr. Cristofano presided as chairman until the conclusion of the meeting.

It was suggested by Mr. Cristofano that a letter would be sent to all members of the section periodically asking for information as to their activities so that this information could be incorporated in the users Newsletter.

All new users were invited to contact any of the older users within the section if they found any particular problem they felt the older user might be of assistance.

All members were encouraged to turn in programs they have available to the users group and to share information through the previously mentioned year so that a minimum of duplication effort might be accomplished.

ABSTRACT OF PAPER GIVEN TO ELECTRICAL AND MECHANICAL ENGINEERING WORKSHOP - G.15 USERS CONFERENCE, Aug.12,1960

2 x 2 COMPLEX MATRIX ALGEBRA PROGRAM

D. C. Baxter

This Intercom 1000DP program (Users Project No. 504) allows a variety of operations to be performed on 2 x 2 matrices with complex elements. The operations include input, output, addition, subtraction, multiplication, inversion and determinant evaluation. More important, it allows computation of so-called "transmission matrices" which are of use in the fields of electrical network theory, optical film calculations, and transient and periodic heat flow through composite slabs.

The program has been used extensively at the Building Research Division of the National Research Council to calculate heat flows and temperatures through building walls. The ambient temperature is broken up into a Fourier series, the amplitude attenuation and phase shift for each harmonic are calculated using the matrix program, and the results are recombined to give the actual temperature-time history.

PRESENTATION BY
MR. E. A. CRISTOFANO
DURING THE
ELECTRICAL AND MECHANICAL ENGINEERING WORKSHOP

My talk today concerns the electronic computer applications we have made at International Engineering Company in San Francisco. Our company in the past several years has designed more than thirty large hydroelectric developments which are located in the United States and in many foreign countries.

The variety of related problems found in the design of a hydroelectric system are almost equally distributed over the fields of civil, mechanical, and electrical engineering. In the solutions of these varied problems, we have encountered several interesting applications for our computer.

The initial phases of the design of a hydroelectric system are for the most part concerned with system layout, computation of hydrologic and hydraulic data and the assignment of various physical parameters, such as: reservoir size and shape, number and size of turbines, power and load factors, load shape or demand requirements (electrical) of the unit or system, etc. In this initial phase, the computer plays a very important role in solving the many complex and tedious power studies which are required to determine the optimum production to satisfy the various demands on the system, so that the overall cost of generation per unit is a minimum.

Previous to the use of the electronic computer for the solution of these power studies, it was generally considered economically prohibitive to study more than two or three alternate schemes for the system where just a few parameter changes were incorporated. Today with the use of the computer, we can study twenty alternate schemes for a cost equal to that of one alternate scheme by the previous manual methods.

When the power studies are completed, the results are distributed to the civil, mechanical and electrical engineering sections for their use in furthering the design of the complete hydroelectric system.

It is at this point that we are able to use effectively our two important computer applications to accelerate solutions of time-consuming problems in the fields of mechanical and electrical engineering.

In the mechanical field, the application concerns the computation of the pressure in the closed conduit and surges in the surge chamber if required, and the speed rise in the turbine -generator unit. Another type of conduit considered is an open conduit, and in this case it is only required to compute the surge rather than the pressure within the conduit.

In the computation for speed and pressure rise for the closed conduit system, we are interested in essentially three major portions of the system; namely, the closed conduit with or without surge chamber, the turbine and the generator. In the open conduit system we are interested in the open conduit with or without forebay, the turbine and the generator. In both cases we are also interested in finding the results of the speed rise and drop of the turbine-generator unit which must be limited to maintain the system stability.

The previous paragraphs have described very briefly the general aspects of the problem concerned with speed and pressure rise computations in mechanical engineering. We have used the computer for this particular computation by designing a program in machine language that solves the problem in two stages.

The first stage of the problem determines the relationship of pressure rise in various sizes of penstocks for various governor times. The governor time is the time required to fully open or fully close the turbine regulating gates. The results are then studied and the most economical penstock diameter and corresponding governor time are selected for use in the second stage of the problem.

The second stage of the problem determines the relationship of the speed rise and drop in the combined turbine and generator unit for various values of fly-wheel effect (rotating mass) of the combined unit. When completed, the entire result of both stages of the problem are reviewed with the following factors reflecting on the final answer:

1. When the results are studied with regard to stability of the power system a maximum safe value for speed rise and drop must be assumed. Inasmuch as extra fly-wheel effect added to the generator will increase the cost, it is preferred to stay within the maximum safe value with minimum cost increases by not adding fly-wheel effect to the generator machine.

2. Since an increase in penstock diameter also will tend to reduce a possible high speed rise and drop, an evaluation must be made between the penstock cost and the cost for additional fly-wheel effect built into the governor.

3. If it should be found advisable to increase the penstock diameter, the resulting velocity change may for checking purposes require a rerun of the second stage of the problem.

This computation when performed manually required several weeks. With the computer we have been able to reduce the time requirement by weeks and the cost of computation by as much as 50%.

The application in the electrical field concerns the computation required to determine the most economical size of cable and height of tower for a single span cable crossing where the size of the cable is determined by the catenary. This particular application was programmed with the use of "Intercom 1000." The program uses basic cable data, elevation of the tower bases and the desired low point of the cable, together with a polynomial expressing tower costs relative to tower height. The program will determine the costs of the cable and tower with various combinations along an overall transmission system. The use of the computer for this particular application has saved a considerable amount of time and costs of computation. It also has enabled us to save money in the design of long transmission systems over difficult terrain.

Presentation by
Mr. C. R. Reese
during the
Electrical and Mechanical Workshop

The John Deere Tractor Research and Engineering Center is an organization which designs and develops future models of John Deere farm tractors. This group of people consists of more than 150 engineers who are engaged in designing internal combustion engines, transmissions and hydraulic systems, and other components of a farm tractor.

Because a great deal of time was being spent by engineers using desk calculators the features of a digital computer were investigated and it was determined that it could possibly be used in the design of spur and helical gears. Gear design was one of the most time consuming design problems.

In December 1956 work was initiated toward programming an IBM 650 to perform gear calculations. Three months later a trial program was placed on a machine in Minneapolis. This provided encouragement to expand the program and for the next 18 months all gear designing was done on an IBM 650 leased by our parent organization, Deere and Company, located 160 miles away in Moline, Illinois.

Because of the work load on the machine, and the distance this arrangement was unsatisfactory.

In December 1958 the Bendix G-15 D was leased by the Research and Engineering Center strictly for the purpose of performing engineering calculations. In May 1960 the original machine was exchanged for an Alpha Numeric Machine.

At present our computer group consists of three men. Two men engage in programming and assist the design engineers in design problems. The third man is employed as a machine operator and will eventually become a programmer. We do not operate the computer on a time schedule nor do we require a formal written request for work to be done. Whenever an engineer has a problem an attempt is made, time permitting, to solve the problem immediately. If the machine is busy at the moment the engineer and one of the computer staff talk over the problem and fill out an input data sheet. The data sheet is then handed to the machine operator to be worked as time permits.

The following is a list of programs which we have set up for the problems we have to solve.

Programs Available

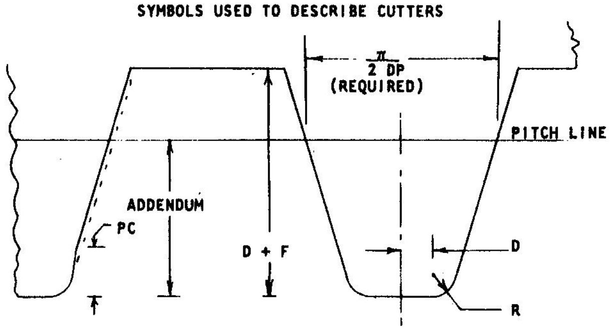
1. External Gear Design (Machine Language)
2. Internal Gear Design (Machine Language)
3. External Gear Design in the metric system (Machine Language)
4. Gear Short Line Calculation (Machine Language)
5. Spline Design (Machine Language)
6. Transmission Bearing Loads (1000-SP)
7. B-10 Life for Tapered Roller - Ball - and Straight Roller Bearings. (1000-SP)
8. Predicted Tractor Field Performance (Machine Language)
9. Shaft Deflections Over Two or More Supports. (1000-SP)
10. Harmonic Cam Design (1000-SP)
11. Polydyn Cam Design (1000-SP)
12. Steering Linkage Geometry (1000-SP)

GEAR DESIGN REQUEST

NAME ____________________

1039 PINION TEETH	1038 GEAR TEETH	1037 PINION R P M	1036 PINION TORQUE (#-IN)
1035 MASTER GEAR TEETH	1034 SHAFT CENTER DISTANCE	1033 SHAFT CENTER DISTANCE TOLERANCE(±)	1032 HELIX ANGLE (GENERATING)
1031 PINION C.D. TOL.W/MASTER GEAR	1030 GEAR C.D. TOL.W/MASTER GEAR	1029 MINIMUM ALLOWABLE TIP THICKNESS (NORMAL PLANE)	1028 DIAMETRAL PITCH (NORMAL)
1027 PINION WIDTH	1026 GEAR WIDTH	1025 FACE CONTACT WIDTH (FOR COMP. STRESS)	1024 MINIMUM BACKLASH (DESIRED)
PINION CUTTER PRESSURE ANGLE	1022 TIP RADIUS	1021 CUTTER TOOTH THICKNESS (MUST BE ½ CP)	1020 CUTTER ADDENDUM
1019 CUTTER D + F	1018 PROTUBERANCE CLEARANCE (PC)	1017 DISTANCE BETWEEN TIP RADIUS AND CUTTER ℄ (D)	1016 *SHAVING STOCK
GEAR CUTTER PRESSURE ANGLE	1014 TIP RADIUS	1013 CUTTER TOOTH THICKNESS (MUST BE ½ CP)	1012 CUTTER ADDENDUM
1011 CUTTER D + F	1010 PROTUBERANCE CLEARANCE (PC)	1009 DISTANCE BETWEEN TIP RADIUS AND CUTTER ℄ (D)	1008 *SHAVING STOCK
GIVEN DIMENSIONS	1006 PINION NOMINAL TOOTH THICKNESS (NORMAL)	1005 PINION C.D. W/MASTER	1004 PINION MEAN OUTSIDE RADIUS
1003 CONTACT RATIO (DESIRED)	1002	1001 GEAR C.D. W/MASTER	1000 GEAR MEAN OUTSIDE RADIUS

SYMBOLS USED TO DESCRIBE CUTTERS



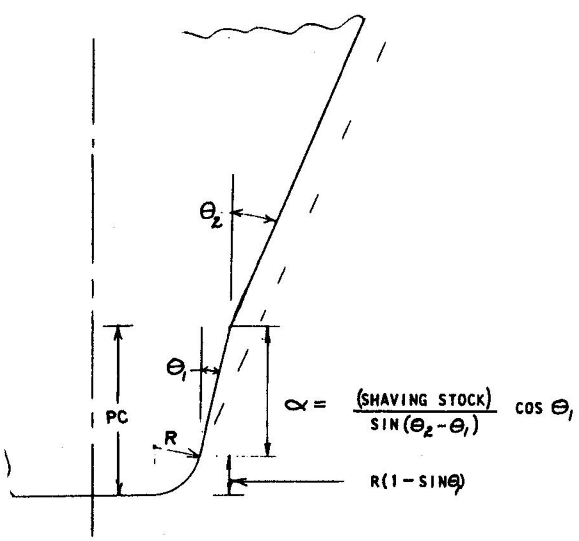
FOR A CLASS "A" HOB

$$D = \frac{\pi}{4\,DP} - (\text{"A"} - \text{"R"})\tan\phi - \frac{\text{"R"}}{\cos\phi}$$

$$PC = \text{"R"}\,(1 - \sin\phi)$$

ONLY THE PINION IS INVESTIGATED FOR UNDERCUT CONDITIONS. IF ONLY ONE GEAR OR DIMENSION IS FIXED IT MUST BE A PINION DIMENSION. EITHER OF TWO GEARS MAY BE CONSIDERED THE PINION.

* SHAVING STOCK IS CONSIDERED AS THE AMOUNT OF SHAVING MATERIAL AT THE POINT ABOVE WHICH THE MATING GEAR WILL MAKE CONTACT.



SUGGESTED PROTUBERANCE DESIGN FOR NEW HOB

FOR REASONABLE CUTTER LIFE $\theta_1 > 10°$ FOR 20° HOB
$\theta_1 > 7°$ FOR 14½° HOB

IF SHAVING STOCK = .003; α = .014 FOR 20° HOB (W/θ_1 = 10°)
(PROVIDED ON HOB) α = .023 FOR 14½° HOB (W/θ_1 = 7°)

$$PC = \alpha + R\,(.82635)_{20°}$$
$$+\ R\,(.87813)_{14\frac{1}{2}°}$$

00368 AUG 8 1960

PINION HOB ____________

GEAR HOB ____________

20500 GEAR DESIGN DATA SHEET

DATE ____________

PINION TEETH 15	GEAR TEETH 71	PINION RPM 735	PINION TORQUE 8383
MASTER GEAR TEETH 36	SHAFT CENTER DISTANCE 7.22910	SHAFT CENTER (±) DISTANCE TOLERANCE .00150	HELIX ANGLE (GENERATING) .00000
PINION C.D. TOL. W/MASTER GEAR (±) .00300	GEAR C.D. TOL. W/MASTER GEAR (±) .00550	MINIMUM ALLOWABLE TIP THICKNESS (NORMAL PLANE) .06200	DIAMETRAL PITCH (NORMAL) 6.00000
PINION WIDTH 1.62500	GEAR WIDTH 1.50000	FACE CONTACT WIDTH (FOR COMP. STRESS) 1.50000	MINIMUM BACKLASH (DESIRED) .00200
PINION CUTTER PRESSURE ANGLE 20.00000	TIP RADIUS .06000	CUTTER TOOTH THICKNESS (MUST BE ½ CP) .26180	CUTTER ADDENDUM .23850
CUTTER D + F .44950	PROTUBERANCE CLEARANCE .07770	DISTANCE BETWEEN TIP RADIUS CENTER AND HOB TOOTH CENTERLINE .00210	SHAVING MATERIAL .00100
GEAR CUTTER PRESSURE ANGLE 20.00000	TIP RADIUS .06000	CUTTER TOOTH THICKNESS (MUST BE ½ CP) .26180	CUTTER ADDENDUM .23850
CUTTER D + F .44950	PROTUBERANCE CLEARANCE .03950	DISTANCE BETWEEN TIP RADIUS CENTER AND HOB TOOTH CENTERLINE .00210	SHAVING MATERIAL .00000
GIVEN DIMENSIONS .00000	PINION NOMINAL TOOTH THICKNESS (NORMAL) .00000	PINION CENTER DIST. W/MASTER GEAR 4.32300	PINION MEAN OUTSIDE RADIUS .00000
CONTACT RATIO (DESIRED) 1.30000	.00000	GEAR CENTER DIST. W/MASTER GEAR .00000	GEAR MEAN OUTSIDE RADIUS .00000

			PINION	GEAR
PITCH LINE VELOCITY 485	CORRECTION FACTOR 1.24261	WORKING PITCH DIAMETER	2.52178	11.93642
WORKING PRESSURE ANGLE (TRANSVERSE) 21.31799	BASE PITCH (TRANSVERSE) .49202	NOMINAL PITCH DIAMETER	2.50000	11.83333
WORKING PRESSURE ANGLE (NORMAL PLANE) 21.31798	WORKING HELIX ANGLE .00000	BASE DIAMETER	2.34923	11.11970
MEAN BACKLASH .00978	MINIMUM BACKLASH .00218	MIN. ROOT RADIUS W/O UNDERCUT	1.06430	5.18507
FACE CONTACT RATIO .00000	MAXIMUM CONTACT RATIO AVAILABLE 1.35202	ROOT RADIUS	1.08897	5.65180
IS EITHER GEAR UNDERCUT PINION ☐ GEAR ☐	WORKING CIRCULAR PITCH .52816	TOOTH THICKNESS (NOMINAL NORMAL)	.31819	.24261
WHAT LIMITS THE OUTSIDE RADIUS OF THE PINION? D + F ☐ R_f ☐	TIP THICKNESS ☒ TIP CL. ☐	TOOTH THICKNESS (WORKING, NORMAL)	.31271	.20567
WHAT LIMITS THE OUTSIDE RADIUS OF THE GEAR? D + F ☐ R_f ☒	TIP THICKNESS ☐ TIP CL. ☐	CENTER DISTANCE W/ MASTER GEAR	4.32300	8.89000
PINION BALL DIAMETER .28125	GEAR BALL DIAMETER .34375	OUTSIDE RADIUS	1.47297	6.05157
PINION MINIMUM DIMENSION / BALLS 2.96840	GEAR MINIMUM DIMENSION / BALLS 12.38329	ADDENDUM	.21208	.08336
PINION MAXIMUM DIMENSION / BALLS 2.97760	GEAR MAXIMUM DIMENSION / BALLS 12.40235	DEDENDUM	.17192	.31641
PINION R_f PROFILE CHECK .21034	GEAR R_f PROFILE CHECK 1.38044	TOOTH TIP (NORMAL) THICKNESS	.09439	.13652
PINION MATING GEAR PROFILE CHECK .22500	GEAR MATING GEAR PROFILE CHECK 1.73105	X FACTOR	.09049	.10082
PINION R_f ANGLE PROFILE CHECK 10.26008	GEAR R_f ANGLE PROFILE CHECK 14.22586	BEAM STRESS	84271	81944
PINION MATING GEAR ANGLE PROFILE CHECK 10.97514	GEAR MATING GEAR ANGLE PROFILE CHECK 17.83895	ADJUSTED BEAM STRESS	73810	81159
PINION MAXIMUM OUTSIDE RADIUS OF MASTER GEAR 3.17889	GEAR MAXIMUM OUTSIDE RADIUS OF MASTER GEAR 3.24483	COMPRESSIVE STRESS	286385	CONTACT RATIO 1.28524
PINION FILLET RADIUS OF CURV. .24213	GEAR FILLET RADIUS OF CURV. .58792	PINION LEAD	.0000	GEAR LEAD .0000

DATE ______________

BEARING LOADS AND B-10 LIFE
DATA SHEET

NAME ______________

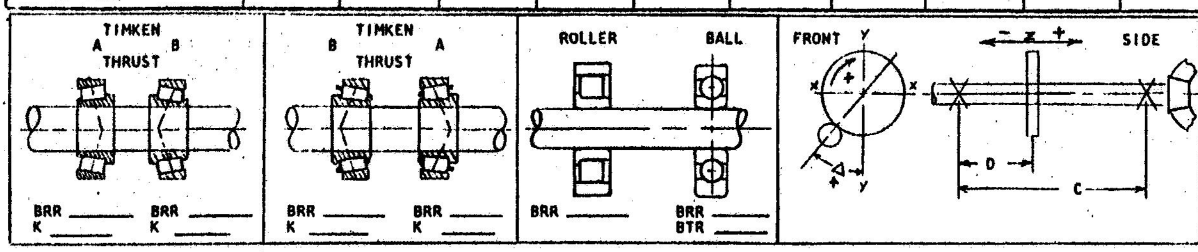
SPIRAL BEVEL GEAR DATA	SPEED 1	2	3	4	5	6	7	8	9	10	11	12	13
TORQUE ±													
PINION RPM ±													
SPIRAL ANGLE ±													
PRESSURE ANGLE ±													
N PINION													
N GEAR													
PINION PITCH DIAMETER													
FACE WIDTH													
A													
C													

STATIC LOAD	SPEED 1	2	3	4	5	6	7	8	9	10	11	12	13
X FORCE ±													
Y FORCE ±													
D ±													
C													

SPUR OR HELICAL GEAR	SPEED 1	2	3	4	5	6	7	8	9	10	11	12	13
TORQUE ±													
RPM ±													
HELIX ANGLE ±													
PRESSURE ANGLE													
PITCH RADIUS ±													
D ±													
ANGLE △ ±													
C													

SPUR OR HELICAL GEAR	SPEED 1	2	3	4	5	6	7	8	9	10	11	12	13
TORQUE ±													
RPM ±													
HELIX ANGLE ±													
PRESSURE ANGLE													
PITCH RADIUS ±													
D ±													
ANGLE △ ±													
C													

DECIMAL FRACTION OF TIME	1	2	3	4	5	6	7	8	9	10	11	12	13



FOR ALL ROLLER - USE BRR FOR 500 RPM

BALL BEARINGS - USE BRR FOR 1000 RPM

INDICATE BEARING SELECTION BY COMPLETING BLANKS UNDER APPROPIATE BEARING

THE PROGRAM IS WRITTEN TO ASSUME A HORIZONTAL AXIS AND A VERTICAL AXIS INTERSECTION AT THE CENTER OF THE SHAFT IN QUESTION AS VIEWED FROM THE FRONT OF THE SHAFT (X IS HORIZONTAL; Y IS VERTICAL)

FORCES IN THE Z DIRECTION ARE VIEWED FROM THE RIGHT SIDE OF THE SHAFT

THE FOLLOWING SIGN CONVENTION IS USED:

Y FORCES ACTING UPWARD ARE POSITIVE
Y FORCES ACTING DOWNWARD ARE NEGATIVE

X FORCES ACTING TO THE LEFT IN THE FRONT VIEW ARE NEGATIVE
X FORCES ACTING TO THE RIGHT IN THE FRONT VIEW ARE POSITIVE

Z FORCES ACTING LEFT IN THE SIDE VIEW ARE NEGATIVE
Z FORCES ACTING RIGHT IN THE SIDE VIEW ARE POSITIVE

TORQUE + IF THE GEAR ON THE SUBJECT SHAFT IS DRIVING
- IF THE GEAR ON THE SUBJECT SHAFT IS DRIVEN

RPM (FRONT VIEW) + IF GEAR ON SUBJECT SHAFT IS TURNING CLOCKWISE
- IF GEAR ON SUBJECT SHAFT IS TURNING COUNTERCLOCKWISE

SPIRAL ANGLE + IF RIGHT HAND
- IF LEFT HAND

PRESSURE ANGLE (SPIRAL BEVEL ONLY)
+ IF SPIRAL GEAR IS ON THE RIGHT SIDE IN THE FRONT VIEW
- IF SPIRAL GEAR IS ON THE LEFT SIDE IN THE FRONT VIEW

N_{PINION} NUMBER OF TEETH IN THE SPIRAL PINION

N_{GEAR} NUMBER OF TEETH IN THE SPIRAL GEAR

A – DISTANCE FROM FRONT BEARING TO SPIRAL BEVEL MEAN PITCH POINT

C – DISTANCE BETWEEN BEARINGS

D – DISTANCE FROM FRONT BEARING TO LOAD

HELIX ANGLE (WORKING) + IF RIGHT HAND
- IF LEFT HAND

PRESSURE ANGLE SPUR OR HELICAL MUST BE WORKING TRANSVERSE

PITCH RADIUS + IF MATING GEAR CENTER LINE IS BELOW X AXIS
- IF MATING GEAR CENTER LINE IS ABOVE X AXIS

ANGLE △ — ACUTE ANGLE MEASURED FROM THE Y AXIS TO THE LINE OF CENTERS OF THE TWO MESHING GEARS (FRONT VIEW)
+ IF MEASURED CLOCKWISE
- IF MEASURED COUNTERCLOCKWISE

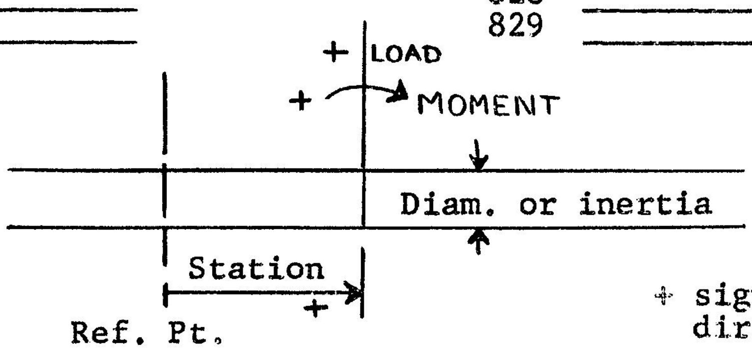
DATA INPUT, SHAFT DEFL. PROGRAM

Intercom 1000 S.P.
Load CH10
Start 1029

Data Location

Location	Value	Description
999	________	Dist. to left brg. from ref point
998	________	Dist. to Cent. brg. from ref point
997	________	Dist. to Right brg from ref point
996	________	Eccentricity of Center bearing
995	________	Modulus of Elasticity
994	________	1 if Diam's to be given; 0 if inertias
(1599	________	Eccentricity of Left bearing) if 998 0
(1598	________	Eccentricity of Right bearing) & 996 = 0

Location	Value		Location	Value
702	________	LOAD	716	________
703	________	MOMENT	717	________
802	________	DIAMETER	816	________
803	________	STATION	817	________
704	________		718	________
705	________		719	________
804	________		818	________
805	________		819	________
706	________		720	________
707	________		721	________
806	________		820	________
807	________		821	________
708	________		722	________
709	________		723	________
808	________		822	________
809	________		823	________
710	________		724	________
711	________		725	________
810	________		824	________
811	________		825	________
712	________		726	________
713	________		727	________
812	________		826	________
813	________		827	________
714	________		728	________
715	________		729	________
814	________		828	________
815	________		829	________



+ signs indicate direction of positive measurement

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Florence and Teale Streets
Culver City, California
Frank J. Bauer
Aerodynamics Department

Statistical Workshop

At the workshop conducted by the ad hoc committee on Statistical Applications, attended by about 40 people, the presentations were organized around the problem of program duplication as exemplified by that existing in the area of multiple regression.

W. E. Davis first presented a brief description of existing statistical programs, after which, a new B. F. Goodrich Chemical Co. program was described by Messrs. Bowles and Schubert. The unique features incorporated in this program are largely in the area of input options, and it was apparent from the subsequent discussion that there are other features which users would like to have available; some of these are pointed out below.

Action was also taken to request the Steering Committee to establish a permanent committee on Statistical Applications. The initial membership of the committee would be the following:

M. R. Rohr
E. I. du Pont (RDL)

Otto Dykstra, Jr.
General Foods

Arthur Squyres
E. I. du Pont (Eastern Lab.)

Robert L. Bowles
B. F. Goodrich Chemical Co.

Alice M. Calhoun
General Telephone & Electronics

Robert U. Bonnar
Shell Development Co.

Floyd L. Carson
Corn Products Co.

H. D. White
Bendix Systems Div.

Roland H. Magee
The Magnavox Co.

Jack Russell
The Ohio Oil Co.

Ralph Sheets
Aurora Gasoline Co.

M. D. Yeaman
Dow Chemical, Pittsburg, Cal.

Florence M. Pohley
Simoniz

D. C. McCure
Jones & Laughlin

George Pratt
American Can Co.

Elsie Merrick
Standard Oil (Ref. Eng.)

John B. Cox
Chemstrand

Francis J. Felix
Systems Development Corp.
Paramus, N. J.

Claude de Courval
Canadian Industries, Ltd.

Robert W. Snyder
Standard Oil Co. (Ohio)

Paul Cook
Consolidation Coal Co.

Stehpen R. Jones
Midwest Computer Serv.

D. E. Englund
Systems Development Corp.
Santa Monica, Cal.

Robert Bowles was elected chairman, with a term of one year, and Robert Snyder to the executive committee for a term of two years.

Possible areas of work mentioned for the committee were the following:

(1) Completion of the summary of existing statistical programs, possibly in somewhat more detail than the sample on regression which was presented at the workshop.

(2) Consolidation of existing programs.

(3) Supply guidance for future programming by coordinating suggestions on requirements not satisfied by existing programs.

(4) Encourage programming in new areas; possible examples suggested include Monte Carlo calculations and response surface analysis.

(5) Organization of meetings, possibly regional at times other than that of the annual Exchange meeting.

Some suggestions have already come in under item (3) with respect to regression programs. These include the possibility of a build-up procedure for multiple regression and a comment concerning the possibility of obtaining the inverse matrix and regression coefficients for a system containing one less independent variable without the necessity of going back to the X'X matrix for the elimination and then reinverting.

Copies of the material discussed at the workshop follow.

W. E. Davis, Chairman
Ad Hoc Committee on
Statistical Applications

SUMMARY & CLASSIFICATION OF STATISTICAL PROGRAMS

1. Simple Demonstration Programs

A.S.P.	25	Standard Deviation
A.S.P.	36	Linear Regression
A.S.P.	42	Probability Analysis (Beard's Method)
A.S.P.	58	Mean, Standard Deviation, Variance Program
A.S.P.	103	Mean, Standard Deviation, Variance Program

2. Matrix Generators

A.S.P.	33	Simple Correlation Coefficients
U.P.	92	Sums of Squares & Correlation Coefficients
U.P.	93	Matrix Normalization I
U.P.	173	ELSIE 820 (Evaluation of a Least Squares Fit to Inconsistent Equations)
U.P.	285	Correlation Coefficients
U.P.	382	Calculation of a Correlation Matrix
U.P.	430	Matrix Preparation Program

3. Curve Fitting Programs

A.S.P.	60	Fitting Smooth Curves by Third, Fourth, and Fifth Degree Polynomials
A.S.P.	90	Polynomial Curve Fitter
U.P.	118	Coefficients for a Fourth Degree Polynomial
U.P.	138	Fit Analysis by Least Squares (FABLES)
U.P.	225	Least Squares Estimates for Non-Linear Models
U.P.	229-30	Value and Derivative of a Polynomial
U.P.	231-32	Value and Derivative of a Polynomial for Logarithmic Variables
U.P.	253	Non-Linear Estimation
U.P.	376	Fit Analysis by Least Squares (FABLES, Rewritten)

4. Time Series Analysis

A.S.P.	73	Moving Averages Program
U.P.	75	Weighted Moving Averages
U.P.	160	Serial Correlation Program
U.P.	282	Calculation of Autocorrelation Function
U.P.	283	Calculation of Power Spectrum from Autocorrelation Function
U.P.	323	Period Search

5. Regression Analysis

U.P.	31	Linear Regression Analysis of Data
U.P.	37	8 Variable Multiple Linear Regression
U.P.	132	Multiple Regression Analysis (Revised)
U.P.	143	Multiple Regression Analysis
U.P.	167	Multiple Linear Correlation
U.P.	177	Multiple Regression Program
U.P.	193	Regression Programs for Bendix G-15 Computer
U.P.	228	Linear Regression & Testing of Significance
U.P.	331	General Intercom Curve-Fitter
U.P.	336	Auxiliary Statistical Routines for U.P. 177
U.P.	406	Parc Analysis
U.P.	421	Least Squares Multiple Linear Regression Analysis and Correlation Coefficients

6. Analysis of Variance

U.P.	62	Analysis of Variance, Factorial Experiments
U.P.	146	ANOVA - Row by Column Analysis of Variance
U.P.	330	Row by Column Analysis of Variance with Replications
U.P.	480	2^n Factorial Design Experiment

7. Miscellaneous

U.P.	110	Erf'(x), Erf(x), Prob'(x), and Prob(x)
U.P.	123	Averaging Data
U.P.	129	Statistical Analysis for Quality Control
U.P.	227	Ranking of Preference Scores of 9-Treatment Balanced Design
U.P.	284	Means and Standard Deviations of Grades
U.P.	435	Basic Statistics (MTA-3 Input)
U.P.	436	Basic Statistics (Type Input)
U.P.	458	Data Distribution Routine

8. Supplementary Routines (Matrix Processors)

A.S.P.	89	Matrix Shrinker
U.P.	104	Evaluation of a Quadratic Form
U.P.	136	Latent Roots & Characteristic Vectors of a Matrix
U.P.	246	Simultaneous Equations Solver
U.P.	248	Matrix Inverter
U.P.	250	Matrix Shrinker
U.P.	277	Multiplication & Interpreter Routines
U.P.	278	MAP to Magnetic Tape
U.P.	332	Simlutaneous Equation Solver
U.P.	340	Solution of n Simultaneous Equations
U.P.	347	Eigenvalues and Eigenvectors
U.P.	411	Matrix Multiplication (Smaysie)

U.P. 31 LINEAR REGRESSION ANALYSIS OF DATA

This is a specialized Intercom 101 program to fit up to 100 sets of measurements to the equation

$$y = a + bx$$

where

$$y = \log_{10} (60\ t)$$

$$x = L/_D$$

and L and t are the measured quantities, D a known constant.

U.P. 37 8 VARIABLE MULTIPLE LINEAR REGRESSION

This program is in Intercom 103, and has been superseded by more complete programs.

U.P. 132 MULTIPLE REGRESSION ANALYSIS

The analysis is carried out for a single dependent variable and up to 19 independent variables. Output available includes means and standard deviations of the variables, sums of squares for error and regression (both multiple and simple), root means square error, multiple correlation coefficient, regression coefficients, estimates of the dependent variables from the regression equation, and individual residuals. Facilities are vavilable for dropping independent variables one at a time, but only in a fixed sequence (the last one of those remaining is dropped). The program is in Daisy 201, and the input data must be on tape prepared under Daisy control.

U.P. 143 MULTIPLE REGRESSION ANALYSIS

This is in Intercom 101, and is limited to 60 sets of data on a dependent variable and up to 8 independent variables. Output includes sums of squares, and cross products, means, regression coefficients, sum of squares for error and some derived quantities.

U.P. 167 MULTIPLE LINEAR CORRELATION

Similar to U.P. 143, but provides facilities for input verification, and output includes the estimated values of y (if desired), and some information related to partial correlation coefficients.

U.P. 177 MULTIPLE REGRESSION PROGRAM

This program will handle up to four dependent variables and fifteen independent variables (including one which may be defined to be equal to 1 for every experiment). Facilities are included for defining second-degree terms, so that these are calculated automatically and need not be entered explicitly. These calculations as well as accumulation of sums of squares and cross-products go on during input. There are also provisions for: (1) data input from tape prepared by Intercom 1000 (Technical Applications Memo #24A), (2) punching of sums of squares and cross-products on tape, (3) read-in of a tape prepared as in (2), after which data on additional experiments can be added, (4) corrections of input errors. The part of the program which solves the normal equations has a number of output options, so that regression coefficients only, inverse matrix only, or both, can be typed out either in a single column or (if the matrix contains no more than 9 columns) in an array of rows and columns. During the matrix inversion, the contribution of each independent variable to the sum of squares for regression is calculated and stored. These are not typed automatically, but are available by use of a memory interrogator which permits typeout of any information stored in the computer.

U.P. 193 REGRESSION PROGRAMS FOR BENDIX G-15 COMPUTER

This package consists of a supervisor and a set of subroutines. When the supervisor has been supplied with register-setting instructions and data tapes spliced in at the proper places, the following operations will be carried out: (1) calculate and type mean, sum of squares, and standard deviation for each variable (up to 5 dependent and 4 independent); (2) correct each variable for mean, generate quadratic terms from corrected independent variables and calculate matrix of sums of squares and cross-products; (3) invert the X'X matrix and type inverse: (4) calculate and type regression coefficients, regression and residual sums of squares, residual variance and standard deviation, multiple correlation coefficient, and variance ratio (f) for the total regression; (5) obtain the value of each dependent variable from the regression equation, and type out, for each dependent variable at each experimental point, the observed value, the calculated value, and the difference between them. A supplementary program, which requires another copy of the input data tape, yields as output for each experimental point the values of the independent variable, calculated values of the dependent variables, and confidence limits for these calculated values.

Note that these routines operate in Daisy 201.

U.P. 228 LINEAR REGRESSION & TESTING OF SIGNIFICANCE

This is an Intercom 103 (or 101) program for fitting up to 202 sets of data to the equation $y = a + bx$; it provides complete information on the significance of the regression.

U.P. 331 GENERAL INTERCOM CURVE-FITTER

This program uses versions of Intercom 1000 (Technical Applications Memo 24A) and MAISIE (U.P. #11) modified so as to permit their joint use. The user must write a program in Intercom 1000 to generate the normal equations for the particular mathematical model he wishes to fit, placing the matrix elements in specified locations. The routine executes this program, then loads and executs the modified MAISIE to solve the normal equations and invert the matrix. The solution vector and the inverse matrix are typed out (with option of punching tape also if desired), and Intercom 1000 is reloaded so that further computations can be carried out on the results; the program for such computations must also be written by the user.

U.P. 336 AUXILIARY STATISTICAL ROUTINES FOR U.P. 177

This program, which operates in Autopoint 24, permits computation of the following from information left in the memory by U.P. 177: regression coefficients with their confidence limits, standard deviations and variance ratios for the regression as a whole; variance attributable to each independent variable, the corresponding variance ratio and significance level; observed and calculated values of dependent variables for each experiment.

U.P. 406 PARC ANALYSIS

This program is in Intercom 1000D, and is intended to study simple linear correlations of up to 10 dependent variables with each of as many as 20 independent variables. Input data is on tape, prepared either by typing under control of Intercom 1000D or on Flexowriter. The output includes all the simple regression coefficients and their significance.

U.P. 421 LEAST SQUARES MULTIPLE LINEAR REGRESSION ANALYSIS AND CORRELATION COEFFICIENTS

This is in effect an extension of U.P. 406, and is also in Intercom 1000D. After an examination of the simple correlations, this program can be used, on those independent variables which appear to be important, to determine their joint effect. Using tape input as in U.P. 406, the regression coefficients are determined, and also the significance of the added amount of variation explained by each additional independent variable. The program handles up to 5 dependent and 9 independent variables.

MINUTES OF INTERCARD WORKSHOP

R.G. Noel of North American Aviation, Missile Division, discussed Intercard, both single and double precision.

He first discussed machine language input and output card conversion, to be used with Intercard single precision.

The new Intercard double precision was then described and the differences between it and the single precision were pointed out.

The off-line tape monitor, for Intercard single precision was described. Bob discussed the operation of his installation using these systems.

Following these discussions, Bob demonstrated Intercard double precision on the G-15 - CA-2 system.

Basil Mikhalkin of Bendix Computer discussed Autocard (commercial) following the coffee break. The differences between Intercard and Autocard were discussed.

V. E. Kohman of Curtiss-Wright distributed a large number of Intercard programs to all interested users and the meeting adjourned.

ATTENDEES AT INTERCARD WORKSHOP - 5TH ANNUAL EXCHANGE CONFERENCE

Name	Company
R. G. Noel	North American Aviation, Missile Div.
V. E. Kohman	Curtiss-Wright, Caldwell, New Jersey
R. W. Albright	Lovelace Foundation
H. A. Clausse	California Dept. of Water Resources
J. R. Bossenga	Bendix Computer, Chicago, Ill.
D. S. Cardner	General Foods, Tarrytown, N. Y.
J. A. Sorbara	Autonetics, Downey, Calif.
J. A. Pierce	Beech Aircraft Corp., Wichita, Kansas
H. Wobus	Navy Weather Research Facility Naval Air Station, Norfolk, Va.
Deborah Jacoby	U.S. Army Signal R&D Labs Ft. Monmouth, New Jersey
Bernard Lanctot	Ecole Polytechnique, Montreal, Canada
N. D. Brewer	Computing Devices
H. C. Bell	B.C.D.
H. J. Chiat	General Mills, Inc.
W. R. Chandler	Waterbury Nat'l Bank
G. P. Casely) D. E. Hiller)	U. S. Weather Bureau
D. A. Ackley	Michigan Highway Dept
G. F. Kirkpatrick	Computing Devices

INTERCARD PROGRAMMING

for

THE BENDIX G-15D COMPUTER

I. Introduction

These notes assume that the reader is familiar with the G-15D computer and with IBM card equipment. Necessary information for the use of the G-15D with a floating point interpretive system is presented.

Input is from IBM cards via the IBM 523. Output is both IBM cards via the 514 punch and line printing on the IBM 402 printer. All input-output is 100 lines and/or cards per minute.

Commands are written with alphabetic operation codes, numeric addresses, and alphanumeric comments. An assembly program converts these symbolic commands to the proper binary machine language and punches binary cards. Programs are then run by reading the binary program cards followed by the data cards into the IBM 523 reader. Results are printed on the IBM 402 printer.

This system is intended as a replacement for Intercom using high speed input-output via the IBM card and printing devices. However, the interpretive routines are written in a very efficient manner and new commands added so that the computing speed will be about 4 times faster than Intercom. The overall capacity of the G-15D will be increased 10 to 20 times over that of the present mode of operation.

SINGLE PRECISION INTERCARD OFF-LINE

OPERATING SYSTEM

I. Introduction

In order to provide more complete time usage of the Bendix G-15D computer and keep the operating costs at a minimun, the Intercard Off-Line System has been developed. In this system all input-output is via magnetic tapes, thereby eliminating the necessity of the IBM component and the CA-2 for executing jobs. Because the assembly process is 100% input-output, it is not provided for in the off-line system.

Due to the use of magnetic tape input-output, the off-line system is in three parts: the Input Translator to prepare the input tape, the monitor to provide off-line program execution, and the Output Translator to process the output tape. These notes provide a general description of the entire system and detailed instructions for its use. The minimum equipment needed for this system is listed below:

1 G-15D Computer

1 IBM 523 Card Reader (or equivalent)

1 IBM 402 Printer (or equivalent)

1 Bendix CA-2

2 Bendix Magnetic Tape Units

DOUBLE PRECISION

INTERCARD PROGRAMMING

FOR

THE BENDIX G-15D COMPUTER

I. Introduction

These notes assume that the reader is familiar with the G-15D computer and with IBM card equipment. Necessary information for the use of the G-15D with a double precision floating point interpretive system is presented.

Input is from IBM cards via the IBM 523. Output is both IBM cards via the 514 punch and line printing on the IBM 402 printer. All input-output is 100 lines and/or cards per minute.

Commands are written with alphabetic operation codes, numeric addresses, and alphanumeric comments. An assembly program converts these symbolic commands to the proper binary machine language and punches binary cards. Programs are then run by reading the binary program cards followed by the data cards into the IBM 523 reader. Results are printed on the IBM 402 printer.

This system is intended as a supplement to the single precision Intercard system now in use. It affords the programmer a means of retaining greater precision in calculations which are prone to loss of significance. Because of the double length numbers, data capacity is reduced to half that of a single precision program. However, the overall computing speed is expected to be only 20% less than that of single precision.

BENDIX COMPUTER DIVISION WORKSHOP

CHAIRMAN: ROGER MATTSON

G-15 ACCESSORIES WERE DISCUSSED.

PLEASE REFER TO THE SPECIFICATIONS

OF THE G-15 ACCESSORIES.

CHEMICAL ENGINEERING WORKSHOP

The workshop was called to order by the chairman of the ad hoc committee, M. R. Rohr. He gave the background of the formation of the committee as a result of the interest shown at the last meeting of the EXCHANGE.

The four papers were then presented (see following program and papers). A general discussion was then held on the following topics:

1. The worth of establishing a regular committee on chemical engineering applications.

2. The prime purpose of such a committee.

3. Methods of standardizing chemical engineering programs for general use.

4. Methods of exchanging programs, especially where proprietary interests are a factor.

5. Cooperative programming efforts.

General conclusions drawn in each of these areas were:

1. A regular committee should be established. A petition for recognition by the Steering Committee was circulated and duly signed by persons attending the workshop.

2. The most important function of the committee will be to develop cooperation in chemical engineering programming efforts, especially in the area of exchange of ideas because of the great incidence of proprietary instances.

3. No conclusions were drawn as to standardizing calculation techniques or program language. It is hoped that by the exchange of calculation methods, one technique may be found which is superior. Consideration will also be given to the standards established by A.I.Ch.E.

4. It was decided that proprietary programs would be released as class 3 programs with the understanding that the requester of the program would be responsible (if necessary) for duplicating the tapes and obtaining information from the originator. This is because many of those at the meeting indicated that the time available for duplication at their companies was limited. In the area of proprietary programs, it was thought that an exchange of mutually advantages programs would facilitate the release of such programs to competitive companies. Portions of such programs could also be released.

5. Cooperative programming efforts may be achieved by use of the progress reports sent out with the Newsletter. It would be the responsibility of each programmer to contact the person currently working on a problem of interest to him in order to exchange ideas and thus develop a program useful to both.

Anne W. Pusterhofer

Bendix G-15 Users Exchange Committee
on Chemical Engineering Applications

Purpose:

The purpose of the Bendix G-15 Users Exchange Committee on Chemical Engineering Applications shall be to promote the exchange of chemical engineering programs, to encourage co-operative programming efforts, and to establish standards for programs dealing with the field of chemical engineering.

Program exchange and co-operation shall be achieved by improving communications by such means as the Exchange Newsletter and Program Progress Reports to avoid duplication of programming efforts. The committee will recommend special calculation techniques and that a fundamental approach be used in these calculations whenever feasible.

Program Standards - Committee on Chemical Engineering Applications

The following material should be included in all writeups of finished programs:

I. Title Page*

Brief title

Name of author, company, group, and address

Class

Date of submission

The following disclaimer clause:

"The computer program and technical information published and furnished herewith have been submitted for publication herein by the above-named company and are provided exclusively for informational purposes and use. Such programs and information are published and released without warranty or indemnity of any kind and neither the publisher nor any of the above-named companies make any representation or express any opinion with respect to any such program and technical information."

II. Brief Program Description* (one page)

An abstract to summarize the body of the report.

Auxiliary equipment required.

Program language.

Average running times for input, computation and output; maximum running time should be included where significant.

Special notes, such as decimal places required for accuracy or special equipment used.

III. Table of Contents

IV. Method of Calculation

Fundamental equations used in calculation with references (if any) to source of equations.

Special mathematical techniques used in solving these equations.

Special options provided by program.

V. Limitations of Method

Physical limitations of chosen equations.

Limitations of mathematical techniques used to solve equations.

Limitations of program as to problem size, for example, maximum number of components.

* Reference may be made to Appendix II of the Exchange Administrative Code which covers Items I and II in more detail.

VI. Input Data Needed and Results Obtained from Calculation

Specify units of measurement.

VII. Flow Diagrams

One flow diagram should be brief and problem-oriented, showing only the general strategy of the solution with cross references to program steps.

This flow diagram should be accompanied by detailed flow sheets showing machine-oriented mathematical and logical decisions depending upon the complexity of the program. Well-written coding sheets could replace this item.

Flow diagram symbols recommended by the Exchange should be used.

VIII. Coding Sheets

A documentation of the finished program with appropriate notations as to the significance of each command should be provided.

A list of memory locations available should be included with the coding sheets.

When a large number of coding sheets are involved, they should be included in a separate section at the end of the writeup and will be included with the operating instructions only at the request of the user.

Subroutines used should be specified.

Program tape check sums should be provided.

IX. Sample Problem

Sample input and output formats, preferably machine prepared, should be included.

I. Operating Instructions

Preparing computer for operation.

Switch settings.

Error stops.

Procedure to follow in the event of an error stop.

XI. Nomenclature

Standard American Institute of Chemical Engineers notation should be used.

QUESTIONNAIRE RESULTS
CHEMICAL ENGINEERING APPLICATION
BENDIX USERS EXCHANGE
AUGUST, 1960

Company	Contact	Contribute	Passive
Allied Research Associates, Inc.	Dr. A. S. Obermayer		x
Aurora Gasoline Company	Ralph W. Sheets	x	
Canadian Industries, Ltd.	N. E. Cooke		x
University of Delaware	R. L. Pigford		x
The Dow Chemical Company	Jack A. Schulz		x
Grand Central Rocket Co.	Sue Hurlbut		x
Gen. App. Sci. Lap., Inc.		x	
The B. F. Goodrich Co.	R. H. Judson		x
Hercules Powder Company	G. H. Hopmeier		x
Kenvil, New Jersey			x
Hercules Powder Company Wilmington, Delaware	S. J. Slough	x	
Jones & Laughlin Steel Corp.	S. S. Lewis		x
The Lumas Company	M. B. Mills		x
McMaster University	J. W. Hodjins		x
Midwest Computer Service, Inc.	Stephen R. Jones		x
Thiokol Chemical Corp.	R. Brockish		x
Scientific Computers Lm.		x	
Shell Development Company	R. U. Bonnar	x	
Standard Oil Company (Ohio)	Ann W. Pusterhofer	x	
Texas Research Associates Corp.	A. F. Wittenborn		x
U.S. Army Snow Ice & Permafrost	Donald E. Nevel		x
Western Electric Research Center	Edward J. Seliqman		x
Wolf Research & Dev. Corp.	William M. Wolf		x

In addition to those responding to the questionnaire the following indicated an interest in Chemical Engineering Application during the workshop session at the 1959 Exchange Conference:

American Can Company	George Pratt
American Viscose Corp.	Robert F. Hays
The Chemstrand Corp.	John Cox
The Ohio Oil Company	John W. Russell
Texas Gas	Dannell Morrow

A PROGRAMMING APPROACH TO THE DESIGN OF SHELL AND TUBE HEAT EXCHANGERS FOR THE BENDIX G-15 COMPUTER

By

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A PROGRAMMING APPROACH TO THE DESIGN OF SHELL AND TUBE HEAT EXCHANGERS FOR THE BENDIX G-15 COMPUTER

This paper concerns an approach to a program for sizing and evaluating standard shell and tube heat exchangers. Although the program I will describe to you today does not actually exist as such, some of the features which will be discussed involve programming techniques which have been used and seem acceptable for this type of computation.

When approaching a new program for the Bendix, some consideration should be given to the following questions.

1. Why write this program at all? Is it worth spending a lot of time on?

2. What other programs are available in the Users library which may be of use to me?

3. What programming system should I use? Is it the most suitable from all standpoints?

4. Can this program be easily modified by either myself or some other User who may have differing future needs?

The first three questions should be given serious consideration before embarking on a lengthy program which eventually may be submitted to the Users library. The fourth item should be kept in mind while the program is being flow charted and coded. It is my belief that a program which is really worthwhile writing deserves to be written well. This usually requires considerably more planning and thought than a program hastily written for a highly specific case. I think that you will all agree that the more general types of programs in the library are of most use to you and, therefore, could be considered more valuable. These points will be discussed in greater detail after we consider the need for a program in this area and a suggested computational approach.

The Need for a Good Program in This Area

The most common type of equipment used to transfer heat from one fluid to another is the standard shell and tube heat exchanger. Since this type of equipment is so widely used in the petroleum and chemical industry, a program in this area would handle a large majority of design and evaluation needs. The main advantages in a program such as this would be in improved design, performance, and evaluation, and possibly a reduction in equipment costs. For example, a heat exchanger properly designed for a pilot plant process could turn up important characteristics of the process being studied, and probably give good performance data on which to design the larger production plant.

What could happen if an exchanger was poorly designed? First of all, I have never seen a rough-estimated design which was not oversized. Usually, when a design is uncertain, safety factors are added to the area just to insure that the design will perform satisfactorily. Almost always this results in an exchanger much larger than needed and is considerably more expensive. The reasoning here is that it is always easier to weld some of the tubes shut than to scrap the exchanger and purchase a new one.

Several years ago I was involved in a pilot plant development project, part of which required the design of a heat exchanger to condense overhead vapor from a stripping column and sub-cool the immiscible condensate to a particular temperature in the presence of non-condensible gases. Since time did not permit a careful design, a rough estimate was made of the number of tubes and tube length, and the design was submitted for purchasing. It was felt that no serious error would result if a generous portion of extra area was added to guarantee its successful operation. Since this was a rather critical part of the process, a simple proportional flow control was placed on the service water stream and was controlled by the temperature of the sub-cooled condensate. When the plant was started, we noticed that the temperature control at this point was unacceptably poor. After it was found that the temperature controller was operating properly, we took a second detailed look at the design of the condenser--something we should have done in the first place. We found that we had unwittingly specified about three times the area actually needed. The controller had attempted to compensate for this by reducing the water rate. This resulted in an increased water hold-up in the shell and a very close temperature approach. The lag introduced into the system by this effect caused flow and temperature cycling. Furthermore, the higher exit water temperature combined with the slower velocity across the tube bank gave rise to rapid growth of slime and scale on the tubes. We had to clean the shell frequently. All of these difficulties could be attributed solely to the lack of a careful design approach.

Another part of the process which was under design soon after the above plant was started required the design of another condenser for somewhat similar process conditions. In our attempts to profit from our earlier mistakes, sufficient time was taken to obtain a near optimum design. All design factors were taken into consideration, and about 5% excess area was included.

When placed in operation this partial condenser performed exactly as designed with the exception that the surface was actually 10% in excess. This exchanger performed its function without fouling, and gave meaningful pilot plant data. Furthermore, this exchanger was designed to handle a higher duty than the other one, was considerably smaller in size and cost much less. Today, with the use of computers, hours of tedious computations can be reduced to less time than it initially took me to roughly design an exchanger. The advantage here is that it is possible to obtain the best design with less effort through the use of computers.

Computational Approach

Although many computational approaches could be used, I think that the nomograph method presented by C. H. Gilmour of Carbide and Carbon Chemicals is most readily adaptable to digital programming. His orderly approach is almost a flow diagram in itself. His series of articles is published in reprint from by "Chemical Engineering". Derivation and arrangement of his equations will be considered to illustrate his approach.

First, let us consider the four resistances to heat transfer as:

1. Inside film
2. Tube
3. Scale or fouling
4. Outside film

In Gilmour's approach each resistance is represented as a temperature drop, or more specifically a reduction in available driving force. For an exchanger to perform its assigned duty, the sum of all the resistances must equal the total temperature-difference driving force. Equation (1) expresses this relationship.

$$\Delta T_i + \Delta T_w + \Delta T_s + \Delta T_o = \Delta T_M \qquad (1)$$

Dividing both sides of the equation by ΔT_M gives the fractional temperature drop associated with each resistance.

$$\frac{\Delta T_i}{\Delta T_M} + \frac{\Delta T_w}{\Delta T_M} + \frac{\Delta T_s}{\Delta T_M} + \frac{\Delta T_o}{\Delta T_M} = 1.0 \qquad (2)$$

The iterative approach used in this method is based on this expression; namely, that the proper exchanger has been found when the sum of all the ΔT's is nearly equal to 1.0.

Each fractional ΔT is derived from a heat balance across the film. In simple terms, the heat entering (or removed from) the fluid must equal the heat which was transferred through the film on the surface of the tube.

As an example, we will consider only the balance for the inside (or tube side).

$$Q = h_i A_i \Delta T_i \tag{3}$$

where: Q = heat transferred to the fluid, BTU/hr.
h_i = inside film coefficient, BTU/hr. ft.^{2} °F
A_i = Surface area, ft.^{2}
ΔT_i = Temperature drop across the film, °F

The heat duty Q may be expressed in terms of the fluid flowing through the tubes.

$$Q = W_i C (T_H - T_L) \tag{4}$$

where: W_i = Flow rate, #/hr.
C = Specific heat, BTU/# °F
$(T_H - T_L)$ = Temperature change in the fluid, °F

Also, the area may be expressed in terms of the number of tubes in parallel, tube diameter, and length.

$$A_i = n \pi d_i L \tag{5}$$

The film coefficient may be expressed by the Seider and Tate relationship:

$$Nu = 0.027 \, Re^{0.8} \, Pr^{1/3} \, (\mu/\mu_w)^{0.14}$$

or

$$\frac{h_i d_i}{k} = 0.027 \left(\frac{d_i G}{\mu}\right)^{0.8} \left(\frac{C\mu}{k}\right)^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14} \tag{6}$$

where: $G = \dfrac{4 W_i}{\pi d_i^2 n}$ (Lbs./hr/ft.^{2}) (7)

Substitution of (4), (5), (6), and (7) in (3) gives:

$$W_i C (T_H - T_L) = \left[0.027 \left(\frac{k}{d_i}\right)\left(\frac{4 W_i d_i}{\pi \mu d_i^2 n}\right)^{0.8} \left(\frac{C\mu}{k}\right)^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}\right] \left[n \pi d_i L\right] \left[\Delta T_i\right] \tag{8}$$

By rearranging and regrouping terms and dividing both sides by ΔT_M, we obtain the final working form of the resistance across the inside film.

$$\frac{\Delta T_i}{\Delta T_M} = \left[9.72\right] \left[\frac{C^{0.67} \mu^{0.33}}{K^{0.67}}\right] \left[\frac{W_i^{0.2} (T_H - T_L)}{\Delta T_M}\right] \left[\frac{d_i^{0.8}}{n^{0.2} L}\right] \left[\mu_w^{0.14}\right] \tag{9}$$

$$\frac{\Delta T_i}{\Delta T_M} = F_N \times F_P \times F_W \times F_M \times F_V$$

Expressions with similar grouping can be developed for each of the other resistances. Note that the expressions are grouped into a numerical factor, a physical property factor, a work factor, and a mechanical design factor. The factor involving the wall viscosity (F_v) is separated from the others because it is dependent upon the wall temperature which is a function of the fractional resistance. A method of handling this factor is to initially assume that μ_w is at the average temperature of the fluid in the shell, as an approximation. Then, after the ΔT_i has been found, the actual wall temperature can be estimated more closely, μ_w computed, and the value of ΔT_i modified. Usually one pass will be adequate to correct for wall effects.

When an exchanger is being designed by the program, the numerical, physical property, and work factors will be computed for all the resistances, and iteration will center around the mechanical design factor. When the condition specified in (2) is satisfied, the exchanger will be operative from a heat transfer standpoint but may not be satisfactory from a pressure drop standpoint. When the pressure drop is computed, it is compared with specified limits to determine what design factors should be modified, if any. Furthermore, if the design was known and it was desired to find the flow quantities, the work factor would be involved in the iteration instead of the mechanical design factor.

The fluids which may occur on either side of the tube are gas, liquid, condensing vapor, boiling liquid or a combination of these. Furthermore, the condenser may be mounted either horizontally or vertically. Also, either fin tubes or bare tubes may be used under viscous or turbulent conditions. The following is a list of the most likely combinations. In each case a different equation in the general form of (9) would be developed.

SHELL SIDE FLUID	TUBE SIDE FLUID	POSITION
gas	gas	horizontal or vertical
liquid	gas	horizontal or vertical
liquid	liquid	horizontal or vertical
liquid	boiling liquid	horizontal
liquid	boiling liquid	vertical
liquid	condensing vapor	horizontal
liquid	condensing vapor	vertical
condensing vapor	liquid	horizontal
condensing vapor	liquid	vertical
condensing vapor - non-condensibles	liquid	horizontal
boiling liquid	condensing vapor	horizontal
boiling liquid	condensing vapor	vertical
boiling liquid	liquid	horizontal
boiling liquid	liquid	vertical
gas	liquid	horizontal or vertical

In consideration of the above possible combinations along with the option of fin or bare tubes, viscous or turbulent flow, and tube size, it seems possible that more than 50 programs could be written to cover all cases, each differing from the other in the way the resistances are computed.

I propose that the programs be grouped into gas-liquid, boiling, and condensing programs. Furthermore, the specific combinations desired could be selected and loaded in a way similar to the Intercom subroutine package.

Let us imagine how this program would work. After the initial part of the program was loaded the program would enter a routine which would control program set-up. Actually it would be a program to modify and assemble a working program. This "master control" routine would include the following features.

1. Selection of fluid to be used on the tube side.
2. Selection of the fluid to be used on the shell wide.
3. Select position of the exchanger, horizontal or vertical.
4. Specify desired table of standard exchangers based on tube size.
5. Specify whether the program is to compute the following:

    a. Mechanical design of the exchanger based on flow quantities, etc.
    b. Flow quantites based on the mechanical design.
    c. Fouling film coefficient based on both flow quantites and mechanical design.

6. Specification of a particular design to be used in items (5b) and (5c).
7. Specification of limits on iteration of $\Sigma \Delta T$'s
8. Specification of limits on iteration of pressure drop.
9. Specification of limits on maximum and minimum baffle spacing.
10. Specification of required input data, such as flow rates and physical properties.

Upon exit from the "master control" mode, the program would search for, and properly position, the selected parts of the program, modify the program slightly, if necessary, and start automatic computations.

With a program as flexible as this, the engineer could automatically tailor the program to perform the specific operation he desires. In one instance the engineer may wish to follow the course of fouling in a particular exchanger. In this case the design dimensions of the exchanger would be entered along with the measured flow rates and physical properties, and the program would be set to iterate on the fouling film coefficient.

The rating engineer may wish to enter the flow rates, etc. and set the program to select several exchangers from a table which would perform the required duty within the specified limits of pressure drop, baffle spacing, % excess area, etc.

The production plant engineer with several used exchangers in the plant "bone yard" may desire to look at each exchanger to see if it would perform some particular duty he has in mind. This feature is especially useful in pilot plant operations where used equipment is rather plentiful. In this case, the physical dimensions of the exchanger would be entered, and the program set to find the maximum flow quantities which could be handled by this exchanger.

Programming Techniques

Put yourself in the place of a new Bendix User who is about to receive shipment of the machine. First of all, Bendix will suggest that at least one person from the installation attend their basic machine language course and will offer to train engineers to use the machine with Intercom. When the User requests programs from the library, he may find that several come close to meeting his needs and may plan to change them so that they will meet his needs more closely. If the programs are written in machine language and Intercom and presented with good flow diagrams and explanatory coding sheets, the job of modification will be relatively easy. But, if the User finds that the programis written in a system different than the one he is accustomed to, and is not adequately explained in flow diagrams and coding sheets, he is faced with the task of learning a new coding system as well as deciphering the program. This task frequently takes longer than to use a familiar coding system and re-write the program from the beginning. It seems that there are two types of programming: the obvious and the obscure, the obscure program being the one written by the other fellow. The importance of submitting well organized programs, complete with coding sheets, to the Users library cannot be over emphasized. Since nearly all engineering programs require floating point arithmetic combined with as much speed as possible, I recommend that the programs be written using Intercom 500-X. Except in rare cases, I think that the precision of 500-X is entirely adequate.

Other items which deserve mentioning along with simplicity of programming and speed are flexibility and ease of operation. When writing a program, a good balance among these factors should be obtained. Ideally, the program should be designed so that non-technical people can be trained to operate it with a minimum of training. Building the flexibility described above into a program will require machine language programming. The time spent doing this will be well worth the effort if the operation of the resulting program is flexible and simple.

I would also suggest that the programs be written for the alpha-numeric accessory. Abbreviated operating instructions, and explanatory error or caution statements could be included in the program to assist the engineer who must analyze the computational results.

It is important that the programmer work closely with the experienced heat exchanger designers in his company so that the program will have maximum utility.

I have found that it is best to allow a new program to stand the test of time and continuous use before submitting it to the library.

Several of you might desire to start working on a heat exchanger program based on the method presented to you today. I urge you to communicate with all the members of the organization to minimize duplication of efforts. The regular program progress reports or the Newsletter are good for this purpose.

I N T E R M A P

The Bendix G-15 Interpretive Matrix Routine

Presented at the

5TH NATIONAL G-15 USERS CONFERENCE
Pittsburgh, Pennsylvania

By

Mr. Ray Berman

Bendix Computer Division

August 10, 11, 12, 1960

- Abstract -

I N T E R M A P

Intermap is a double precision floating point interpretive system compatible with Intercom 1000 double precision, which permits the coding of problems in terms of matrix operations only.

In the automatic mode, up to 108 interpretive commands may be executed sequentially in one block.

A pre-punched program tape may then be read in under program control so that a program with more than 108 interpretive commands can be readily handled.

In the manual mode, commands may be typed in and executed one at a time.

Intermap may be operated with the basic G-15D computer or with any combination of four magnetic tape units, three auxiliary photoreaders, and a punched card coupler with assorted punched card equipment. Out of the four magnetic tape units, one may be used for rapidly accessible program storage and up to three may be used for data storage. Similarly, additional auxiliary photoreaders may be used for both program or data.

Intermap consists of many different routines, each one defined by an op-code. These routines are stored on a library type program tape from which they are automatically selected.

The largest single matrix which may be stored in the G-15D memory is of 28 x 29 dimension. A number of smaller matrices may be stored, as long as the total number of elements does not exceed 812.

The following operations are included in the basic package at the present time:

- a. Intermap PPR
- b. Accumulator Selection Routine
- c. Input-Output Routine
- d. Inversion and Equation Solver Routine
- e. Transposition
- f. Store and Transfer
- g. Addition and Subtraction
- h. Multiplication

Additional routines which have not been completed are:

- i. Eigenvalues and Eigenvector Routines
- j. Punched Card Input and Output Routine

Intermap may be expanded to include other routines not presently part of the program and specific routines which are not needed by a user may be removed at his option.

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The punched card portion of the program, which will be available at a later date, will serve exclusively for the input and output of data.

Intermap consists of many different routines, each one defined by an op-code. These routines are stored on a library type program tape from which they are automatically selected. The reading of program tape from more than one photoreader, or program storage on magnetic tape will speed up the op-code search and selection. Similarly, the use of magnetic tape for data storage, as an extension of the G-15D memory, and/ or several auxiliary photoreaders will make data handling more efficient.

The largest single matrix which may be stored in the G-15D memory is of 28 x 29 dimension. A number of smaller matrices may be stored, as long as the total number of elements does not exceed 812. Each matrix occupies one accumulator and up to seven accumulators may be addressed at any one time. The designation of each accumulator may be changed under program control, so that any accumulator may, in turn, contain any set of data placed anywhere in the memory.

The location of matrices in the memory is at the option of the programmer. All matrix operations have conformability checks, as well as tests which will prevent the accidental destruction of the contents of other accumulators or the Intermap program itself.

The arrangement of the accumulators is such that several of them may be contained within one larger accumulator. Thus, the partitioning of a large matrix into several smaller ones, and the composition of a larger matrix from several smaller ones can be performed under program control.

Other manipulations which can be performed manually or under program control are: The input or output of single rows or columns or of any diagonal, not only the main diagonal. Any row or column may be made equal to zero or may be copied into the $(i-1)^{th}$ or $(j-1)^{th}$ row or column, respectively. The latter is equivalent to a matrix shrinker.

There are 64 op-codes possible in Intermap.

The following operations are included in the basic package at the present time.

a. Intermap PPR
b. Accumulator Selection Routine
c. Input-Output Routine
d. Inversion and Equation Solver Routine
e. Transposition
f. Store and Transfer
g. Addition and Subtraction
h. Multiplication

Additional routines which have not been completed are:

i. Eigenvalues and Eigenvector Routines
j. Punched Card Input and Output Routine

Intermap may be expanded to include other routines not presently part of the program, and specific routines which are not needed by a user may be removed at his option.

Intermap PPR

This routine generally performs the same functions as the Standard PPR, in that it accepts decimal type-ins of pseudo commands, as well as the input of hexadecimal constants. It also contains a lister.

PPR also controls the automatic and manual modes of operations, looping, and error indications.

Accumulator Selection Routine

Controls the location, size and shape of each accumulator. It permits manual or automatic changes to such accumulators.

Input-Output Routine

It permits selective decimal type-in and type-out of data into, and from any accumulator. It also contains the matrix shrinker described above. Furthermore, it permits the acceptance of off line prepared decimal data. An accumulator may be cleared prior to input to eliminate the need to type in zero elements.

Inversion and Equation Solver Routine

This routine may perform either one of the above two operations. In the first operation an inverse alone may be obtained or an inverse with as many solutions as desired. The equation solver will not provide an inverse, only as many solutions as are required. The computing time for the inversion of the most dense matrix is $.004\ N^3$ minutes. For a 28 x 28 matrix with a predominance of zero elements, computing time may be as low as 6 minutes. The computing time for the equation solver is approximately 30% below the inversion time.

Transposition

This routine may, at the option of the programmer, also change the algebraic sign of each element of the matrix.

Store and Transfer

This routine performs no arithmetic operations on the elements of a matrix. It transfers a matrix from any source to any destination, where source or destination may be any combination of the following three media:

a. Accumulator (memory drum)
b. Punched Tape
c. Magnetic Tape

This permits nine different combinations. In addition, these nine combinations may be performed in the following modes.

a. Clear and Add
b. Clear and Subtract
c. Clear
d. Transpose, (with certain limitations)

Addition Routine

This routine will perform any of these four operations:

$$\pm(A)\pm(B)=(C)$$

(A) is always an accumulator and (B) and (C) may be:

Accumulators
Punched Tape and
Magnetic Tape

Multiplication Routine

This routine will perform the following operations:

$$(A) \times (B) = (C)$$

Where (A) is always an accumulator and (B) and (C) may be:

a. Accumulator
b. Punched Tape
c. Magnetic Tape

(A) may also be a scalar or a diagonal matrix for which storage requirements are only one and n elements respectively. (B) may also be a diagonal post-multiplier.

It follows that the addition and multiplication routines may operate on large matrices of such size that only (A) and (B), or even (A) alone need be stored on the drum at any one time.

Punched Card Routine

This routine will provide a means of input and output of data from and to punched cards. In addition to adding the medium of punched cards it will have the following different characteristics. Data will be contained as one element to a punched card. The card will also contain the i and j for each element. Thus, zero elements are not punched for either input or output and a deck of cards containing a matrix may be read in any sequence desired.

The Pseudo Command

The pseudo command is a three address instruction as follows:

$$OP.C.A.T_S.SRC.T_D.DST.$$

The following rules apply for all algebraic matrix operations:

OP = Op-code
C = Characteristic or mode
A = Accumulator
T_S = The number of the magnetic tape unit or of the auxiliary photoreader used as data source.
SRC = The data source i.e. an accumulator number, file no. on magnetic tape, or a punched tape.
T_D = The number of the magnetic tape unit used as a destination of data.
DST = The data destination i.e. an accumulator number, file no. on magnetic tape or a punched tape.

Examples:

a. Invert matrix [A] in accumulator no. 2

12.0.2.0.000.0.000

b. Solve equations in accumulator no. 3

12.1.3.0.000.0.000

c. Add matrix [A] in accumulator no. 4 to matrix [B] on the auxiliary photoreader no. 3 and store the sum [C] on magnetic tape unit no. 2, file no. 120.

33.0.4.3.000.2.120

To subtract [B] from (A)

33.1.4.3.000.2.120

All service routines such as

<u>Op-code</u>

.00	Intermap PPR
.01	Accumulator Selection Routine
.02	Input-Output Routine

may be operated by manual type-ins as well as automatically by pseudo commands. For these routines, the various portions of the pseudo command assume a different meaning. Generally a type-in consists of the following:

A (tab) s ± H ab.cd (tab) s

where A = Accumulator No.

H = a number between 9 and z for a specific operation

ab cd = ii.jj

ab 00 = Location of pseudo command

The translation of such an instruction will follow these rules:

$H - 9 = T_S + T_D$

ab = SRC

cd = DST

A = A

The rules for the characteristic C are:

	plus	minus
manual mode	0	1
automatic mode	2	3.

In the manual mode the program will return to the type-in after execution, and in the automatic mode the next pseudo command will be executed.

Example: The following manual type-in will initiate the type-out of the matrix in accumulator 7 starting from i = 1 and j = 1. 7 (tab) s z01 01 (tab) s.

To execute this with a pseudo command in the automatic mode, the following instruction has to be written

02.2.7.3.001.3.001.

IV. Operating Instructions

A. Data Input Preparation

The input data is taken from the Annual Equipment Operation and cost record, total annual costs, (form A), and is punched on two IBM cards. The format for the two input cards are shown as input No. 1 and No. 2 of Equipment Operation Costs and Rental Card Payout format. (form C) The IBM 026 or 024 is recommended for the preparation of these cards

THE B.F.GOODRICH MULTIPLE CORRELATION PROGRAM

By

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Presented at:

Bendix G-15 Users Exchange Conference
Pittsburgh, Pennsylvania
August 10-12, 1960

THE B.F.GOODRICH MULTIPLE CORRELATION PROGRAM

I. Introduction

In presenting the B.F.Goodrich Multiple Correlation program to you this afternoon, I would like first to give you a brief background of the type of computations which are performed by this program. Without going into the details of the program, I would also like to discuss some of the more interesting features of the program, followed by examples to demonstrate the ease of operation as well as applications.

The first version of the program was written more than a year ago. Since then considerable work was done to incorporate new features into the program which would increase its capacity, speed, flexibility, and ease of operation. Six major revisions were required before we achieved what we considered a good balance among these features. Our head statistician, Mr. Robert L. Bowles, rather than be concerned with the many problems of G-15 programming, spent his time evaluating computational results, devising new methods of application, and developing changes in the computational approach with a view towards incorporating the statistical features into the program which would not only be very useful to himself but to other statisticians as well. On the other hand, my concern was to incorporate his statistical computational approach into a program which would be as fast as possible, include all of the various optional ways of modifying the program and data as a routine part of the program, and retain operating simplicity so that non-technical employees could be trained to operate it with a good degree of proficiency in about a week's time.

This program was designed to handle high-volume production work when used with a magnetic tape unit. This program was also designed to be successfully operated by Users with no more than a basic G-15.

Although this program has application in many areas of scientific activity, I will indicate only the areas in which B.F.Goodrich has used it. A partial list of the uses for this program is:

1. Multiple Regression Analysis
2. Development of Digital Process Simulation Equations
3. Evaluation of Different Experimental Strategies
4. Sales Forecasting
5. Determining Optimum Process Conditions
6. Simple or Multi-dimensional Curve Fitting

The latest version of this program, which is the one we have just submitted to the Users library, has been in operation for the past six months and has solved considerably more than 100 problems in that time. To my knowledge, all of the bugs have been worked out of the program.

II. Problem Description

Today in nearly every area of scientific activity, numerical data are being gathered and recorded to represent the behavior of a process or some other recurring phenomenon. Although some data are recorded for the record's sake alone, most of the data are arranged in tables to be analyzed in one way or another. The chemist, for instance, records data to describe the course of laboratory experiments and analyzes it to determine what factors need to be investigated further. His purpose may be to investigate the basic mechanisms of the process and use this information to plan the strategy for further experiments so that a minimum of experimentation will be required to completely define the behavior of the process. The plant engineer gathers data on plant performance to determine the factors which may help him improve productivity and quality control. The computer programmer may be given a table of data or a set of curves which define the operating characteristics of a particular piece of equipment and must reduce this to digital form so that it can be included in a program.

Data are usually separated into two groups consisting of independent (or factor) variables and dependent (or response) variables. To illustrate the difference between these variables, let us consider a simple chemical reactor (figure 1) which reacts materials A and B, in the presence of a catalyst C, to form a product D. The reactor also is equipped with an agitator, pressure guage, and temperature controller. Independent variables which could be measured for this process would be:

1. The Ratio of the Reactants, A/B
2. Catalyst Concentration, C/A + B
3. Agitator RPM
4. Temperature of the Reactor, ^{o}F
5. Pressure, psig

Notice that these variables consist of conditions which are imposed upon the system being studied and are controlled by the operator who charges the reactor with A, B, and C and sets the agitator speed and temperature controller. In a way, these conditions could be considered as possible "cause" variables.

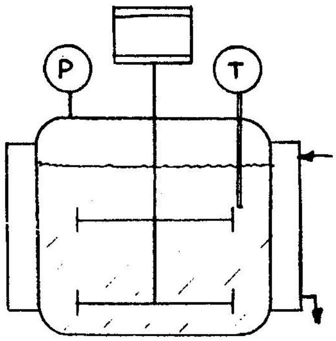
As the reaction proceeds to completion, three more variables could be measured. These are dependent (or response) variables.

1. Yield of Product D
2. Reaction Time, Hours
3. Density of Product D

Notice that these variables are usually observed characteristics or

Figure 1

1. Reaction



$$A + B \xrightarrow{(C)} D$$

2. Variables

Independent	Dependent
1. The ratio of the reactants, A/B	1. Yield of product D
2. Catalyst concentration, C/A + B	2. Reaction time, hours
3. Agitator RPM	3. Density of product D
4. Temperature of the reactor, °F	
5. Pressure, psig	

3. Data

Run	A Lbs.	B Lbs.	C Lbs.	Agitator RPM	Temp. °F	Pressure psig	Yield	Check Sum
1	790	1128	39	55	150	87	40	2289
2	630	700	16	160	110	30	64	1710
3	740	673	7	250	122	42	23	1857
4	590	454	10	140	140	66	44	1444
5	610	611	9	180	120	40	46	1616
6	810	1013	11	200	100	23	42	2199
7	750	625	20	80	125	45	78	1723
8	770	906	30	225	105	26	72	2134
9	640	914	12	60	115	35	45	1821
10	690	775	28	120	135	60	67	1875
11	720	576	16	90	145	76	44	1667
12	850	739	18	100	130	52	59	1948

4. Empirical Equations

$$Y_1 = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

$$Y_2 = b'_0 + b'_1X_1 + b'_2X_2 + b'_3X_3 + b'_4X_4 + b'_5X_5$$

$$Y_3 = b''_0 + b''_1X_1 + b''_2X_2 + b''_3X_3 + b''_4X_4 + b''_5X_5$$

properties which are a possible result of the independent variables. In a sense, these variables could be considered as "dependent" upon the independent variables.

To investigate the relationships which exist between the variables, data from a number of experiments or runs must be obtained, preferably over a range of conditions. This program will compute all expressions required to investigate interrelations which exist among all the variables. One product of the multiple correlation program is the development of an empirical equation which relates the independent variables to each of the dependent variables. Let us consider independent variables 1 to 5 as X_1 to X_5 and the dependent variables as Y_1 to Y_3. The empirical equations developed by the program may then be written as:

$$Y_1 = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

$$Y_2 = b'_0 + b'_1X_1 + b'_2X_2 + b'_3X_3 + b'_4X_4 + b'_5X_5$$

$$Y_3 = b''_0 + b''_1X_1 + b''_2X_2 + b''_3X_3 + b''_4X_4 + b''_5X_5$$

The "b" constants, which are developed by the program, are called the multiple regression coefficients, and the "b_0" constants are the intercepts. The program will also compute expressions which tell us how well the X variables predict each Y variable, how significant each X variable is in explaining each Y variable, and other expressions which I will mention when we consider the example problems.

This program has capacity to handle a total of 21 variables with the restriction that no more than eight Y variables be handled at one time. Thus if eight Y variables were to be handled, the problem would have capacity to handle 13 X variables. Also, if only one Y variable was being considered, 20 X variables could be handled. All computations are performed using double precision numbers. There is, therefore, no limit to the number of experiments or runs which can be handled by the program. The program uses Intercom 1000 D and MAP-29. Machine language programming was used when necessary to obtain operating simplicity and flexibility.

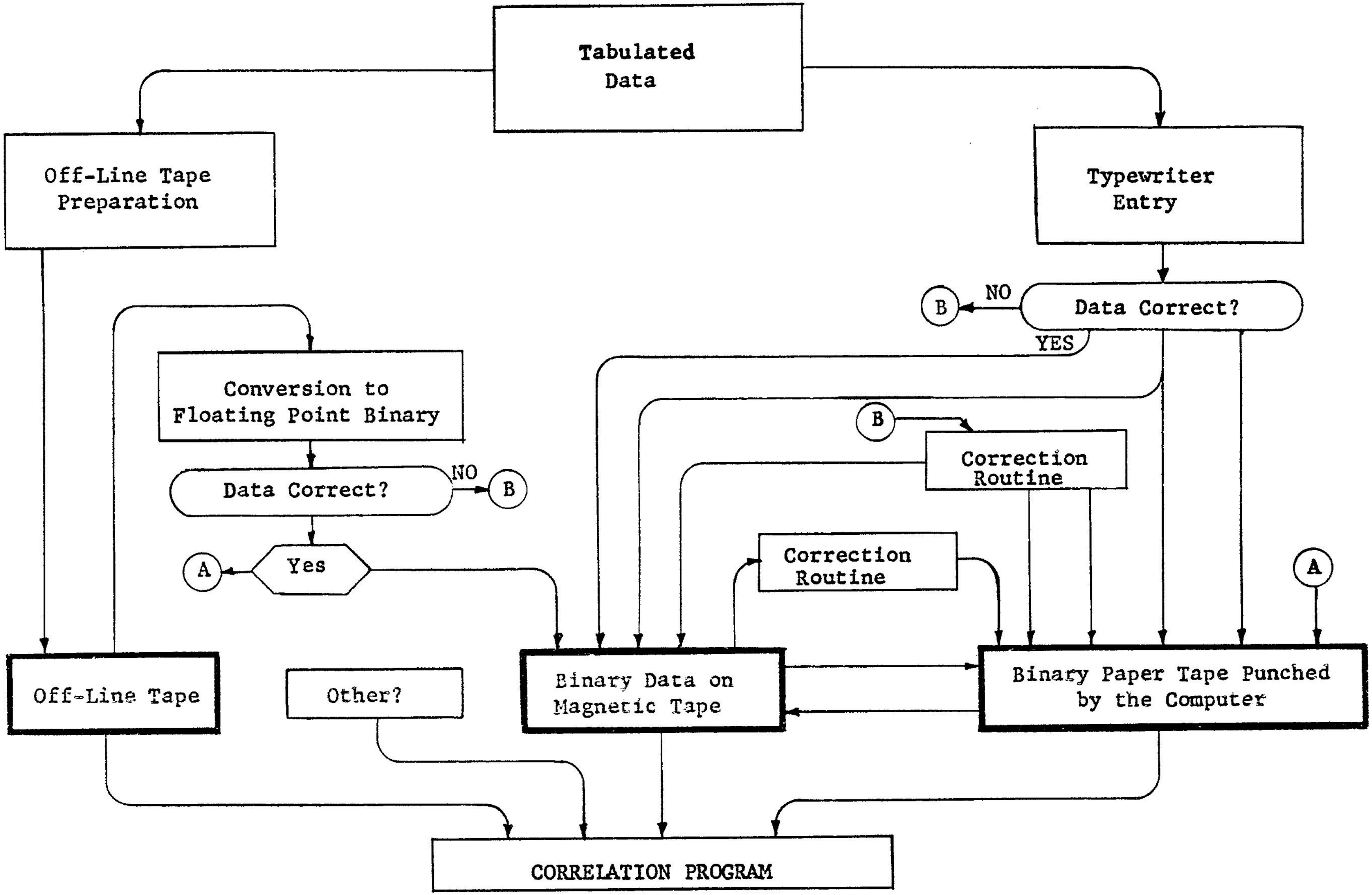
III. Data Handling

Data for each run in a problem must be prepared on separate blocks for processing by the program. For high volume work, data handling becomes the most worrisome part of the program. Figure 2 shows the various ways that input data may be handled by the program.

Data may be prepared for entry into the program using either off-line tape punching equipment or the computer typewriter. Once the off-line tape has been prepared, the operator may either hand check

Figure 2

INPUT DATA HANDLING



each entry by verifying the tape and set the program to process off-line tape directly, or let the program check it and either record the correct data on magnetic tape or punch it on paper tape. This feature is helpful when very large amounts of data are being handled by a limited staff. Thus far we have always recorded the correct data on magnetic tape rather than punch it on paper tape. This feature was included for use by those who have a limited number of trained personnel and only a basic G-15. Direct processing of off-line tape involves the least amount of machine time for data preparation before being processed by the program.

When data are entered through the typewriter, the operator has the choice of punching the correct data on paper tape only, writing the data on magnetic tape only, or punching paper tape and writing on magnetic tape. This provides a considerable degree of flexibility. In some cases, the statistician may wish to separate the data for one problem into two groups. For example, let us suppose that the first and second parts are to be run separately, and then both parts are to be run together. The first half of the data could be prepared using the "punch paper and write mag." routine, the second part could then be entered using the "write on magnetic tape only" routine. To run the problem, the first part could be run from the data prepared on paper tape. The second part could be run by positioning the data on magnetic tape such that only the last part would be processed. The third part of the problem could then be run by starting at the beginning of the data recorded on magnetic tape.

Data which have been recorded on magnetic tape may be retrieved by using the "read magnetic tape, punch paper tape" routine in the program. Similarly, binary data which has been punched on paper tape can be read and recorded using the "read paper tape, record magnetic tape" routine. The correction routine shown on the diagram serves a number of functions:

1. Permits data to be read from paper tape, permits entry of additional data to each row, and then the revised data may be punched on paper tape or recorded on magnetic tape. As you can see on the diagram, data may also be read from magnetic tape, revised, and punched on paper tape. Also, it is possible to read paper tape, add additional data to each row, and then punch the revised data on paper tape.

2. When an error has been made in entering a variable, provisions are included to permit the operator to document the row of input data for checking purposes and enter correct values in any specified position before writing data on magnetic tape, punching it on paper tape, or both.

As you can see, data may be processed from paper tape or magnetic tape as well as off-line tape. Perhaps you are wondering what the "other" block is for. It is very likely that the three modes of data input are not adequate for your purposes. For example, your requirements may be to enter data as single precision fixed point numbers and convert them to double precision floating point numbers before being processed by the program. Too, you may have punched card equipment and would like to enter data in this way. When I was writing the program, I thought of you who might wish to modify the program for other inputs and provided space in the program for inclusion of another mode of data input. Who knows, I may even use it myself someday.

IV. Modification of Input Data

Input data are frequently recorded in a form which cannot be processed by the program without modification. The input data for the reactor example (figure 1) were presented as recorded by the reactor operator in pounds of A, B, and C, agitator speed, temperature, and pressure. To consider the ratio of the reactants (A/B), the ratio of catalyst to reactants, (C/A + B), and the log of the agitator speed, the data must be transformed. One way to transform raw input data is to have the statistician do it with a desk calculator and log tables. I am certain that the statisticians, above all, will agree that this is the poorest, least efficient, way of all to transform data. It is far easier to do it with the computer.

Most of the computer programs which I have examined (not all Bendix) read the raw data from cards or paper tape, perform the necessary transformations and re-punch the revised data on paper tape or cards for re-entry into the program at a later time. This method is usually adequate when relatively small problems are being handled. Perhaps the transformation and re-punch takes only 30 minutes of computer time. However, the disadvantage of this method becomes increasingly apparent as the number of runs and variables increase. If about 300 runs are to be handled with several different sets of data transformations and rearrangements, you could spend days of computer time doing nothing but reading and re-punching data tapes. I think that you will agree that handling data transformations in this way is wasteful of computer time, operator efforts, and paper tape.

To overcome this disadvantage, a compiler routine has been included in this program which accepts simple instructions and assembles a program which transforms raw input data immediately after it is read by the correlation program. Transformed data are then processed directly by the main part of the program. Since transformed data are not punched out by the program, only one input data tape is required for each problem regardless of the number of different sets of transformations desired. Arithmetic operations such as addition, subtraction, multiplication, division, and reciprocal may be performed on raw input data. Furthermore, transformations such as logarithm or exponential to the base 10 or e and square root may be obtained. Input variables may also be repositioned from one location to another without modification.

V. Part I Flow Diagram

Before we consider an example, I would like to show you the various parts of the program and how they are related. The program is separated into three main parts and includes two separate auxiliary routines. Figure 3 shows the first part of the program. In light of the many different versions of Intercoom 1000 D which exist, I felt that I would be doing a service to the User to include the version which is compatible with this program as part of the tape. When Intercom and part of the program has been read and stored, the program will enter the master routine which includes all the data handling features I mentioned a few moments ago and other magnetic tape control features. When the mode of data input has been specified, the program will read additional tape and enter the data transform compiler mode for specification of the number of X and Y variables to be handled. Additional program will be read after the data transformation instructions have been entered.

When the program is started, the data are processed one row at a time. Notice that the assembled program is entered immediately following read in before the data are processed by the main correlation program. I might add that the program can be run without modification of input data if desired.

When the last row of data has been processed, the program will compute and type averages, standard deviations, and simple correlation coefficients. These will be discussed in greater detail when we consider an example problem. After completion of type out, the program punches matrix and other miscellaneous data on paper tape. This serves as a complete representation of the computations performed by this part of the program and is used as input to the second part of the program.

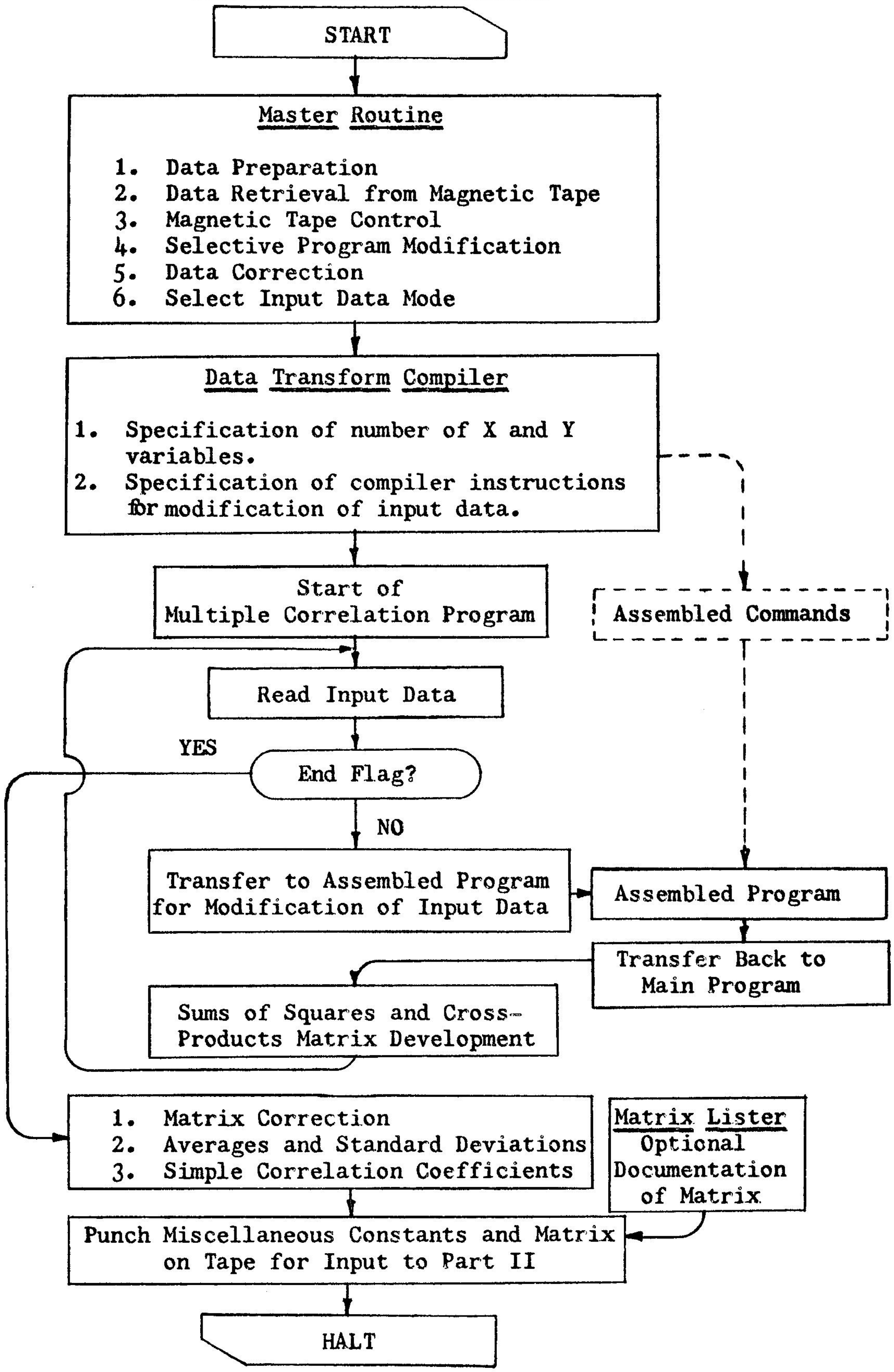
We have found that this is a convenient stopping place in a problem because the statistician frequently spends time analyzing the computational results obtained to this point before deciding how the problem should be completed. During this time the computer can be used for some other purpose.

VI. Magnetic Tape Operation of Part I

The processing of each row of input data by Part I of the program is the most time consuming part of any problem. Under high volume operations, several problems may be presented for solution as quickly as possible. Operation of Part I of these problems may require more than 12 hours of continuous operation.

Figure 3

PART I PROGRAM FLOW DIAGRAM



To handle this type of work load, a feature was included in Part I of the program whereby a number of different sets of input data and programs can be recorded on magnetic tape and run automatically using a specially prepared executive routine which controls the sequence of problem operation. Control and set up of this type of operation is included as part of the master control routine.

Figure 4 shows the flow diagram for automatic operation of Part I. The flow diagram for the executive routine shows the set up of two problems. Each program is located by the pair of Intercom commands which will "search for the FILE number" on magnetic tape which preceeds the recorded program. The program loader is read into line 09 from magnetic tape, and control is sent to location 0900 using the Intercom "Mark Place and Transfer I" command. When the correlation program has been read, the loader will search for the FILE number representing the data which are to be processed and start the correlation program.

The executive routine consists of Intercom commands for each problem to be run and a magnetic tape subroutine. These are punched on paper tape and spliced to form a continuous loop and mounted on the photoreader using a capstan cluge.

At the completion of each problem, the program will read the executive routine into line 12 and the magnetic tape subroutine into line 18. The program will then execute the "Return to Marked Place I" command. Control will then be returned to the executive routine for selection of another problem. Finally, after the last problem has been completed, the "Halt and Return to Manual Mode" command will be obeyed.

This executive routine approach is general in nature and, therefore, can be used to control operation of other Intercom 1000 D programs as well as multiple correlation programs. We have a general Mass Spectrometer program which uses a similar executive routine. We often mix mass spectrometer analyses and multiple correlation problems on magnetic tape and run them automatically at night with a common executive routine. The maximum capacity of the executive routine allows for operation of 20 different problems.

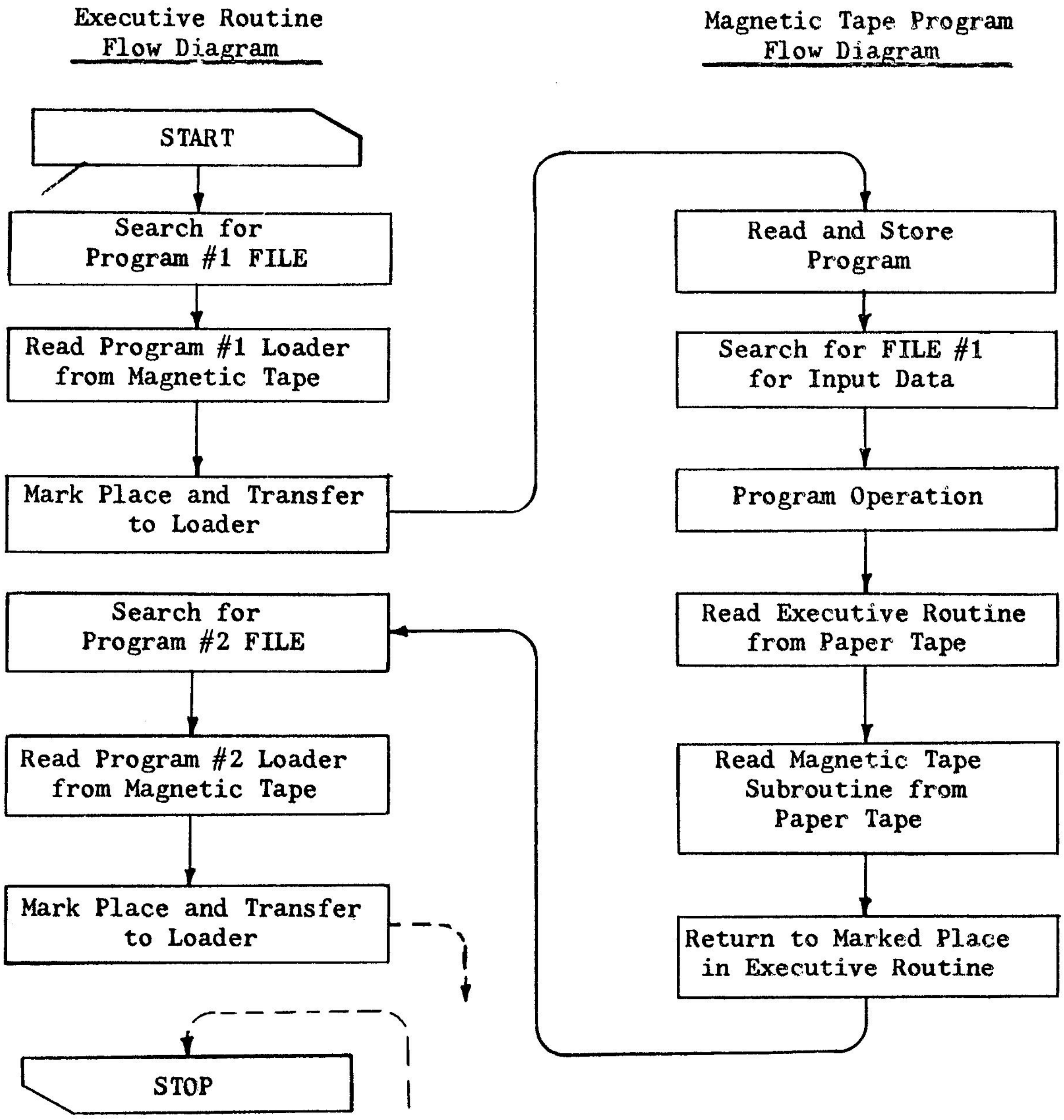
VII. Matrix Shrinker

Figure 5 shows the flow diagram for the matrix shrinker and Part II of the correlation program.

Upon examination of the simple correlation coefficients in the light of what is already known about the problem, the statistician may find that several independent variables have been included in the problem which are closely related and, therefore, must be deleted before

Figure 4

MAGNETIC TAPE OPERATION OF PART I



it is completed. The matrix shrinker is an axuiliary routine which reads the tape punched by Part I, deletes the specified variables from the matrix, and punches the rearranged data on tape. This revised tape then replaces the original Part I tape during operation of Part II.

VIII. Part II Flow Diagram

Part II of the program accepts the tape punched either by the matrix shrinker or Part I and processes it to complete the multiple correlation analysis. The first part consists of a modified version of MAP-29, the forerunner of Intermap, followed by an Intercom 1000 D program which completes computation and type out. At the end of Part II a tape may be punched which is used as part of the input to Part III of the program. Figure 6 shows the flow diagram for Part III.

IX. Part III Flow Diagram

This part of the program is used to compute the predicted value of each dependent variable based on the determined empirical equation. A master control is included for selection of mode of data input and magnetic tape control. The data transform compiler is similar to the one included in Part I and is used to again transform and modify the input data to coincide with the terms in the empirical equation. As an aid to plotting the results, transformed variables, such as the ratio of A/B, may be typed out if desired.

X. Reactor Problem Example

The example we shall consider is the reactor problem described in our introduction. The input data for this problem were shown in Figure 1. For simplicity of demonstration, we will consider yield as the only dependent variable. The problem will be to investigate the effect which the independent variables have on the yield.

Figure 7 shows the data preparation and program set-up portion of the problem. After part of the program has been loaded, the master control mode is entered. The various routines which are available as part of the master control program are selected by first entering a single digit, including sign, followed by a (tab) . The following digits entered may either determine the number of variables to be entered, the number of blocks of data to be handled, or a magnetic tape FILE number, depending upon the routine being selected. In this instance (1) indicates that routine no. 7 is to be used and that 7 variables are to be entered. Routine no. 7 is one of the data preparation routines which will permit data to be entered through the typewriter keyboard and punch the correct data only on paper tape. After this entry is made, a carriage return occurs, the bell sounds, and the program gates for entry of the first number in the first row

Figure 5

MATRIX SHRINKER AND PART II
PROGRAM FLOW DIAGRAMS

Matrix Shrinker
Optional

Part II

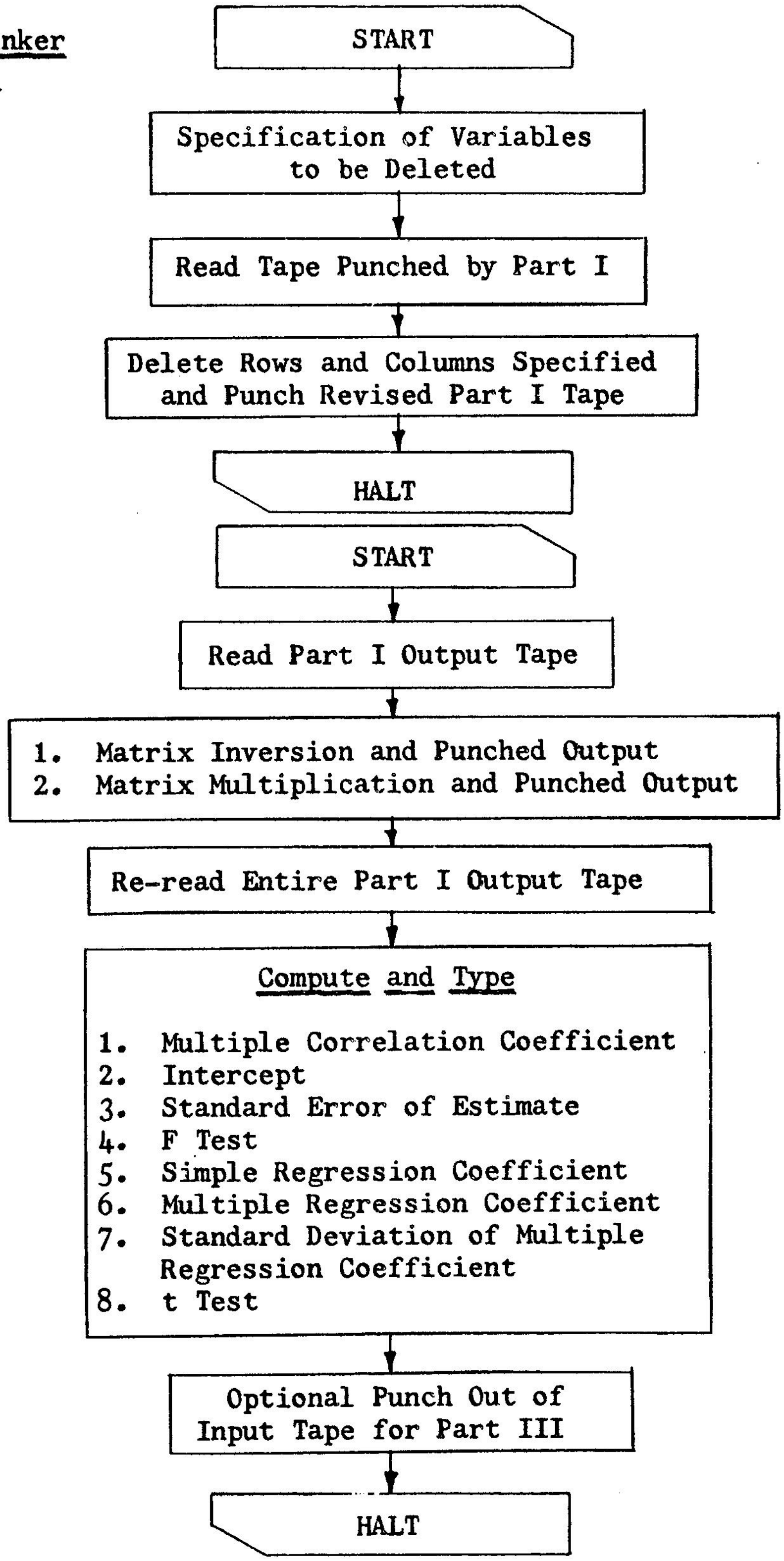


Figure 6

PART III PROGRAM FLOW DIAGRAM

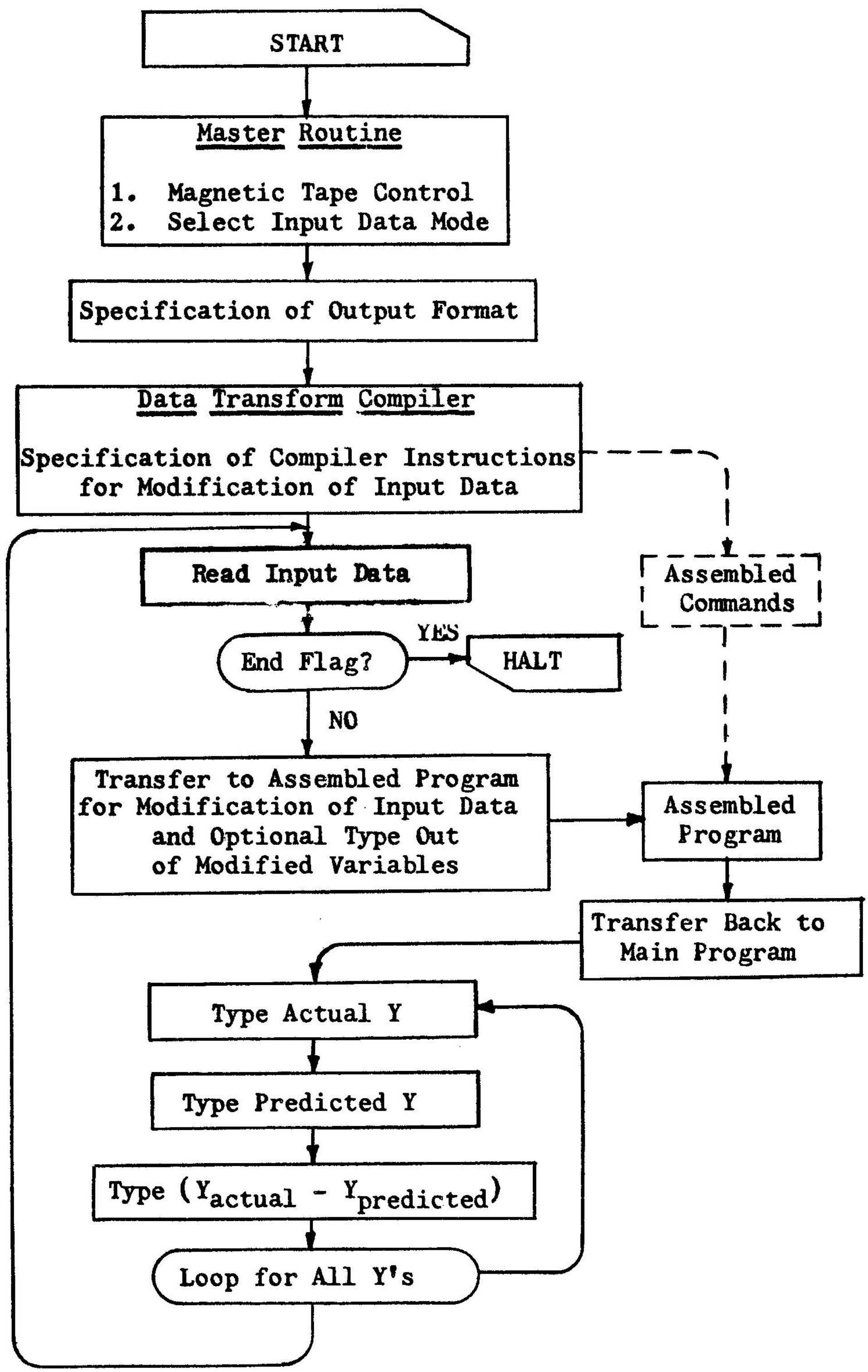


Figure 7

Data Preparation and
Program Set Up

```
p           (1)
7  7  s
                                                                   (2)
790/  s1128/  s39/  s55/  s150/  s87/  s40/  s    2289.000  s  (3)
630/  s700/  s16/  s160/  s110/  s30/  s64/  s    1710.000  s
740/  s673/  s7/  s250/  s122/  s42/  s23/  s    1857.000  s
590/  s454/  s10/  s140/  s140/  s66/  s44/  s    1444.000  s
610/  s611/  s9/  s180/  s120/  s40/  s46/  s    1616.000  s
810/  s1013/  s11/  s200/  s100/  s23/  s42/  s    2199.000  s
750/  s625/  s20/  s80/  s125/  s45/  s78/  s    1723.000  s    (5)
770/  s960/  s30/  s225/  s105/  s26/  s72/  s    2188.000  2  s
(4)
  2  906/  s    2134.000  s
                                                                 (6)
640/  s914/  s12/  s60/  s115/  s35/  s45/  s    1831.000  -  s

    1        650.000  (7)
    2        914.000
    3         12.000
    4         60.000
    5        115.000
    6         35.000
    7         45.000

1  s

 1  640/  s    1821.000  s

690/  s775/  s28/  s120/  s135/  s60/  s67/  s    1875.000  s
720/  s576/  s16/  s90/  s145/  s76/  s44/  s    1667.000  s
850/  s739/  s18/  s100/  s130/  s52/  s59/  s    1948.000  s

sssssss  (8)

y-  s  (9)

 x  5  s  (10)
 y  1  s          (12)   (13)
xx  01  s  02  s  21  s
(11)

xx  01  s  v02  s  01  s  (14)

xx  03  s  v21  s  02  s  (15)

xx  04  s  y00  s  03  s  (16)

xx  05  s     s  04  s   (17)

xx  06  s     s  05  s

xx  07  s     s  06  s

xx     s
      (18)
```

of data. The type out of ADDR, conversion of the number from binary to decimal floating point, and floating point verification have been omitted from op code 51 data input mode. This produces a better input format and nearly doubles input speed. When seven numbers have been entered, the check sum (2) of the variables entered will be typed by the program. The row of data was determined to be correct and "s" was typed (3) to instruct the program to punch data on tape. When punching was complete, the program executed a carriage return and gated for entry of the first number in the next row. At (4) an error was made in entering a variable. The position of this variable was noted, i.e. position no. 2, and the remaining variables entered. When the check sum was typed, the position of the variable was entered (5) to permit entry of the correct value into this position. The program verified the position and gated for entry of the number. After the correct number had been entered, the corrected check sum was typed by the program. The "s" was typed to punch the correct data on tape.

In some instances it cannot be determined which variable has been entered incorrectly. This is frequently the case if two keys are depressed at one time. When this is the case "- (tab)s" is entered as shown at (6) to document the entire row for checking. Tab numbers are typed for easy identification of the incorrect variable. The incorrect variable is shown by (7) and corrected as shown.

When all the rows have been entered and punched on tape, an end flag block must be punched to serve as a signal to the program that all the data have been processed. This block is obtained by entering an entire row of zero numbers as shown by (8). The data tape is now ready to be processed by the program. When the program returned back to the master control following punch out of the end flag, the mode of data input was specified at (9) by entering "y - (tab)s". This sets the program to select and position the paper tape input routine. An entry of "x - (tab)s" would have set the program to read data punched by the Flexowriter, and "z - (tab)s" would have set the program to read data from magnetic tape.

When additional program was read from the magazine, the data transform compiler mode was entered. At (10) the program typed "x" and gated for entry of the number of X variables which would be considered by the program. The six independent variables which were entered during data preparation will be modified and transformed to form five independent variables before being processed by the program. Therefore, "5 (tab)s" was entered. Only one Y variable will be considered by the program.

Regardless of the sequence of input data on the tape read by the program, the X variables must be arranged to occupy positions 1 to 5, followed by the Y variable in position 6.

The arrangement of input data will appear in the sequence shown in figure 1, i.e., pounds of A in position 1, B in position 2, C in position 3, agitator in position 4, temperature in position 5, pressure in position 6, and finally yield in position 7.

As mentioned earlier, the first entry following type out of "xx" specifies the location of the variable which is to be the operand. The instruction identified by (11) indicates that variable in position 1 is to be the operand. The operation which is to be performed on the operand is specified next and is identified by (12). The operation instruction format consists of a sign followed by a digit to specify the operation and two additional digits which may specify the position of the variable. To avoid going into detail of all the operation instructions, I will describe only the ones actually used. The operation instruction "02 (tab)s" is interpreted as add variable in position 2 to the operand. The next entry shown by (13) is the position where the result of the operation is to be stored. In this sequence of instructions the value of A will be picked up from position 1 into the A register, added to B (in position 2) and stored temporarily in an unused position, 21.

The instructions indicated by (14) obtains the value of A (position 1) divided by B (position 2) and stores the quotient as variable 1. As you might suspect, the value of A/B replaces the previous contents of A in position 1.

(15) shows that the pounds of catalyst in position 3 are divided by the sum A + B, which was stored in variable position 21, and the result stored as variable 2. Again, this replaces the previous contents of position 2. Next, it is desired to obtain the log (to the base 10) of the agitator RPM and position it as variable 3. (16) indicates that the agitator RPM was picked up from position 4, the log obtained by entering "y00 (tab)s" as the operation instruction, and the result stored in position 3. The temperature, pressure, and yield in positions 5, 6, and 7 must be moved to positions 4, 5, and 6 respectively. When "(tab)s" is entered for an operation, the program interprets this as a no-operation instruction and proceeds to the point where the variable storage location is specified. (17) shows that the variable in position 5 was moved to position 4 unchanged. Variables 6 and 7 were handled in similar fashion. After all the instructions are entered, the "s" is typed to exit from the compiler mode as shown at (18).

Additional program was read from the magazine, and the program came to a halt to allow the operator to position the data tape on the photoreader.

Figure 8 shows the type out for Part I of the program, the matrix shrinker, and Part II. When all the data have been processed by Part I, the program types the number of rows processed and the degrees of freedom as shown by (19). The average and standard deviation of each variable is typed as shown.

Figure 8
Part I Cont'd.

(19) → 12.0 n
6.0 d.f.

AVG.	STD. DEV.
.9865058	.2103896
.0119378	.0051582
2.0926417	.2200379
124.7500000	15.8350876
48.5000000	20.2192527
52.0000000	15.9316722

A/B	1.000					
C/A+B	-.219	1.000				
LOG RPM	(20) → .136	-.391	1.000			
TEMPERATURE	.378	.405	-.574	1.000		
PRESSURE	.276	.453	-.583	(21) → .985	1.000	
YIELD	.022	.581	-.104	-.193	-.224	1.000

p ← (22)

Part II

6.0 d.f.

R	b_o	Sy.x	F
.9669775	41.6704806	5.4977668	17.2745035

SIMPLE b's	MULTIPLE b's	STD. DEV. OF MULTIPLE b's	t	
1.7015439	43.7894251	12.7061615	(23) → 3.4463142	A/B
1793.1943287	3285.1431836	394.1214218	(23) → 8.3353580	C/A+B
- 7.6146185	- 30.0441357	10.6662368	(23) → - 2.8167512	LOG RPM
- .1950512	.3800167	.8438184	.4503536	TEMP.
- .1776740	- 1.1674674	.6179883	- 1.8891416	PRESSURE

p4 s s p ← (25)
(24) ↑ (points to p4)

Matrix Shrinker & Part II

7.0 d.f.

.9658415	75.5773051	5.1752559	24.3110410

1.7015439	47.5725838	8.9738449	5.3012487	A/B
1793.1943287	3280.3742552	370.8674696	8.8451388	C/A+B
- 7.6146185	- 31.6664639	9.4505694	- 3.3507466	LOG RPM
- .1776740	- .8948893	.1174899	(26) → - 7.6167301	PRESSURE

The simple correlation coefficients, which are typed next, show how well each pair of variables correlate ignoring the variation in the other variables. A perfect straight-line correlation will be indicated by a value of 1.000. Coefficients approaching zero indicate the lack of a straight-line correlation. For example, the first column of coefficients at the left indicates how well the ratio A/B correlates with each of the other variables. The value of .136 shown by (20) indicates that A/B and log RPM are almost completely independent of one another.

Of particular interest is the correlation coefficient between temperature and pressure as shown by (21). The value of .985 indicates that temperature and pressure are closely related and that, for this reaction, an increase in temperature will be accompanied by an increase in pressure. Essentially, pressure and temperature are explaining the same phenomenon.

If both temperature and pressure are permitted to remain as independent variables during operation of Part II of the program, the program will attempt to determine how each affects yield separately. However, they are so closely related that this is not possible. If one is not deleted from the problem, erroneous conclusions will result.

To illustrate the importance of variable deletion, the multiple correlation analysis was completed without deleting pressure or temperature from the problem.

At (22), Part II of the program was loaded and the original tape punched by Part I was read. After additional tape was punched onto the end of the original Part I tape, the entire tape was re-read by the last part of the program to obtain the type out shown. The following expressions are typed:

1. Multiple correlation coefficient, R, which shows how much variation in yield can be explained by the independent variables considered.

2. The intercept of the empirical equation, b_0.

3. Standard error of estimate, $S_{y.x}$, which shows how accurately the yield can be predicted from the independent variables.

4. F test shows how well the data fit the determined empirical equation.

5. Simple regression coefficient, simple b's, which gives the "best" slope of the plot of each independent variable vs. yield, ignoring the effects of all other variables.

6. Standard deviation of each multiple regression coefficient shows how accurately each multiple regression coefficient is known.

7. The t test shows how significant each independent variable is in explaining the yield when all the other independent variables are held constant.

Let us now return to the problem of temperature vs. pressure. First, notice that the t test values shown by (23) indicate that A/B, C/A + B, and RPM have a significant effect on yield. The indication is that yield increases with an increase in the ratio of A/B. Further, the yield increases with an increase in catalyst ratio, C/A + B, and decreases with RPM. Notice that temperature and pressure are indicated to have no significant effect on yield. The t test value of .450 for temperature was obtained by holding pressure and the other independent variables constant while varying temperature. We stated earlier that temperature and pressure were closely related and that temperature could not be held constant while varying pressure.

We shall now delete temperature from the analysis. The matrix shrinker was loaded at (24) and the 4th variable, temperature, was deleted. The matrix shrinker read the original tape punched out by Part I of the program, deleted the specified variable from the matrix and punched a revised tape for processing by Part II. Part II of the program was re-run at (25) to obtain the revised multiple correlation analysis.

Notice that the t test for pressure, (26), now shows that pressure has a very significant effect on yield, and that yield increases with decreasing pressure. This point was substantiated by further experiments where it was shown that tar formation increased and yield decreased at higher reaction pressures.

Figure 9 shows the operation and type out of Part III of the program. The operation of this part is similar to Part I in that a master routine and data transform compiler is used. The program was loaded as shown at (27). The paper tape mode of data input was specified by entry of "y (tab)s" as shown by (28). The format for all typed output was specified at (29). The instructions for the data transform compiler are the same as used in Part I except that the temperature is now deleted from the problem. Since four X variables are to be hendled, the value of A/B, C/A + B, log RPM, and pressure must appear in positions 1 to 4 respectively. The yield must now appear in position 5. (30) shows that temperature was deleted from the input data by moving pressure from position 6 to position 4, and yield from position 7 to position 5. A tape punched at the end of Part II was read by the program at (31) following type out of "3". The program verified the number of X and Y variables which would be considered by the program at (32).

Figure 9

Part III Operation

```
(27) P   (28)   (29)
y  s  3  s
xx  01  s  02  s  21  s
xx  01  s  v02  s  01  s
xx  03  s  v21  s  02  s
xx  04  s  y00  s  03  s
xx  06  s       s  04  s   (30)
xx  07  s       s  05  s
xx  s
3  (31)

x  4  (32)
y  1
```

ACTUAL YIELD, Y	PREDICTED YIELD, Ŷ		Y - Ŷ
40.000	42.630	-	2.630
64.000	61.212		2.787
23.000	30.617	-	7.617
44.000	41.798		2.201
46.000	40.039		5.960
42.000	39.962		2.037
78.000	79.844	-	1.844
72.000	76.974	-	4.974
45.000	46.590	-	1.590
67.000	61.095		5.904
44.000	45.645	-	1.645
59.000	57.587		1.412

The yield, predicted yield based on the determined empirical equation, and the difference are typed for each row of input data processed by the program. If desired, the value of A/B, C/A + B, and log RPM could have been typed out by the program along with the data shown.

XI. Conclusion

I realize that the computations performed by this program may not satisfy the needs of all Users. Various intermediate results are computed by the program but not typed out because we did not feel that they were necessary to the analysis. To solve this problem, we have submitted complete coding sheets, technical description, and flow diagrams in a 263 page write up of this program for use by those of you who may wish to modify the program to suit your own needs.

Although considerable work has already been done on this program, I believe that further improvements could be made by other interested programmers. I can envision a program in which all three parts are run automatically from start to finish using perhaps two or more magnetic tape units or a magnetic tape unit and several auxiliary paper tape readers. Perhaps automatic deletion of independent variables could be included as part of the main program. I know that the matrix algebra operations in Part II could be speeded up by replacing MAP-29 routine with the new Intermap program. Faster matrix development could be achieved in Part I by machine language programming with floating point subroutines. To obtain the maximum flexibility of data transformation, the Intercom exponential and logarithmic subroutines were included as part of the main correlation program. This, of course, reduces the size of the program which can be handled from about 24 to 21 variables. If you are willing to give up these routines, the program can be easily modified to give this additional capacity. If all data transformation features are given up, the maximum size of this program will approach the maximum capacity of Intermap. Furthermore, additional work could be spent writing other data input subroutines.

I hope that the detailed write up of this program will encourage other programmers to modify this program for their own specific needs rather than to duplicate the efforts of others by writing their own separate multiple correlation programs. I think it is important that we try to build on the programs written by others so that we can take maximum advantage of the thinking and planning of other programmers.

Finally, I would like to say that I think that this program, in addition to being an acceptable tool for the statisticians, is also a powerful engineering tool of many uses. I hope that you will put it to good use.

ALGO

The Bendix Algo (Algebraic Language for G-15 Operation) is a programming system that provides an unambiguous language for the statement of a mathematical procedure and an automatic means of translating this language into an efficient machine-oriented code. The ALGO language is a rigorous means of expressing a scientific problem in a systematic format which minimizes the possibility of not listing essential facts and maximizes the efficiency of communicating the problem to a computer or an individual.

The ALGO compiler contains facilities for the input, translation and interpretation, check-out and punch-out of a procedure expressed in the ALGO language. It contains input/output conversion routines, subroutines for the elementary functions, format generation routines and an elaborate routine for the detection and easy correction of errors.

In summary, the ALGO system was designed and developed for two purposes:

(1) To provide all G-15 users with a common language for the expression of mathematical procedures.

(2) To provide Alpha G-15 users with an automatic method of translating this common language into a computer program.

R E G I S T R A T I O N   L I S T

5TH NATIONAL BENDIX G-15 USERS CONFERENCE
PITTSBURGH HILTON HOTEL
PITTSBURGH, PENNSYLVANIA
AUGUST 10, 11, 12, 1960

Ackley, D.	Michigan Highway Dept.
Adams, G.	Aberdeen Proving Ground
Albright, R.	Lovelace Foundation
Andersen, Dennis	Research, Inc.
Anderson, R.	Standard Oil Company of Ohio
Arunson, M. H.	Instruments Publishing Co.
Bair, J. W.	E. I. duPont - Pioneering Research
Barkocy, A.	Vogt, Ivers, Seaman and Associates
Barnhard, P.	E. I. duPont - Gibbstown
Barth, D.	Unit Structures
Baxter, D.	National Research Council - Canada
Bliss, D.	Michael Flynn Manufacturing
Boemer, J.	The Duriron Company
Boldrey, G. L.	Ohio Oil Company
Bomberger, D.	Consolidation Coal Co.
Bonnar, R.	Shell Development Company
Bowles, R.	B. F. Goodrich Chemical Co.
Boyce, H.	Duquesne Light Co.
Boyd, J.	Duquesne Light Co.
Brewer, N. D.	Computing Devices of Canada
Bridge, David	American Natural Gas Co.
Briggs, William	Massachusetts Institute of Tech.
Burdick, W.	E. I. duPont

Calhoun, Alice	General Telephone/Electronics Lab., Inc.
Calistri, Peter J.	Eclipse-Pioneer Division
Capling, L.	Ebasco Services, Inc.
Casely, G. P.	U. S. Weather Bureau
Cassidy, R.	Canadian Pratt and Whitney Aircraft
Cavinness, L.	University of North Carolina
Chamberlain, R.	Standard Oil of Ohio
Chandler, W. R.	Waterbury National Bank
Chang, Jerry C. L.	Richardson, Gordon and Associates
Charlton, Frank	Palmer and Baker Engineers
Cheng, E.	Canadian Industries Limited
Chiat, H.	General Mills, Inc.
Clausse, H. A.	California Dept. Water Resources
Collins, W. H.	Bureau of Public Roads
Conner, H.	Portland Cement Association
Corson, F.	Corn Products
Cook, P.	Consolidation Coal Company
Cox, J. B.	The Chemstrand Corporation
Crane, John Kail	Cook County Highway Department
Crawford, Lewis	Wilson and Company, Engineers
Cristofano, Eugene A.	International Engineering Co.
Czyzewski, L.	DeLeuw, Cather and Company

Daugherty, D.	Duquesne Light Company
Davis, W.	Hercules Powder Company
DeCourval, Claude	Canadian Industries Limited
Dykstra, O.	General Foods
Englund, D. E.	Systems Development Corporation
Faflick, L. J.	Standard Oil of Ohio
Fan, George	DeLeuw, Cather and Company
Fedde, Paul	Texas Gas Transmission Corp.
Felix, F.	Systems Development Corporation
Fliess, M.	Jones and Laughlin
Fontaine, A. P.	The Bendix Corporation
Gardner, D.	General Foods Company
Goode, Harry	University of Michigan
Goudge, M. G.	Computing Devices of Canada
Guderley, G.	Cook County Highway Dept.
Hays, R. F.	American Viscose Corporation
Hayward, A. P.	Duquesne Light Company
Heath, Bill	Continental Oil Company
Hiller, D. E.	U. S. Weather Bureau
Huss, P. O.	University of Akron
Jackson, R. F.	University of Delaware
Jacoby, Deborah D.	U. S. Army Signal R and D Lab.
Jensen, R.	Pacific Missile Range
Johns, Roy F.	Richardson, Gordon and Associates

Jones, S. R.	Midwest Computer Service, Inc.
Jones, W.	Queen Knitting Mills
Judson, R.	B. F. Goodrich
Keifer, C. J.	City of Chicago
Kellgren, John W.	Ellerbe and Company
King, E. H.	Alfred Benesch and Company
Kirkpatrick, G. F.	Computing Devices of Canada
Kissling, K.	Panhandle Eastern Pipeline Co.
Kohman, V.	Curtiss-Wright Corporation
Kudlick, W.	Parsons, Brinckerhoff, Quade and Douglas
Kuhlman, F. W.	General Electric
Kullgren, Dennis	Bendix Industrial Controls
Kulunk, Raif	Vogt, Ivers, Seaman and Associates
Kupferman, Arnold	Tippetts-Abbett-McCarthy-Stratton
Lanctot, B.	Ecole Polytechnique
Landry, Oliver	Meissner Engineers, Inc.
Lee, Jan	Queens University
Logan, William G.	Duquesne Light Company
Lowery, Richard	Bendix Products Division
Lundt, Elsie	Eclipse-Pioneer Division
McCune, D. C.	J and L Steel Corporation
McDowell, Raymond D.	Richardson, Gordon and Associates
McQueen, B.	B. F. Goodrich Company

Madigan, J.	B. F. Goodrich Chemical Co.
Magee, R.	The Magnavox Co.
Martin, D.	Post - Gazette
Martin, David B.	Palmer and Baker Engineers, Inc.
Mecca, T. D.	E. I. du Pont
Merrick, Elsie	Standard Oil Co. (Ohio)
Mills, M. B.	The Lumnus Co.
Morgan, Betty	Fairchild Publications Inc.
Morrison, N. J.	J. E. Greiner Co.
Moyer, Howard	Pittsburgh Press Photography
Mundy, Peter G.	ASC Tabulating Corp
Murphy, W.	E. I. du Pont
Nagle, F. W.	N.W.R.F. Norfolk, Virginia
Nakanishi, Danny	Lockwood, Kessler and Bartlett, Inc.
Noel, Robert G.	North American, Missiles Division
Paulson, T. A.	Dow Chemical, James River Division
Petersen, C.	Elliott Co.
Pierce, J.	Beech Aircraft Corporation
Possik, S.	Dow Chemical Co.
Pohley, F.	Simoniz Company
Potts, John T. Jr.	Reynolds, Smith and Hills
Pratt, G. B.	American Can Co.
Pusterhofer, Anne	Standard Oil Co. (Ohio)
Reese, C. K.	John Deere Research Center
Richardson, George S.	Richardson, Gordon and Associates
Ringstrom, R. M.	Gibbs and Hill, Inc.

Rohr, M. R.	E. I. du Pont
Russell, J. W.	The Ohio Oil Co.
Salin, J. A.	Ebasco Services Inc.
Salter, W. O.	Parsons, Brinckerhoff, Quade and Douglas
Schmalenberger, J. A.	Pan American World Airways
Schmidt, R.	Pratt and Whitney Aircraft-Canel
Schubert, R.	B. F. Goodrich Chemical Co.
Scruby, R. E.	E. I. du Pont
Seligman, E.	Western Electric Co.
Sheets, R.	Aurora Gasoline Co.
Simonetti, P.	Consolidation Coal Co.
Snyder, R.	Standard Oil Company (Ohio)
Sollfrey, W.	General Mills, Inc.
Sorbara, Joe	Autonetics, NAA
Spalding, Al	Tippetts-Abbett-McCarthy-Stratton
Squyres, A.	E. I. du Pont
Stansbury, J.	Scientific Design Co., Inc.
Storey, S. H.	Canadian Industries, Ltd.
Taner, Turhan M.	Scientific Computers, Inc.
Terry, R.	Barber Colman Co.
Thacker, G. R.	Beech Aircraft
Thomas, George C.	Pittsburgh, Press
Thompson, Robert G.	Dodge Manufacturing Corporation
Van Auken, M.	Michigan State Highway Department
Varnum, Edward	Barber-Colman Co.
Villani, C.	Vitro Laboratories
Vogt, Robert S.	Vogt, Ivers, Seaman and Associates
Wall, J. R.	Aurora Gasoline Co.

Watson, R.	Bendix Radio Division
West, D. C.	Canadian Industries Limited
White, H.	Bendix Systems Division
Whitney, Don	Fellows Gear Shaper Co.
Wieland, C. E.	E. I. du Pont
Wittenborn, A. F.	Texas Research Associates
Wobus, H.	Navy Weather Research Facility
Wolf, Lyle	J. Stephen Watkins Consulting Engineers
Wolf, W.	Wolf R and D Corporation
Wright, R. E.	J. E. Greiner
Yang, K. T.	Dodge Manufacturing Corporation
Yeaman, M. D.	Dow Chemical Company
Zimmerman, E.	U. S. Naval Air Turbine Test Station
Zinser, A.	Waterbury National Bank

Adair, Frank	Bendix Computer Division
Annable, John	Bendix Computer Division
Armstrong, C.	Bendix Computer Division
Avery, S. Jr.	Bendix Computer Division
Bell, H.	Bendix Computer Division
Berman, Ray	Bendix Computer Division
Bobrowicz, V. F.	Bendix Computer Division
Bossenga, J. R.	Bendix Computer Division
Buchynsky, P.	Bendix Computer Division
Cannon, Chuck	Bendix Computer Division
Clearwaters, H.	Bendix Computer Division
Cole, Chuck	Bendix Computer Division

Cvetic, F.	Bendix Computer Division
Doyle, H. V.	Bendix Computer Division
Ferguson, M. P.	The Bendix Corporation
Fopeano, R.	Bendix Computer Division
Goldman, R.	Bendix Computer Division
Haladej. A.	Bendix Computer Division
Hassell, D.	Bendix Computer Division
Hatter, E. E.	Bendix Computer Division
Horrell, M. W.	Bendix Computer Division
Huggins, Phyllis	Bendix Computer Division
Johnson, L. E.	Bendix Computer Division
Kaye, R. S.	Bendix Computer Division
Lee, W. T.	Bendix Computer Division
Lorch, H.	Bendix Computer Division
Mattson, R.	Bendix Computer Division
Mikhalkin, B.	Bendix Computer Division
Moore, M. R.	Bendix Computer Division
Myers, J.	Bendix Computer Division
Neary, D.	Bendix Computer Division
Peterson, G.	Bendix Computer Division
Sirvis, G.	Bendix Computer Division
Spalding, R.	Bendix Computer Division
Staderman, O. P.	Bendix Computer Division
Sweet, R. A.	Bendix Computer Division
Turner, L.	Bendix Computer Division
Walls, R.	Bendix Computer Division
Walz, R.	Bendix Computer Division
Whiting, R. C.	Bendix Computer Division
Yamashita, Tak	Bendix Computer Division

REW

COMMITTEE REPORTS

presented at the Steering Committee Meeting

5th NATIONAL G-15 USERS EXCHANGE CONFERENCE

Pittsburgh Hilton Hotel
Pittsburgh, Pennslvania

August 10, 11, 12, 1960

Eastern Laboratory
E. I. du Pont de Nemours & Company
Gibbstown, New Jersey

August 4, 1960

TO: STEERING COMMITTEE
G-15 USERS' EXCHANGE ORGANIZATION

FROM: A. L. SQUYRES, PROGRAM SECRETARY
E. I. DUPONT DE NEMOURS & COMPANY, INC.
EASTERN LABORATORY
GIBBSTOWN, NEW JERSEY

PROGRAM SECRETARY'S REPORT
MAY 9, 1960 - AUGUST 4, 1960

Since the last meeting of the Steering Committee, the following programs have been submitted to the EXCHANGE Program Library:

Table 1

PROGRAMS SUBMITTED SINCE MAY 9, 1960

U.P. No.	Class	Program	Contributed by
473	2	Hydrologic Mass Curve Analysis	Tippetts-Abbett-McCarthy-Stratton
474	1	Interruption and Dump of Intercom 1000DP Program	National Research Council, Canada
475	1	Sorting and Tabulating Reproduction Charges	Reynolds, Smith and Hills
476	1	Multiple Intersections of Circles and Lines	Cook County Highway Dept.
477	1	Six Alphanumeric Routines	Pomona College
478	1	12 x 12 Determinant Evaluation	National Research Council, Canada
479	1	Fixed and Floating Point Output Routine	Canadian Pratt & Whitney Aircraft
480	2	2^n Factorial Design Experiment	Scientific Design Co.
481	1	HEXY - Hex Debugger	Western Electric

Eastern Laboratory
E. I. du Pont de Nemours & Company
Gibbstown, New Jersey

August 4, 1960

TO: STEERING COMMITTEE
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480	2	2^n Factorial Design Experiment	Scientific Design Co.
481	1	HEXY - Hex Debugger	Western Electric

U.P. No.	Class	Program	Contributed by
482	1	Cross-Correlation Function	Seismological Lab., Calif. Inst. of Tech.
483	1	Rayleigh Wave Dispersion - 20 Layers	Seismological Lab., Calif. Inst. of Tech.
484	1	Love Wave Dispersion - 40 Layers	Seismological Lab., Calif. Inst. of Tech.
485	1	Alphanumeric Input/Output Routine	E. I. duPont deNemours Eastern Laboratory
486	1	Intersections of Two Lines - Multiple Input	Cook County Highway Dept.
487	1	Conversion of Floating Point Data from Single to Double Precision	Philips Laboratories
488	2	Meridional Raytrace with Astigmatism	Eastman Kodak Co.
489	2	Building Heat Loss	Stanley Engineering Co.
490	2	Grid North Azimuth of a Line from Polaris Observations	Meissner Engineers
491	2	Machine Language Bar Summarizer	Enelco Limited
492	2	Arithemtic Integration of Restricted Orifice Surge Tank	Tippetts-Abbett-McCarthy-Stratton
493	1	Intercom X-500 Lister	Ledex Inc.
494	1	Simple Program Questioning Routine	University of Delaware
495	2	Orthogonal Polynomial Curve Fitting	Bendix-Pacific Division
496	1	Evaluation of a Definite Integral	National Research Council, Canada
497	2	Geometry Program with Filing Option	Reynolds, Smith and Hills
498	1	Spherical Bessel Function, $j_n(t)$	McMaster University
499	1	Spherical Hankel Function, $h_n^{(1)}(t)$	McMaster University
500	2	Station and Offset	Lockwood, Kessler and Bartlett
501	1	Complete Elliptic Integrals of First and Third Kind	Seismological Lab., Calif. Inst. of Tech.

U.P. No.	Class	Program	Contributed by
502	1	Co-ordinate Conversion Subroutine	National Research Council, Canada
503	1	Subroutine to Calculate Hyperbolic Function with Complex Arguments	National Research Council, Canada
504	1	2 x 2 Complex Matrix Program	National Research Council, Canada
505	1	Analysis of Fixed and Hinged Circular Arches of Constant Cross Section	Portland Cement Association
506	1	Off-line Tape to Tape Version of Intercard Single Precision	North American Aviation
215A	2	Water Distribution System Analysis - Revision	Reynolds, Smith and Hills
413A	1	AROWA WOPPER II	U. S. Navy Weather Research Facility
376A	1	Fit Analysis by Least Squares (501 FABLES)	Douglas Aircraft Company
40C	1	Revised Functional Subroutine Package for DAISY	Bendix Radio

The 155 completed programs which have been processed since the last conference are distributed according to originator as follows:

TABLE 2

User	No. of Programs Contributed
Aurora Gasoline Co.	1
Autonetics	1
Bendix -Pacific Division	1
Bendix Products Division	2
Bendix Radio Division	4
Bucyrus-Erie Co.	1
Butler Manufacturing Co.	1
California Department of Water Resources	2
Canadian Pratt & Whitney Aircraft Co.	4
City of Chicago, Bureau of Engineering	2
Continental Oil Co.	2
Cook County Highway Department	3

User	No. of Programs Contributed
De Leuw, Cather & Co.	1
Douglas Aircraft Co.	1
Dow Chemical Co., Eastern Division	2
Du Pont Economic Studies	6
Du Pont Mechanical Development Lab.	2
Du Pont Pioneering Research	4
Du Pont Repauno Process Lab.	1
Eastman Kodak Co.	1
Ebasco Services, Inc.	1
Ellerbe and Co.	2
Enelco Limited	1
Fellows Gear Shaper Co.	1
General Mills, Inc.,Mechanical Division	1
J. E. Greiner Co.	3
Illinois Department of Public Works	1
Ledex, Inc.	1
Lockwood, Kessler & Bartlett, Inc.	3
McMaster University	3
Meissner Engineers, Inc.	4
Midwest Computer Service	5
National Research Council of Canada	9
North American Aviation	4
Pacific Union College Data Processing Lab.	3
Palmer and Baker Engineers, Inc.	7
Parsons, Brinckerhoff, Quade and Douglas	4
Philips Laboratories	1
Pomona College	3
Portland Cement Association	2
Reynolds, Smith and Hills	3
Richardson, Gordon and Associates	5
Scientific Computers, Inc.	1
Scientific Design Co.	5
Seismological Laboratory, Calif. Inst. of Tech.	4
Stanley Engineering Co.	2
Sun Oil Co.	1
Texas Gas Transmission Corp.	1
Textile Research Institute	1
Tippetts-Abbett-McCarthy-Stratton	2

User	No. of Programs Contributed
Thiokol Chemical Co.	1
Tudor Engineering Co.	2
U. S. Army Artillery and Misslie School	1
U. S. Army Engineer District, Los Angeles	1
U. S. Navy Weather Research Facility	4
University of Arkansas	1
University of Delaware	1
University of Wisconsin	1
Vitro Labs.	1
Vogt, Ivers, and Seaman and Associates	2
J. Stephen Watkins, Consulting Engineers	1
Western Electric Co.	1
Wilson and Co.	1
Wyoming Highway Department	4

In view of the increasing number of programs in the Exchange Library and the increasing frequency with which these programs require correction or revision, it is proposed that a standard procedure be set up for handling corrections to programs in the library. It seems to me that there are different classes of corrections, some of which are minor in nature, involving changes in a few commands, or perhaps only a modification of the operating instructions, while others may be significant revisions with changes amountin to several pages of coding. It is essential that corrections be distributed to all users having the program and that the Library copy of the program and write-up be up-to-date, but it does not seem practical to distribute corrected tapes and write-ups for minor corrections in programs.

I have divided the types of corrections into three categories, and I am listing the material which should be submitted with each of these categories. In each case, Item 1 is for distribution to all users (along with abstracts of new programs) and Item 2 is for purposes of correcting the copy of the program in the Exchange Library.

A. Minor changes involving changes in operating instructions or descriptive matter only, but no change in coding.

    1. One-page description of the change.

    2. Revised page for program write-up. In some cases, this may be the same as (1) and simply attached to the write-up.

B. Corrections involving changing a few commands in program.

    1. List of corrected commands and a description of the effect of the changes, if applicable.

2. a. New tape.
   b. Corrected coding sheets for replacement in write-up if coding sheets were originally submitted.

C. Large revisions involving many commands.

1. A new abstract to inform users of the change. In this case, the project will have a letter added to the project number to indicate the revision.

2. a. New tape.
   b. New coding sheets if coding sheets were originally submitted.
   c. New descriptive matter where applicable, together with instructions as to how this matter is to be included in the write-up, that is, by replacement or addition to the existing write-up.

In order to conform to established procedure, all corrections should be submitted to the program secretary.

(HMBo)

SHELL DEVELOPMENT COMPANY
A DIVISION OF SHELL OIL COMPANY
EMERYVILLE, CALIFORNIA

August 4, 1960

AIRMAIL

Dr. J. C. L. Chang, Chairman
Bendix G-15 Users' Exchange Organization
Richardson, Gordon and Associates
3 Gateway Center
Pittsburgh 22, Pennsylvania

Dear Sir:

During the period since the last Annual Conference, Informational Memoranda numbered 14 through 19 have been compiled from the Program Progress Reports received. There have been 46 individual reports averaging somewhat over 4 programs per report. The schedule agreed upon at the last annual conference has been maintained.

Yours very truly,

R. U. Bonnar, Report Secretary
Bendix G-15 Users' Exchange Organization

RUB:cac
cc: Messrs. H. Chiat
L. Czyzewski
W. Davis
P. Fedde
J. Russell
W. Salter
W. Sollfrey
A. Spalding
A. Squyres
T. Yamashita

PROGRAM DISTRIBUTION STATUS REPORT
Corrected and complete as of August 6, 1960

Prepared for the Fifth National Bendix G-15 Users Exchange Conference; August 10, 11, 12, 1960 at Pittsburgh.

Company	Programs Submitted	Class 2 Requested	Remaining Entitlement
ACF Industries	0	0	5
Aberdeen Proving Ground, Maryland	0	0	5
Aconstica Associates, Inc.	0	0	5
Allied Research Associates, Inc.	0	0	5
AiResearch Manufacturing Company	0	2	3
Allis Chalmers Manufacturing Company	0	0	5
Amalgamated Wireless (Australasia) Ltd.	0	0	5
American Can Company	0	1	4
American Viscose Corporation	2	10	5
University of Arkansas	1	0	10
Army Map Service	1	5	5
ASC Tabulation Corporation	0	0	5
Aurora Gasoline Company	1	0	10
BJ ELECTRONICS, Borg-Warner Corp.	0	0	5
Beech Aircraft Corporation	1	1	9
Beechcraft Research	0	0	5
Bendix Aviation Corporation	30	17	178
Bendix Computer	0	0	5
Bendix Pacific	1	0	10
Bendix Products	3	5	15
Bendix Radio	26	12	123
Dept. 8710, Utica, N. Y.	0	0	5
E. P. Div., Elec. Instr.	0	0	5
E. P. Div., Systems Lab.	0	0	5
Eatontown, N. J.	0	0	5
Kansas City Div.	0	0	5
Alfred Benesch and Associates	2	12	3
Bucyrus-Erie Company	1	2	8
Butler Manufacturing Company	3	2	18
State of California	2	6	9
California Institute of Technology	3	1	19
Caltec, Incorporated	0	0	5
Cambridge Electron Accel.	0	1	4
Canadian Industries Ltd.	0	5	0
Canadian Pratt and Whitney Aircraft	4	3	22
The Chemstrand Corporation	2	1	14
Charles W. Cole and Son	0	5	0
City Bureau of Engineering, Chicago	2	8	7

Company	Programs Submitted	Class 2 Requested	Remaining Entitlement
Coleman Engineering Company, Inc.	0	0	5
University of Colorado	0	1	4
Computing Devices of Canada	18	8	87
Consolidation Coal Company	0	0	5
Consoer, Townsend & Associates	4	24	1
Continental Oil Company	3	1	19
Cook County Highway Department	8	29	16
Corn Products Company	0	2	3
Curtis-Wright Corporation	0	1	4
Datron, Incorporated	0	2	3
State of Delaware	0	0	5
University of Delaware	2	2	13
DeLeuw, Cather & Company	8	14	31
Douglas Aircraft Company, Inc.	1	0	10
Dow Chemical Company	4	6	34
James River Division	3	3	17
Rocky Flats Plant	0	0	5
Western Division	1	1	9
Texas Division	0	2	3
Du Pont de Nemours	61	30	340
Benger (Orlon) Laboratory	2	2	13
Carothers (Nylon) Laboratory	5	0	30
Cumberland Group	0	1	4
Dacron Research Laboratory	0	1	4
Eastern Laboratory	5	0	30
Economic Studies	34	7	168
Engineering Department	1	1	9
Film Department	0	0	5
Mechanical Development Laboratory	3	13	7
Pioneering Research	10	5	50
Repauno Process Laboratory	1	0	10
Textile Research Laboratory	0	0	5
Yerkes Research Laboratory	0	0	5
Duquensne Light Company	0	0	5
Dynamics Research Corporation	0	0	5
Eastman Kodak	1	1	9
Ebasco Services	1	0	10
Ecole Polytechnique	0	1	4
Edwards & Kelcey	8	15	30
Electronic Calculating Service	3	0	20
Ellerbe & Company	2	7	8
Enelco Ltd.	5	14	16
Experiment Incorporated	1	1	9
Falcon Research & Development	0	0	5
Fellows Gear Shaper Company	2	4	11
Michael Flynn Manufacturing Company	0	7	0
Fordham University	0	1	4

Company	Programs Submitted	Class 2 Requested	Remaining Entitlement
Foster Wheeler Corporation	0	5	0
General Applied Science Laboratories, Inc.	0	0	5
General Electric Company	0	1	9
Flight Prop. Div.	0	1	4
Lamp Division	0	0	5
General Foods Corporation	0	0	5
General Mills, Incorporated	7	4	36
B. F. Goodrich Company	4	1	29
Avon Lake	0	1	4
Akron, Ohio	4	0	25
W. R. Grace & Company	0	5	0
Grand Central Rocket	0	0	5
J. E. Greiner Company	7	20	20
Harley, Ellington & Day, Incorporated	9	11	39
Harza Engineering Company	0	0	5
Hercules Powder Company	3	3	17
Highway Research Board	1	3	7
Illinois Division of Highways	7	8	32
International Engineering Company, Inc.	0	0	5
International Petroleum	0	0	5
Jones & Laughlin	0	2	3
Lafayette Clinic	0	5	0
Land-Air Incorporated	0	2	3
Ledex Incorporated	1	0	10
H. W. Lochner, Incorporated	3	21	0
Lockwood, Kessler & Bartlett, Inc.	11	30	30
Los Angeles City College	0	0	5
Lummus Company	0	1	4
E. J. McDonald & Associates	1	4	6
McMaster University	31	0	20
The Magnavox Company	0	0	5
University of Manitoba	1	2	8
Martin Company	0	0	5
Mead Corporation	0	2	3
J. F. Meissner, Engineers Incorporated	13	45	25
Michigan College of Mining & Technology	0	0	5
Michigan State Highway Department	8	15	30
Midwest Computer	15	37	43
Minneapolis Honeywell (St. Petersburg, Fla.)	0	0	5
Mitsubishi Electric	2	0	15
National Commercial Bank	0	0	5
National Research Council of Canada	13	25	45
National Aeronautical Estb.	0	0	5
Naval Air Development Center	4	0	25
North American Aviation, Inc.	1	0	10
Nortronics	0	0	5
Ohio Oil Company	2	2	13

Company	Programs Submitted	Class 2 Requested	Remaining Entitlement
Omni Ray A. G.	0	0	5
Pacific Union College	2	3	12
Packard Bell Computer Corporation	0	0	5
Palmer & Baker Engineers	9	30	20
Panhandle Eastern Pipe Line Company	0	2	3
Parsons, Brinckerhoff, Quade & Douglas	14	36	39
Philco Corporation	0	1	4
Philips Laboratories	1	5	5
Pomona College	3	0	20
Portland Cement Association	4	6	19
Queen Knitting Mills	0	0	5
Queen's University	0	0	5
RCA Service Company	0	0	5
Research, Incorporated	0	2	3
Reynolds, Smith & Hills	6	17	18
Richardson, Gordon and Associates	15	46	34
Rohm and Haas Company	0	0	5
Sacramento Peak Observatory	0	1	4
Scientific Computers, Incorporated	1	8	2
Scientific Design Company	5	9	21
Shell Development Company	5	8	22
Seismograph Service Corporation	0	0	5
Standard Oil Company (Ohio)	0	2	3
Stanley Engineering Company	3	10	25
Sylvania Electronic Tubes	0	0	5
System Development Corporation	0	0	10
Paramus, New Jersey	0	0	5
Santa Monica, California	0	0	5
Texas Gas Transmission Corporation	6	12	23
Texas Research Associates Corporation	0	0	5
Textile Research Institute	2	0	15
Theo. Chemical Lab., Univ. of Wisconsin	4	4	21
Thiokol Chemical Corporation	1	0	10
Tippetts-Abbett-McCarthy-Stratton	10	36	19
Transcontinental Gas Pipe Line Corp.	0	0	5
Tudor Engineering Company	5	15	15
Unit Structures Incorporated	0	0	5
United Air Lines	0	0	5
U.C.L.A. Geophysics Institute	1	0	10
U. S. Artillery School	1	0	10
U. S. Army Engineering District (L. A.)	10	0	55
U. S. Snow, Ice, etc.	1	4	6
U. S. Dept. of Commerce (W.B.)	0	0	5
U. S. Dept. of Interior Bu. Recl.	0	6	0
U. S. Naval Test Station	0	4	1
U. S. Naval Engineering Experiment Station	0	2	3
U. S. Navy Hydrographic Office	0	1	4

Company	Programs Submitted	Class 2 Requested	Remaining Entitlement
U. S. Navy Research Lab., Radar	0	1	4
U. S. Navy Research Lab., Upper Air	0	2	3
U. S. Navy Weather Research Facility	2	2	13
Vitro Laboratories	2	0	15
Vogt, Ivers, Seaman & Associates	13	40	30
J. Stephen Watkins	8	33	12
Western Electric Company	2	1	14
Wilson and Company	12	20	45
Wolf Research and Development Corp.	0	5	0
Worthington Corporation	0	1	4
Wyoming Highway Department	2	4	11
University of Wyoming	0	0	5

Paul C. [signature]

Distribution Secretary
Bendix G-15 Exchange Organization

General Mills

MECHANICAL DIVISION

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August 10, 1960

TO: Steering Committee, G-15 Users Exchange Organization

FROM: Harvey J. Chiat, Publicity Chairman

This past year has been very successful, publicity wise, for the Exchange Organization. Notices of this Annual Conference, as well as the Semi-Annual Civil Engineering Conference in March, were carried by many publications. We also had reviews of our last conference in a number of computer publications. Thanks is due to Bendix Computer Division and especially Phyllis Huggins, Applications Editor, who has been responsible for placing many of the notices and reviews.

The Exchange NEWSLETTER was "born" in this past year. Five issues, not including the Conference Issue which will be distributed tomorrow, have been published this year. Such sections as "Coders' Corner" and "News from the Computer Division" have become permanent parts of the NEWSLETTER. We have tried to make the NEWSLETTER a tie for the members of Exchange between conferences with news on new programs, reports on Steering and Executive Committee meetings, and notices of forthcoming conferences. We have received contributions for "Coders' Corner" from many of the Users.

In closing, I would like to thank each of the members of the Steering Committee for their help in getting news items for the NEWSLETTER. Special thanks goes to Arthur Squyres for sending advanced copies of abstracts of noteworthy new programs. Also special thanks are due to Tak Yamashita and the Bendix Computer Division for reproducing, collating, and distributing the NEWSLETTER for the Exchange Membership.

Harvey J. Chiat

Harvey J. Chiat
Publicity Chairman

HJC:meb

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BATON ROUGE

August 11, 1960

To: Steering Committee, Bendix G-15 Exchange Organization

From: W. O. Salter, Chairman, Committee on Civil Engineering Applications

Subject: Report of Committee Activities

Since the last Steering Committee meeting in May the Committee on Civil Engineering Applications has held an election of officers to their Executive Committee, and has appointed a Chairman for the year 1960-1961. Lew Crawford of Wilson and Company, of Salina, Kansas, is the incoming Chairman. The newly elected members to the Committee are John Crane, John Potts, and Andy Barkocy. A complete list of the new Executive Committee is attached to this report.

The representation of this Committee on the Steering Committee will change somewhat. Lew Crawford will replace Win Salter for a one-year term as C. E. Committee Chairman. Andy Barkocy will replace Murph Czyzewski, whose two-year term expires. Al Spalding remains on the Steering Committee for his second year.

The survey conducted by Al Spalding to measure the extent of real interest and potential participation in an academic course in matrix algebra has been completed with disappointing results. There is not sufficient interest or available time, on the part of enough users to warrant the proposed two-week, $100 course. A more detailed description of the survey results is being prepared and will be available.

A general survey of C. E. members was also conducted in connection with the balloting for officers. Members were asked to name the top five library programs found to be most valuable to them. The detailed results of this survey have been tabulated and are available.

Since May, two new members have joined the civil engineering group: ASC Tabulating Corporation of Lake Bluff, Illinois, and Caltec, Inc., of Toledo, Ohio.

At the close of this conference the new Executive Committee will begin working on the time and place of the 14th Conference of the Committee on Civil Engineering Applications.

Respectfully submitted,

W. O. Salter

W. O. Salter

COMMITTEE ON CIVIL ENGINEERING APPLICATIONS
EXECUTIVE COMMITTEE MEMBERS
1960 - 1961

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General Secretary
Basil Mikhalkin
Applications Section
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Representatives of Membership-at-Large
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Palmer and Baker Engineers
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John Kail Crane
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County of Cook
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Subcommittee on Structural Design

Chairman
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Tippetts-Abbett-McCarthy-Stratton
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Subcommittee on Highway Design

Chairman
Andrew R. Barkocy
Vogt, Ivers, Seaman and Associates
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Secretary
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John F. Meissner Engineers
300 West Washington Street
Chicago 6, Illinois

COMMITTEE ON CIVIL ENGINEERING APPLICATIONS

PROGRAM VALUE SURVEY
1960

REPORT ON REPLIES

The Executive Committee has attempted to determine which programs in the Exchange library have proven to be most valuable and useful to civil engineering users. A survey form was distributed, with the annual ballot for officers, which asked all committee members to list in order of decreasing worth these programs, up to five in number. Service routines, interpreters and compilers were to be omitted from consideration. The purpose of the survey was to give newer users some idea of what programs in practice have proven most useful and to determine, if possible, whether there exists a predominant subject area of value. Also, there is no doubt general interest by all members in the worth to others of what they have produced.

No statistical analysis is attempted here. Such analyses and conclusions, if needed, are left up to the reviewer.

Survey forms went out to the 50 members of the Committee. Of these, 29 were returned. This ratio seems good considering that of the 50 members, three are relatively new users with nine months or less experience and 12 are members who have been relatively inactive in the civil engineering group, because of a highly specialized installation, greatly limited civil engineering applications, or a proprietary policy.

Of these 29 returns three cited no programs and said, in effect, that so far no use had been made of the Users Library. The number of replies or programs cited contained in these 29 returns is as follows:

Number of Projects Cited	Number of Returns Citing This Many	Total Number of Votes Cast
5	16	80
4	3	12
3	1	3
2	2	4
1	4	4
0	3	0
Totals	29	103

In tallying the votes in the 26 returns which cited at least one program, it was necessary in three instances to group the votes of interdependent programs. These cases were where one program was cited which will generally require operation of another program. These instances of grouping are:

U.P. #100 and U.P. #182
U.P. #24 and U.P. #119
A.S.P. #32 and U.P. #107

Thirty-four programs were cited only once. The remaining 69 votes were distributed to 14 projects, recognizing the groupings of the three pairs of programs listed above. That is, 14 projects received two or more votes.

In an effort to recognize the relative rank of the worth of these programs, a value has been assigned to each of the five places, i.e., each first place vote has been assigned a value of 5; second place, 4; third place, 3; fourth place, 2; and fifth place, 1. This is rather arbitrary and open to question. Listed below in apparent order of decreasing worth are the 14 projects which received two or more votes.

		Votes Cast by Place					Total	Total
Rank	Project No.	1	2	3	4	5	Votes	Worth
1	UP 21	6	3	1	1	0	11	47
2	UP 106	3	4	1	0	1	9	35
3	ASP 32/UP 107	1	0	4	3	1	9	24
4	UP 49	2	2	1	0	1	6	22
5	UP 26	1	3	1	0	1	6	21
6	UP 24/UP 119	1	0	1	3	1	6	15
7	UP 100/UP 182	1	1	2	0	0	4	15
8	UP 134	0	1	1	2	0	4	11
9	UP 30	2	0	0	0	0	2	10
10	UP 215	1	0	0	1	1	3	8
11	UP 133	0	1	0	1	1	3	7
12	UP 88	0	1	1	0	0	2	7
13	UP 242	0	1	0	1	0	2	6
14	UP 203	0	0	1	1	0	2	5
	Totals	18	17	14	13	7	69	

The 34 programs for which single votes were cast, listed by place, are these:

PLACE 1	2	3	4	5
UP 79	UP 28	ASP 60	UP 82	UP 22
UP 224	UP 118	UP 97	UP 140	UP 90
UP 236	UP 167	UP 184	UP 208	UP 126
UP 295	UP 235	UP 279	UP 223	UP 131
UP 376	UP 326	UP 321	UP 294	UP 159
UP 423		UP 363	UP 407	UP 210
UP 428				UP 259
UP 444				UP 365
				UP 398

Respectfully submitted,

W. O. Salter

W. O. Salter, Chairman

General Mills

MECHANICAL DIVISION

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August 10, 1960

TO: The Steering Committee

FROM: William Sollfrey, Chairman
Committee on Electrical and Mechanical Engineering Applications

During the current report period, the principal activity of this committee has been to establish an up-to-date roster of membership. A copy of same is attached herewith. Also, elections by mail have been conducted in the normal manner for new officers, and Mr. E. A. Cristofano of the International Engineering Company will be the chairman of the committee for 1960-61.

The agenda for the annual workshop has been established. It will include four papers on selected subjects, followed by general discussions of the activities of the committee in the past and coming year.

W. Solly

WS/meb