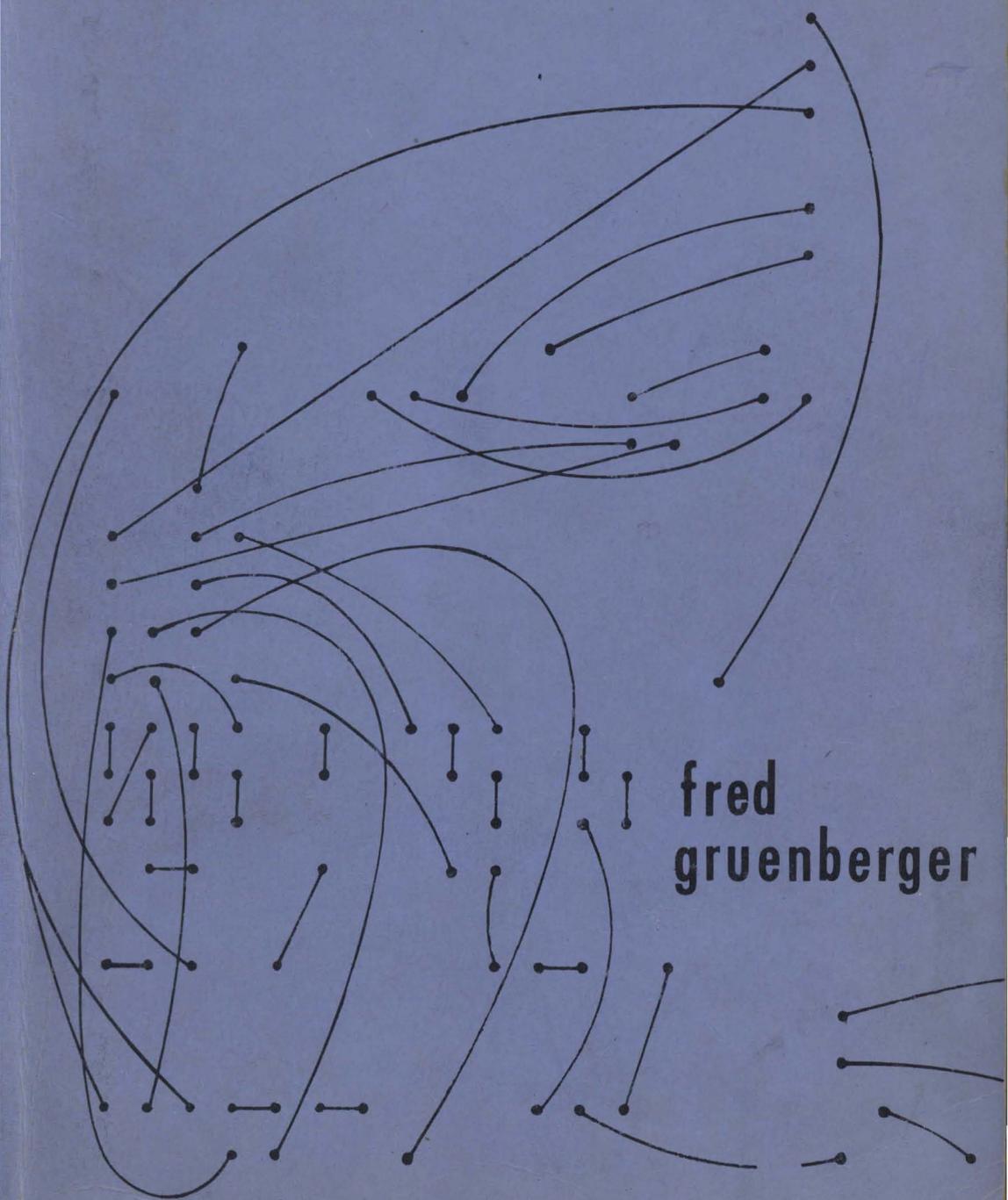


computing manual

Fred Gruenberger
SILVER



**fred
gruenberger**

Compliments of the
author

Fred Gruenberger

**computing
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**fred
gruenberger**

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Preface

With the rapid growth of separate computing installations in industry and in universities, there is need for a book to help train machine computers. This book is intended as such an aid, particularly in training personnel for work in (IBM) punched card computing.

Grateful acknowledgement is made to K. J. Arnold, who guided the University of Wisconsin Computing Service from its early stages—desk calculators, plus a keypunch and sorter—to its present size. Many of the technical developments are the work of Marjorie S. Herrick. The section on questionnaire methodology was written by David A. Grant.

The first two editions have been used as a text in the course in Theory and Operation of Computing Machines (Mathematics 131) at Wisconsin during 1951 and 1952.

Fred Gruenberger

Madison, Wisconsin

July, 1952

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part I
computing
notes

1 Questionnaires

If data, gathered by multiple-choice answers to questions, is to be tabulated by machine, the layout of the original schedules should be gone over with someone familiar with IBM equipment and techniques. Often the format of the schedule can be arranged to speed up key-punching. For each question, the paramount consideration is the use to which the data is to be put. For example, if the age of the person answering is needed, and the ultimate tabulation groups ages by ten year groups, the question could readily be worded to code the answer in that form. All sorts of coding can be incorporated directly into the schedules, saving a costly editing job later. If space for answers is reserved uniformly down the right or left margin of the sheet, editing, coding, and keypunching is materially speeded.

If possible, it is well to avoid ranked answers, or questions in which more than one answer is permissible, since these situations are more difficult to handle in punched card tabulation. Double punching in any column of the IBM card is to be avoided, since it sends the cost of punching up sharply and makes the duplication of a damaged card rather difficult.

It is usually better to plan the punching of a long schedule on two cards (per schedule) rather than compress the data into one card. For example, seventy-six answers might be compressed into one card (reserving four columns for identification) by such devices as using only one column for an item with a range of sixteen, through double punching. It is probably as efficient and as cheap to use two cards and, for the item in question, use two columns for the range from one to sixteen. When two cards are used, it is best to split the punching approximately equally between the two; wear and tear on the two decks is thus minimized, and if cross tabulations are needed between the decks, room is left on either for reproducing parts of the other.

It should be pointed out that if the object is simply a distribution of each of the items of the schedule, punched cards are not efficient.

The distributions can be obtained quicker and cheaper by paper and pencil methods. IBM equipment should be used in tabulating questionnaires only when involved cross tabulations will be needed.

Some of the above precautions can be contradicted in some cases. It is possible to punch 4096 different combinations in one column of an IBM card, though it is seldom necessary to punch more than twelve or, in the case of mixed alphabetic and numeric information, serial numbering (and hence identification) can still be added in binary form, using the X and Y punch positions.

It is always a splendid idea to serial number the original schedules and the cards to correspond.

Editing and coding should be done—preferably by the person who collected the data—prior to keypunching. If the keypunch operator is expected to code while punching (or even to have to look around the schedule sheets for the next item) the error level in punching will soar.

Coding

As a general practice, in coding data for punching, it is well to reserve Y punches (12's) for "no answer," X punches (11's) for controls of various kinds, zero for true zeros, and to code missing data according to how it is to be handled in tabulation. In many cases, absence of data is the most important situation to tabulate; it may be convenient to indicate it by blank columns. However, it is usually easier to keypunch (and more positive) some combinations of holes to indicate missing data.

It is generally easier and faster to punch digits from one to nine rather than zeros or X's. Hence for variables with a range of two, it is best to code the possibilities as one and two in preference to X and Y or other punches. On the other hand, in coding such things as ages of people in ten year groupings, it is better to use the actual ten's digit of the age, since the code is more readily memorized.

When a particular item has a range of only 12, there is a temptation (sometimes a necessity) to punch it in the 12 hole positions of one column. However, it must be kept in mind that if the variable involved is to be treated arithmetically (e. g., for correlation data),

the X, Y, and zero holes will not act properly. Furthermore, the provision for "no answer" is lost.

An X punch is frequently reserved in coding to be only the control which ejects the card on an O16 punch (using an uncut low skip bar). The X in the master card then performs ejection automatically and also signals that the proper number of columns have been punched. However, with O36, O24, or O26 punches (or O16 or O31 punches for which a special skip bar is cut), X need not be reserved for ejection and can be used in the coding.

If X's and Y's are used in coding, it must be remembered that collating operations, such as merging, may be upset, since the numeric collator does not sense other than digit punches in the sequencing unit.

Control on the IBM Tabulator

The tabulator has two complete 80-brush reading stations, spaced one card apart. As one card is being read at the lower brush reading station (where information is usually read for adding, subtracting, etc.) the card following it is being read in perfect synchronization with it at the upper brush station. Controlling or identifying information read from any column of successive cards can be compared. Thus the tabulator automatically senses a change between groups of cards previously sorted and acts on that change by halting feeding and then printing (or punching on the 513) totals from counters. At the same time it is usually directed to turn the counters back to zero and then automatically start feeding the cards of the next group.

Three levels of such control are available on the machine; major, intermediate, and minor. Suppose, for example, that in a sociological study, cards are punched for each individual, showing sex (either 1 or 2 in column 1 of the cards), intelligence (some digit from zero to 9 in column 2) and residence (1, 2, or 3 in column 3). Other columns on the card contain various information. If information is to be tabulated by sex, I.Q. within sex, and residence within I.Q., then column 3 is the minor control column, column 2 the intermediate control column, and column 1 the major control column, and the cards must be sorted on columns 3-2-1 in that order. For simplicity, let us suppose we have exactly 3000 cards evenly distributed on these three characteristics

(i.e., 1500 males, 300 of I.Q. zero, 1000 of residence 2, etc.). Sorted as indicated, the first 1500 cards are all sex 1; of those, the first 150 are all I.Q. zero; of those, the first 50 are residence 1. The tabulation of data on any other portion of the card, then, will be broken into such groups.

Now it is essential that the correct order of control be maintained. We have chosen residence within I.Q.; that is, for each I.Q. group we will obtain totals for the three possible residences. See Table II. If we wish, on the other hand, I.Q. within residence, the order of sorting is changed to columns 2-3-1 in that order, and column 2 has minor control, column 3 intermediate, column 1 major as before. See Table I.

Note that though we are using only three controls (which seems at first glance to be rather small), we have broken our deck into 60 parts ($2 \times 10 \times 3$). If within each such subgroup we wish to distribute some other column into 12 parts, then if the distribution is approximately even, we should expect all frequencies of the order of 4 or 5.

Persons unfamiliar with this technique of sorting are prone to request four levels of control (or more). Now, this is quite possible if needed. For example, suppose that the 3000 cases we have used were all Dane county. Another 3000 may be available, all Milwaukee county. If both decks are sorted independently, when run through the tab successively we will have effectively a super major control (on counties). The break between the two decks of 3000 will be quite apparent on the printed listing, even though the machine is not directly controlling on county.

However, in normal practice, four levels of control are seldom needed. In a study of only 3000 cards, if the four control variables have ranges of 2, 10, 3, and 10, respectively, the use of four control levels would break the deck into 600 parts (not necessarily equal). On the average, we would be taking a control "break" every five cards. This is seldom what is really desired.

Let us emphasize that it is important which variable be considered major, intermediate, and minor. The clue to the whole situation is the word "within." Which variables are to be included within which others? A variable within another variable is to have a more minor

control level (i.e., "minor" is lower than "intermediate" and the latter is lower than "major.")

Table I

Sex	Res.	I.Q.	Card Count	Sex	Res.	I.Q.	Card Count
1	1	1	2	2	1	2	2
1	1	2	2	2	1	3	1
1	1	3	2	2	1	4	4
1	1	4	2	2	1	5	5
1	1	5	4	2	1	6	1
1	1	6	3	2	1	7	1
1	1	7	3	2	1	8	5
1	1	8	2	2	1	9	4
1	1	9	2				
				2	2	2	1
1	2	1	3	2	2	3	6
1	2	2	3	2	2	4	4
1	2	3	2	2	2	5	5
1	2	4	3	2	2	6	7
1	2	5	7	2	2	7	7
1	2	6	4	2	2	8	1
1	2	7	5	2	2	9	2
1	2	8	3				
1	2	9	3	2	3	1	1
				2	3	2	1
1	3	1	1	2	3	3	1
1	3	2	2	2	3	4	6
1	3	3	2	2	3	5	2
1	3	4	1	2	3	6	1
1	3	5	3	2	3	7	1
1	3	6	1	2	3	8	1
1	3	7	1	2	3	9	3
1	3	8	9				
1	3	9	5				

Table II

Sex	I.Q.	Res.	Card Count	Sex	I.Q.	Res.	Card Count
1	1	1	2	2	1	3	1
1	1	2	3	2	2	1	2
1	1	3	1	2	2	2	1
1	2	1	2	2	2	3	1
1	2	2	3	2	3	1	1
1	2	3	2	2	3	2	6
1	3	1	2	2	3	3	1
1	3	2	2	2	4	1	4
1	3	3	2	2	4	2	4
1	4	1	2	2	4	3	6
1	4	2	3	2	5	1	5
1	4	3	1	2	5	2	5
1	5	1	4	2	5	3	2
1	5	2	7	2	6	1	1
1	5	3	3	2	6	2	7
1	6	1	3	2	6	3	1
1	6	2	4	2	7	1	1
1	6	3	1	2	7	2	7
1	7	1	3	2	7	3	1
1	7	2	5	2	8	1	5
1	7	3	1	2	8	2	1
1	8	1	2	2	8	3	1
1	8	2	3	2	9	1	4
1	8	3	9	2	9	2	2
1	9	1	2	2	9	3	3
1	9	2	3				
1	9	3	5				

Questionnaire Methodology

Questionnaires deal with verbal responses only, although the verbal responses presumably have implications with respect to other behavior of the respondents. The following remarks are intended to serve as suggestions and warnings to investigators who must use questionnaire techniques in their research.

The Absolute Percentages of Replies Mean Very Little

The absolute number of responses of one sort or another to a questionnaire item can not be taken as having absolute meaning. The percentage figures can be altered easily by changing order, format, wording, and techniques of questioning the respondents.

Wording conditions the percentage of answers. First of all, the questionnaire writer usually possesses more facility with words than do questionnaire respondents. This leads to misunderstandings of the question on the part of the respondent with resulting confusion in responses. The questionnaire writer can not overestimate the ignorance of the respondent as far as words are concerned. He should choose his words from some source of words in frequent use, such as the Thorndike word lists. There he should stick to the most frequent 5000 if possible.

The danger following from the use of emotionally toned words is well-known and can not be overestimated. For example, inclusion of the late President Roosevelt's name in connection with people's acceptance of the changed date of Thanksgiving Day increased the favorable answers over 10 per cent. Although 90 per cent of the respondents said we should do everything possible to avoid war, only 45 per cent thought we should "become involved in" an international organization to maintain peace.

It has been demonstrated clearly that the order in which the questions appear in the questionnaire will result in statistically significant changes in the percentage of responses to single items. Furthermore, if items with alternative answers are provided, the ordering of the alternatives will change significantly the percentage of answers.

The way in which the questions are asked and the condition of the respondent at the time the questions are asked also make a great deal of difference as to the answers given. For example, one would scarcely consider having an experimental group of respondents fill out their questionnaires in an assembled group while he had the control group fill out their questionnaires in isolation. Nor would one have an experimental group fill out the questionnaires in isolation while the control group had their questionnaires filled out for them by an interviewer. The careful investigator would try to reach his different groups of people at approximately the same time of day and while the people were in relatively the same "mood."

Respondents' Answers Have Low Reliability

It is a notorious fact that respondents fill out questionnaires very carelessly. This is particularly the case if the questionnaire is long and involved. It is unlikely that the ordinary respondent will give close attention to more than ten or twelve questions, and even the most clerically minded respondent is apt to become bored with a 300-question schedule. Things such as this result in haphazard answers, so that the same questionnaire given a week or two later will elicit quite different responses from the same respondents. It is interesting that actual studies have shown that the variability in so-called "factual" material is greater from time to time than is the variability in attitudinal responses.

Validity of Responses is Questionable

The responses to questionnaire items have a "face validity" as simple verbal behavior. On the other hand, we usually are interested in other aspects of behavior than the answers per se. Thus, for example, soldiers' attitudes towards their commissioned and noncommissioned officers and toward their cause, etc., would be investigated in hopes that it would lead to predictions as to their effectiveness in battle. The pre-election polls are aimed at predicting behavior in the voting booth. Very little has been done to relate these items of verbal behavior, namely, the responses to the questionnaire, to other behavior in which one is interested. The occasional spectacular fail-

ures of pre-election polls suggest that work needs to be done along these lines. Because a group of soldiers answer in their questionnaire responses that they will fight no more, that they have done their share, one cannot conclude that they will not fight effectively in battle. The case of the First Infantry Division is interesting in this regard. This Division was studied by the Army's Research Branch of Morale Services Division after it had been pulled out of Sicily and sent to England following two hard Mediterranean campaigns. For lack of something better to do, the First Division was put through basic training again in England and then was queried on questionnaires. Their attitude towards the general situation could be described simply as negative. They stated that they had fought their fight, and someone else should do the rest of the fighting during the war. It is well known that subsequent to this the First Division fought with great valor through France, Belgium, and Germany. The general conclusion is that we cannot take the answers to questionnaire items too seriously unless we have specific data showing that these verbal responses are indeed related to the other forms of behavior in which we are interested.

A Priori vs. a Posteriori Analysis of Questionnaire Data

From the standpoint of inductive methodology one of the most startling misuses of questionnaires might be called the shot-gun technique. In this, the investigator, having decided an area which he wishes to study, prepares a long questionnaire including innumerable items related to his topic of study. He has two or three hunches as to how the respondents will react, but for the most part he is "just fishing." As soon as the questionnaires have been filled out they are analyzed to see if they "show anything." By this it is meant that all possible and some impossible breakdowns of the data are examined, and all possible differences are tested to see if any of them might be statistically significant. As a result quite a few differences are pointed out by the statistical techniques as being significant at, say, the 5 per cent level. The analyst then concludes that these differences have some basis in fact and draws his conclusions accordingly. If the items had been answered by purely haphazard technique about 5 per cent of the differences would turn out to be significant at the 5 per cent

level, so that if enough differences were investigated a substantial number would be detected where none in fact existed. This procedure of investigation is obviously indefensible. It is particularly dangerous when the questionnaire technique is used, because a questionnaire can generate so many possible comparisons to bolster the chance effects.

There is a way out of the difficulties implied in the preceding paragraph. The questionnaire can be used conservatively. By this is meant the method may be restricted to the investigation of concrete hypotheses. In other words, the investigator, upon selecting his area of investigation, delays writing the questionnaire until he has set down a number of hypotheses about the relationships in the area of investigation. These hypotheses then would govern the choice of questionnaire items and would presumably limit and restrict the total length of the questionnaire somewhat. Before the questionnaire has been filled out by the respondent, the investigator should know every break and analysis that he intends to employ. Each analysis should be aimed at testing one or more of the hypotheses set up by the investigator before he started. The total number of statistical tests can then be counted beforehand, so that the investigator knows about how many to expect to be significant in the absence of real population differences. The investigator is now in a position to proceed with his analysis when the data are gathered. He may test each of his hypotheses and indicate whether they are supported or failed to receive support from the responses. Conclusions thus obtained have a sounder basis than purely ex post facto rationalizing of obtained results. This does not exclude the investigator from examination of his data to see if there are suggestions in it which he had not previously considered. He is permitted to set up a posteriori hypotheses and to rationalize unexpected findings. These additional hypotheses, however, have about the same status as a priori hypotheses before they are tested. In other words, these products of ex post facto reasoning must be subjected to a subsequent test or cross validation, as it sometimes is called. These are the bases for future questionnaire investigations.

In conclusion we simply remark that these difficulties and pitfalls of the questionnaire must always be considered in designing question-

naire investigations. The social studies will long be stuck with the questionnaire as an investigative device. They are not, however, restricted to ineffective and unscientific use of the imperfect device.

2 Digiting

The computation of sums of products by progressive digiting on the IBM tabulator has been discussed at length elsewhere. (See footnotes 1,2,3,4,9.). However the process is briefly reviewed here.

The IBM tabulator is essentially an adding machine. Mathematically, it is capable of addition and its inverse, subtraction.

A frequent problem is that of obtaining sums of products (or sums of squares, which is a special case of products). For example, given the following test scores in two subjects:

Pupil	M Math	P Physics
1	91	89
2	94	79
3	75	91
4	79	80
5	90	88
6	84	90
7	71	70
8	57	70

The correlation between the scores on the two subjects, given from this limited data, is given by the formula:

$$r^2 = \frac{[N \sum XY - \sum X \sum Y]^2}{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}$$

calling for the sums of squares of the two variables, the simple sums, and the sum of cross products. Notice that for purposes of getting the value of "r" it is not necessary to obtain (much less record) any individual product or square; it is only the sums that are needed. Similarly, the normal equations for linear curve fitting;

$$\sum Y = m \sum X + b N$$

$$\sum XY = m \sum X^2 + b \sum X$$

call for the same sort of data.

These sums may be obtained by addition on the tabulator. Having both scores for each pupil on separate cards, let us sort the cards on the units digit of the M's. (We will form our sums of products one digit of the multiplier variable at a time.) The card we take first is that of pupil 4 (scores 79, 80). We can form the product of 9 X 80 (neglecting for the time being the 7 of the 79) by adding the 80 nine times. We could, if we wished, take that card and run it through the tabulator nine times. Then we can take the "8" cards (pupil 15, scores 88, 84) and add the 84 score eight times and so on for each digit. For the "4" we have here three pupils; namely numbers 2,6,14. We take all three of those cards and add them in four times.

Upon completion of this process, we will have in one counter the sum of the products of the units digit of M, by all of P.

We can repeat the whole thing for the tens digit of M, and multiply this latter result by ten and add it to the former. We will have, then, the complete sum of products MP. Since the tabulator is resplendent with counters, it costs nothing to add both variables at once throughout, and we produce ΣM^2 at the same time.

We can routinize this process as follows: Having the cards sorted in descending order on any multiplier digit, we can run the "9" cards through the tabulator; then the 9's and 8's, and so on. It is evident that at the end, all cards having 9's will have been added nine times, the cards having 8's will have been added 8 times, and so on, thus effecting the desired multiplication. Note that this routine has not gained any speed, but has reduced the chances of human error. This has all been based on the assumption that the cards sort into an unbroken sequence of digits from the highest down. In our example, there are no 2's in the units digit of the M's. We can provide for the omission in the process just described, but it will be taken care of more simply as we speed up the process more.

It is interesting to note that, historically, the digiting process has developed almost exactly as it is explained here, Before the introduction of automatic control and progressive totaling on tabulators and, even after those devices were available but summary punching was uncommon, digiting was done in just this way.

Let us feed the 9's cards into the tabulator and add them, printing the result and holding the result in the counter; then the 8's cards are added in the same counter, a total printed and held in the same counter, and so on. This is "progressive totaling" and is done by wiring the special device for that purpose on the machine. The 9 results (zero digit cards are not included (e.g., pupil 5) since the product of zero times anything equals zero.) we get must then be summed themselves to give one piece of the desired sum of products.

Now we add to the process the feature of automatic control on the tabulator. The cards after sorting in descending order may be put in the tabulator all at once. The machine will automatically take a total at the end of the 9's cards, print the result, hold it, add more cards, take a total at the end of the 8's, print it, hold it, and go on to the end.

Note that at this stage we can most efficiently take care of missing digits.

In the example we started with, we need punch only one dummy card, having a 2 in the units column of M, to cause the machine to take an extra total for the 2's, even though nothing adds in the counters at that time. (In practice, we use a special dummy "deck"; a description of it is given below.)

If the tabulator is equipped with the card cycle total transfer device, and if few enough variables are involved so that less than half the counter capacity is needed, the nine progressive totals may be totalled simultaneously in other counters, so that the final sum of products is produced in one run.

As a result of experience in digiting at the University of Wisconsin Computing Service, certain shortcuts and precautions have evolved which are worth noting.

Normally, when cutting summary cards in the digiting process, the counters on the tabulator are set to progressive total on each minor control break between digits, and to reset to zero on the automatic major control break at the end of the deck. It has been pointed out that for this purpose the progressive total device on the tabulator is not necessary (see footnote 8). If the counters are wired to reset on a major control break (i.e., not reset on minor), then when a minor

total is called for, the counters will transmit to the summary punch without resetting, and hence will progressive total automatically. On the other hand, if the progressive total device is available (the type which is controlled from the plugboard—plate type—can be installed without charge) it is more positive to wire it.

It is necessary, in the digiting process, that every digit after the first (highest) digit in each column of the multiplier be present. That is, if the cards sort on a particular multiplier column into pockets 7-6-5-3-1-0, the digiting process will fail unless the tabulator is forced to take a control break for digits 4 and 2. It has been found convenient in practice to include all digits on each column (i.e., in this case forcing digits 8 and 9 also.) For this purpose a dummy deck of 10 cards is added to the data cards, each card of the dummy deck having one of the 10 digits punched clear across columns 1-79, and X punched in column 80. The X in column 80 suppresses the plus input to all counters which add variables, so that the dummy digits in the variable fields do not add, but merely produce, with certainty, all 10 control breaks on every column of every variable. If several decks are being digitized simultaneously, a dummy digit deck is inserted in each data deck; the column containing the deck number should then have deck numbers on the dummy cards also. If card counts are being taken and summary punched, the card count should also be suppressed on the X-80 cards so that the X-80 cards are not counted. For any variable column in which all 10 digits appear in the data, the dummy cards will pass through the tabulator with no effect whatsoever.

In all digiting work, it is efficient to have two duplicate sets of all cards, so that one set can be sorting while the other is passing through the tabulator. In most cases this will insure that the tabulator is operating constantly and that idle time of the summary punch, sorter, and operator is kept at a minimum.

It is a good check to cut the zero summary card in every case. This card is not essential to the digiting process, but the information on it (simple sums) is usually needed, and every zero summary card must be identical if all variables are present on every card. A running check to see that the zero cards continue to be identical insures that all

components of the machinery remain constant; a loose wire or a misplaced card flashes an error immediately.

The summary cards should have cut in them—even at the expense of using two or more boards on the tabulator to handle all the variables—the following information:

1. The deck number, if more than one deck is being digitized at once. The deck number read from the detail cards can be transmitted to the summary punch through a counter which is wired to add on major first card control.
2. The digitizing digit. Usually every counter group is set to progressive total. The digitizing digits can be produced, however, by subtracting one (i.e., the card count impulse) in a counter set to operate on minor first card control. This operation will produce the sequence 9,8,7,6,5,4,3,2,1,0 on each 10 summary cards regardless of the order in which the cards are actually sorted. Thus, if cards are inadvertently taken from the sorter in ascending order, the sequence of digitizing digits in the summary cards will not reflect the error. For that reason it is well to cut also:
3. Progressive digitizing digit. The particular column being digitized on is wired to a counter which is controlled to add on minor first card control. This counter will then have totals as follows: 9,17,24,30,35,39,42,44,45,45. It is sufficient to punch only the units digit of this sequence; i.e., 9,7,4,0,5,9,2,4,5,5. Item 3, then is the check on correct sorting; provided that it checks out, item 2 can be used, for instance, to sort out the zero summary cards. If the summary punch is equipped with a counter, an additional check is furnished, inasmuch as each pass through the tabulator must produce $10k$ summary cards, k being the number of decks.
4. Card count. A counter which is controlled to reset on a major control break adds the card count impulse on cards which are not punched X in column 80. The progressive count of cards is cut on each summary card; the only card count which is of interest is that appearing on the zero summary card.
5. Tabulator board number. If, for example, all possible sums of products between thirteen 4-digit variables are needed, and the variables have simple sums of the order of 10^6 , it is necessary to set up two tabulator boards (assuming an 80 counter machine) to handle all variables. For a smaller counter capacity machine, even more boards might be needed. Generally it is advisable to have the boards as much alike as possible (i.e., same size variables entering the same counter groups, nearly equal numbers of variables on each board, etc). Using a digit selector as an emitter, the number of the board can be transmitted through the same counter as the deck number (Item 1.)
6. If the variables run to two or more digits, it is expedient to wire a summary punch board for each type of digit, as units, tens, hundreds, etc., each board having its wiring offset one column from the previous board. Thus the summary cards cut from digitizing on a tens digit will be offset one column (i.e., by a factor of 10) from the

cards cut on the units digit run. All summary cards relating to the digiting of one variable may then be added in one run on the tabulator. For example, digiting on a 3-digit variable produces 30 summary cards of which 3 (the zero cards) are laid aside. The other 27 can all add directly into one counter group on a later tabulator run if this off-setting has been done. It is necessary, then, to identify each summary board by emitting into some column a 1 for the units board, 2 for the tens board, etc. If the summary punch is not equipped with a gang punch emitter, this information may be gang punched by inserting a set-up card in front of each group of summary cards as they are cut.

The digiting process produces all sums of products twice (i.e., ΣXY and ΣYX) but each sum of squares only once. It is fairly safe to assume that if the two cross products agree in every case, the sums of squares are also correct; however, it is better to make an independent check on the sums of squares, either by digiting again, using other counters on the tabulator, or by a calculating punch if one is available. If the data is to be used in the product-moment correlation formula, there is another check in that the factor $N\Sigma X^2 - (\Sigma X)^2$ cannot be negative.

If the original data contains missing cells on many of the variables, the digiting process loses a great deal of its power. In the extreme case, where every variable can have missing cells, using an 80-counter tabulator and each variable having 3 digits with simple sums not over 6 digits, it is possible to handle only 4 variables at once, including the variable being digitized. Counter groups must be made available for ΣX_Y^2 (that is, sum of squares on X for those cards on which Y is also present), ΣX_Z^2 , ΣX_W^2 , ΣXY , ΣXZ , ΣXW , card count of active Y, card count of active Z, card count of active W (it is assumed that inactive X cards are sorted out). The addition of one more variable would necessitate counters for ΣX_T^2 , ΣXT , and the card count, which would leave no room on the summary card for any identifying information. The production of the correlation matrices for 20 variables and 20 decks, averaging 200 cards apiece, where missing cells must be taken into account, can consume as much as six months time for three machines and an operator.

Mr. John Sheldon, of IBM's New York Technical Service Bureau, has suggested an attack on the case of missing cells. The entire problem is done by digiting in the usual way, treating every variable as pre-

sent in every case. Note that there is no need to reserve counter capacity for card counts. Then the cards with missing cells (identified, say, by Y punches) are sorted out and correction factors calculated on sums of squares, sums of cross products, and card counts for those cards only. Thus, if the percentage of missing cells for any variable is low, as it usually is, the additional calculations caused by missing cells will be in direct proportion to that percentage.

Technical literature (see footnote 5) contains many articles on digitizing. Some of them refer to special techniques for specific problems; for example (see footnotes 7, 10), the digitizing process can be extended to the calculation of such factors as ΣXY^2 .

Castore and Dye (see footnote 6), have described an ingenious modification of the digitizing process in which the original data is offset on separate decks (three decks for three digit variables, etc.) as a result of which only one sort is needed for each variable and all summary cards are cut with one control panel. For problems in which all the variables have the same number of digits and none of them has missing data, the method they describe has a decided advantage in speed. Such a situation is common in the calculation of the correlation matrix for a factor analysis.

Footnotes

1. Columbia University Statistical Bureau. The Mendenhall-Warren-Hollerith Correlation Method. Document No. 1, 1929

2. A. E. Brandt, "Use of Machine Factoring in Multiple Correlation," Journal of the American Statistical Association (September 1928).

3. IBM "Pointers," February 1947

4. IBM "Examples of Electronic Calculation," 1950.

5. IBM Bibliography on the Use of IBM Machines in Science, Statistics, and Education, January 1950.

6. George Castore and William Dye, "A Simplified Punch Card Method Determining Sums of Squares and Sums of Products," Psychometrika, XIV, (September 1949), 243.

7. Max Ellis and Arthur Riopelle, "An Efficient Punched Card Method of Computing ΣX , ΣX^2 , ΣXY and Higher Moments," Psychometrika, XIII, 2 (June 1948) 79.

8. L. R. Tucker, "Simplified Punched Card Methods in Factor Analysis," Proceedings of the Research Forum, IBM, 1946

9. W. J. Eckert, Punched Card Methods in Scientific Computation, Columbia University, 1940.

10. Paul S. Dwyer, "The Computation of Moments with the Use of Cumulative Totals," Annals of Mathematical Statistics, IX, 4 (December 1938) 288.

3 Cycling and Selector Control

Cycling

Sequencing of operations on the 416 tabulator is possible to the extent of selector capacity, and is used in several important applications. A repeating sequence of operations is most often used, and the process is sometimes called "cycling." The basic scheme for the operation of the selectors can be used on any machine where an impulse to a pickup hub of a selector transfers the selector for the following cycle or cycles, but cannot be used on the regular collator selectors, for example, which are transferred on the same cycle in which a pickup impulse is received. The 602A has a sequencing capacity of twelve pluggable program steps. These program steps, or selected ones, can be repeated, within the limits of available selectors. The number of repetitions, and changes during the successive repetitions, can be controlled by a cycling selector scheme.

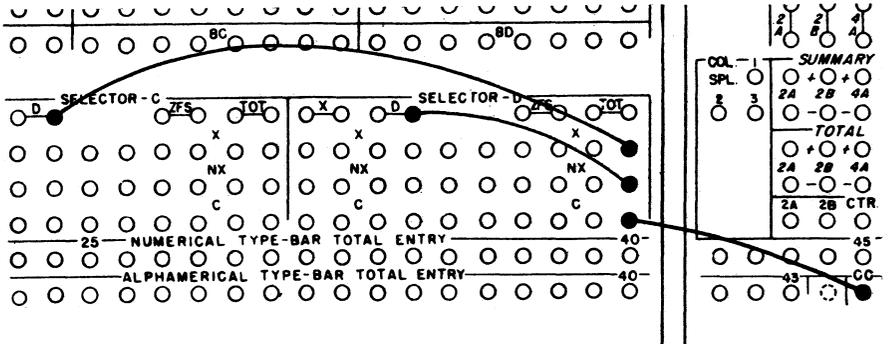
Tabulator

Any impulse which is available every list cycle, such as card count or UCI, can be used to control the cycling. If UCI is used, it should be wired to a comparing relay, and the unequal impulse wired to the selectors. This unequal impulse will be accepted by either the X or D pickup hub of a selector. If the card count impulse is used, it must be wired to the D pickup hub.

Two Cycle or Alternating Selector Scheme

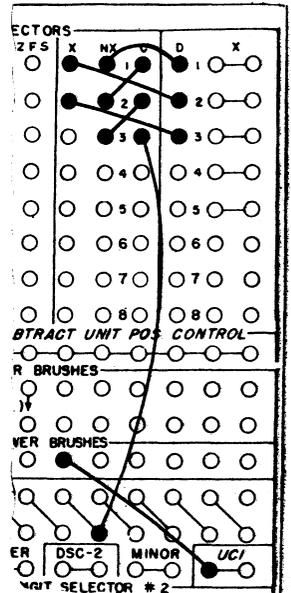
Card count (or UCI unequal impulse) is wired to the C hub of a class selector or X-distributor, out of the NX hub to the D pickup hub. On the first cycle, the impulse reaches the pickup hub and the selector is controlled (transferred) for the following cycle. On the second cycle the card count impulse reaches the C hub but is not transmitted from the NX hub to the pickup hub because the selector is transferred (C is internally connected to X instead of NX.) Since no impulse reaches the

pickup hub on the second cycle, the selector returns to normal (C internally connected to NX) for the third cycle. The third cycle is like the first cycle. Thus on alternate cycles the selector is transferred; on the remaining cycles it is normal. If desired, the X hub of the selector can be wired to the pickup hub of a second selector. Then the first selector will be transferred on the 2nd, 4th,...cycles, and the second selector will be transferred on the 3rd, 5th,...cycles.



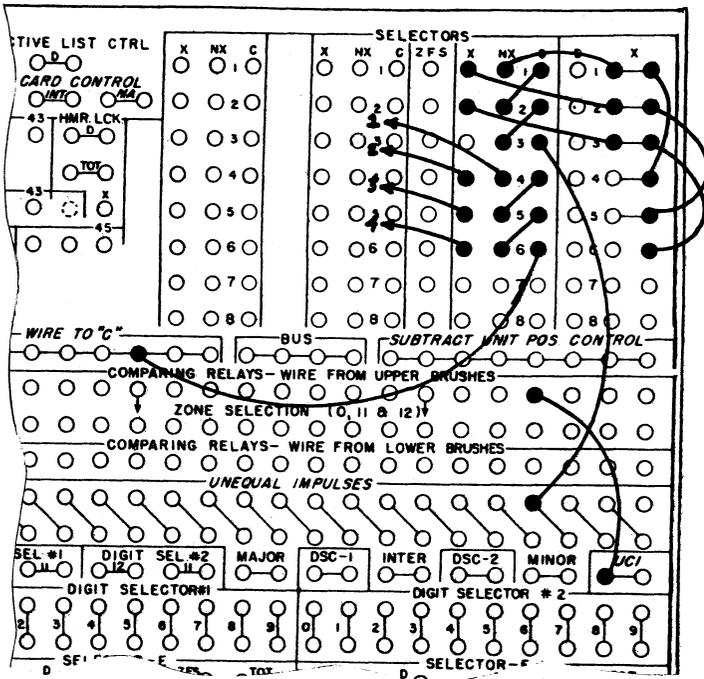
Four Cycle Scheme

A series of three selectors is needed. The controlling impulse is wired to the C hub of the third selector; the NX hub of selector 3 is wired to the C hub of selector 2; NX of selector 2 is wired to the C hub of selector 1. The NX hub of this selector is wired to its own X or D pickup hub, depending on the timing of the input impulse. The X hub of selector 1 is wired to the pickup hub of selector 2, and the X hub of selector 2 to the pickup hub of selector 3. On cycle 1, none of the selectors is transferred and the controlling impulse passes through the chain of C-NX connections, out of the NX hub of selector 1 and impulses the pickup hub of selector 1. On cycle 2, selector 1 is transferred and the controlling impulse passes



through the C-NX connections of selectors 3 and 2, through the C-X connection of selector 1 to the pickup hub of selector 2. On cycle 3, selector 2 is transferred and the controlling impulse passes through the C-NX connection of selector 3, the C-X connection of selector 2 to the pickup hub of selector 3. On cycle 4, selector 3 is transferred and the controlling impulse is not used. On cycle 5, all selectors are normal and the pattern begins again.

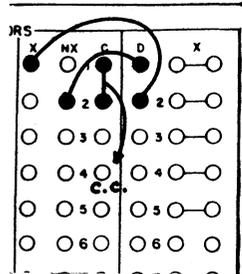
Counter controls, such as plug to C impulses, can be controlled through other positions of the same selectors if ten position selectors, or three position X-distributors, are used to set up the cycling. If single position X-distributors are used, the impulses to the pickup hubs can be split wired to pick up another set of selectors. The plug to C impulse for counter control must be wired through the series of selectors starting with the last in the chain in a manner similar to the selector controlling impulse above. On the first cycle the plug to C impulse passes through the C-NX connections of the third, second, and first selectors and is taken from the NX hub of the first to a



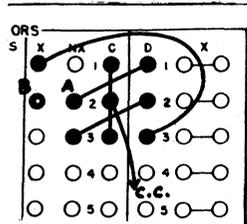
counter as desired. On the second cycle, the plug to C impulse passes through the C-NX connections of the third and second selectors and through the C-X connection of the first selector. On the third cycle, the impulse is available from the X hub of the second selector, and on the fourth cycle, from the X hub of the third selector.

Other methods of selector control for cycling are possible. For example:

Four cycle scheme
using two selectors



Method (due to Paul Herget) of obtaining either three or six cycles, using three selectors. The change of one wire from A to B changes from three to six cycles.



602A Repeating Program Steps

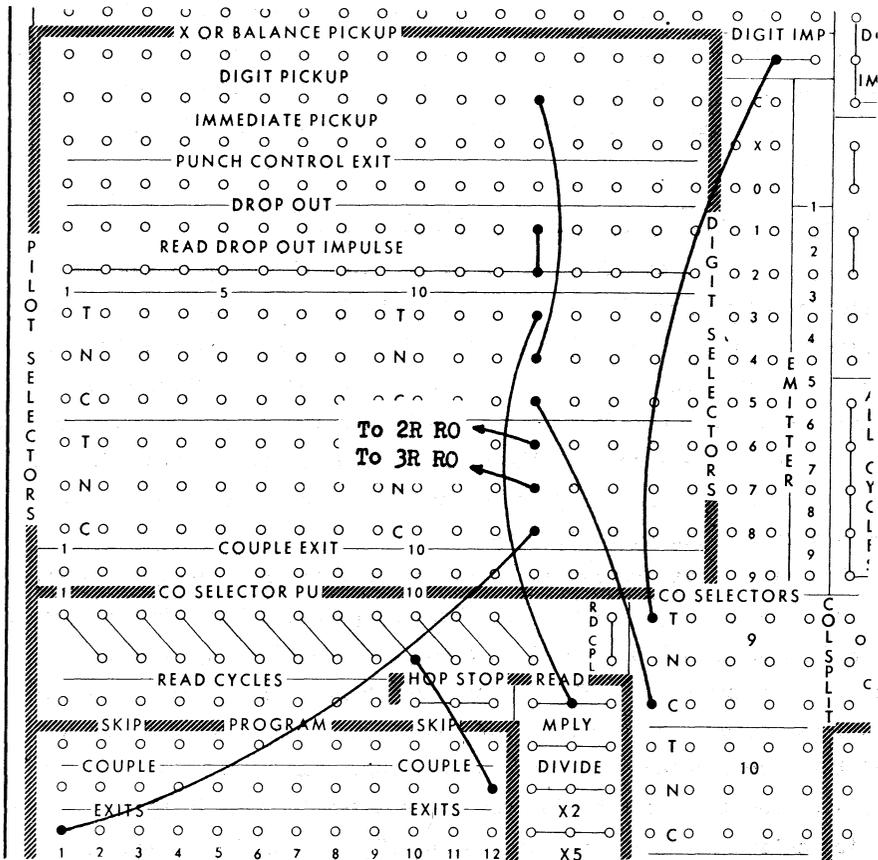
If several iterations are needed to calculate one value, or if several results are to be calculated on one card by like operations but using different amounts, it is possible to set up one sequence of operations on the control panel and repeat the sequence as many times as needed, selecting the necessary factors for each repetition from storage. If it is an iteration problem, the sequence may have to be repeated an indefinite number of times until two successive results agree to a specified degree of accuracy.

It should be noted here that program 12 must be used in order to repeat any program steps, and that program 1 will automatically follow

program 12 if no impulse reaches the Read hub signalling for a new card feed cycle. (Program 1 can be skipped only after a read cycle.) For example, it is not possible to skip directly from program 5 to program 1, nor is it possible to skip from program 12 to program 5.

In many problems the factors for the first sequence of operations can be set up on the read cycle and the factors for the repetitions can be set up on program 1. Program 1 is skipped after the read cycle, programs 2 on are used for the sequence of operations up to the last step in the sequence. The last step is planned for program 12 and the unnecessary programs between the next to last step and program 12 are skipped.

One Repetition of Sequence



As the machine passes through program 12 on the first sweep, a pilot selector pickup hub is impulsed. Any impulse later than 50° (a program exit cannot be used) such as the digit impulse ($800-360^{\circ}$) (hubs B, 18-20) wired through the C-T connection of a coselector picked up on program 12, is wired through the C-N connection of a pilot selector to its own C or X pickup hub. The selector will be transferred near the end (355°) of the same cycle, and will remain transferred until the end of the next read cycle if a read drop out impulse is used to drop out the selector. When the machine reaches program 12 the second time, the digit impulse wired through the C-T connection of the pilot selector reaches the Read hub. Further sequencing is stopped, and the following cycle is a read cycle.

An alteration in a repeated program step can be controlled through the same selector. Suppose it is necessary to read out of storage unit 2R on cycle 1 of the first sequence and out of storage unit 3R on the repetition of cycle 1. A program 1 exit impulse can be wired to the C hub of the selector, from the N hub to 2R Read Out, and from the T hub to 3R Read Out.

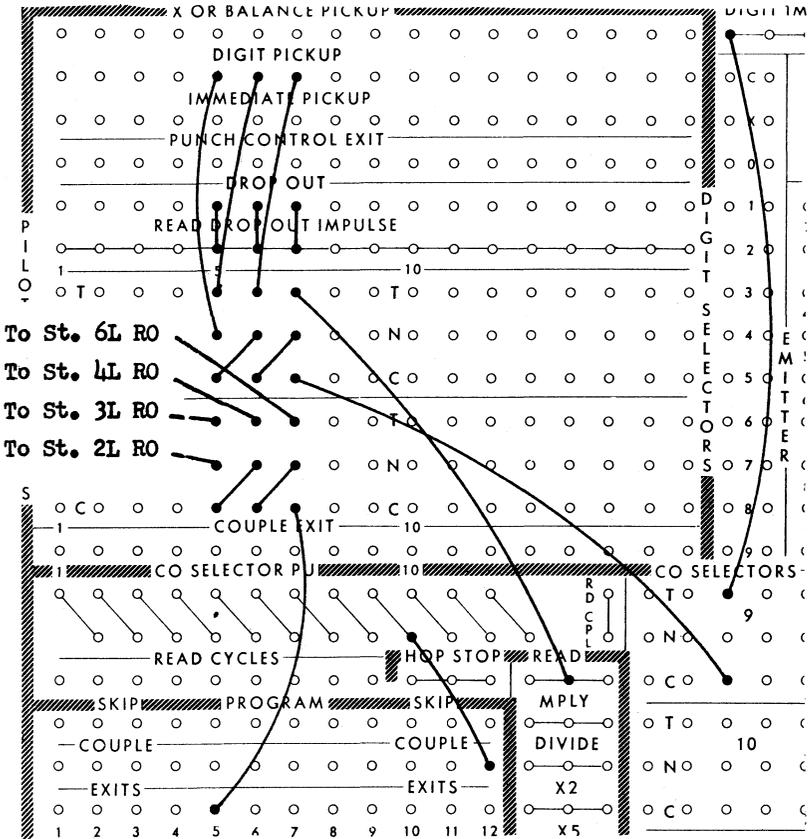
Repeating a Sequence Three Times (Four Cycles)

A chain of three pilot selectors is used. The digit impulse is selected on program 12 by wiring through the C-T connection of a coselector picked up by the couple exit of program 12. The T hub of the coselector is wired to the C hub of the last pilot selector to be picked up, the N hub of this third selector to the C hub of the second, the N hub of the second to the C hub of the first, and the N hub of the first to the D or X pickup hub of the first selector. The T hub of the second to the pickup hub of the third.

The first time program 12 is taken, none of the selectors is transferred and the digit impulse reaches the pickup hub of the first selector from the N hub of the first selector, transferring the selector at the end of program 12. The second time program 12 is taken, the digit impulse passes from the T hub of the first selector to the pickup hub of the second selector. On the third program 12, the digit impulse passes from the T hub of the second selector to the pickup hub of the third selector. On the fourth program 12, the third selector is trans-

ferred, and the digit impulse or a program 12 exit is taken through the C-T connection to the Read hub to suspend further programming. The pilot selectors are returned to normal by read drop out impulses.

Four Cycle Scheme



The second positions of the same selectors, or positions of coselectors picked up by the couple exits of the pilot selectors, can be similarly used to select different factors on each repetition of a particular program step. The program exit is wired through the chain of selectors, starting with the third; from the N hub of the first to the read out hub of the storage unit needed on the first sequence, then from the T hub of the first selector to the read out hub of the storage unit needed on the first repetition of the program step, from T

hub of the second selector to the read out hub of the storage unit needed on the second repetition and from the T hub of the third selector to the read out hub of the storage unit needed on the third repetition.

Cycling principles are shown in use in problems of multiplication and division in the diagrams in Chapter 9.

As in the case of the tabulator, the number of repetitions possible is dependent on the number of pilot selectors available. Coselectors cannot be used because they transfer on the same cycle in which a pickup impulse is received and return to normal at the end of the cycle.

Selector Control-416

Controlled Pickup and Drop Out of a Selector

Ex.: Pickup after X79 card passes lower brushes and drop out after X80 card passes lower brushes.

An auxiliary X-distributor is used. The UCI hub is wired to a comparing relay. The unequal impulse is wired through the normal (C-NX) side of this distributor, then through the transferred (C-X) side of the class selector which is to be controlled, to the X pickup hub of that selector. The UCI impulse cannot reach the pickup hub of the class selector until the selector has been transferred once by another source. Lower brush 79 is wired to the X pickup hub, and transfers the selector after an X79 card has been read at the lower brushes. On the next cycle the UCI impulse passes through the C-X connection to the same X pickup hub and transfers the selector for the following cycle. On the following cycle the UCI impulse again reaches the pickup hub, etc. The process continues until an X80 card passes the lower brushes. Upper brush 80 is wired to the X pickup hub of the X-distributor and X-distributor is transferred as the X80 card passes the lower brushes. The UCI impulse cannot get through the C-NX connection, and no impulse reaches the pickup hub of the class selector. Therefore, the selector will be in its normal position on the following cycle. On this cycle the UCI impulse passes through the C-NX connection of the X-distributor but cannot get through the C-X class selector connection.

Therefore, the selector remains normal until a new X79 card passes the lower brushes.

4 Bivariate Tables and Differencing

A bivariate distribution between two single-digit variables can be produced readily on a counting sorter. The deck is sorted on one variable and the distribution into the pockets of the sorter is kept distinct. Then each pocket is counted on the other variable; the reading of the counters for each run being recorded. The method does not extend readily to variables with a greater range.

If many such distributions are to be made, the work is more readily carried out on the tabulator. The deck is sorted on one variable; minor control is taken on that variable. The controlling variable here can be of any size. The other variable is distributed through a digit selector. Selectors are picked up for each possible digit, and through them the c.c. impulse is taken to counters controlled to add on every card. With a full size tabulator, it is possible to distribute two columns completely, even with only 22 selectors, since the ones from the digit selector can be taken to counters directly. It is necessary, however, to make sure that the first card does not contain ones (or always precede the deck with a blank card), since the counters will not add when the first card is still at the upper brushes.

Making bivariate distributions on the tabulator has the decided advantage that the variables may be broken into convenient class intervals. The digits of the controlling variable may be grouped by inserting X cards for control, rather than controlling directly on the digits themselves; the digits of the distributed variable may be grouped by wiring together groups of hubs of the digit selector.

If the distributed variables have a smaller range, it may be possible to distribute three or more columns at once. For example, if these variables have a range of only 1 to 3, the columns can be matched against 1, 2, and 3, from the emitter through the comparing relays, and as many as 6 columns can be distributed at once.

If the variables to be distributed have a greater range, say 1 to 20, one variable can be distributed by running each digit of the two

through a separate digit selector, picking up selectors for all possible digits, and running the c.c. impulse through these selectors in the proper way to counters.

For even greater range on the distributed variables, it is necessary to sort on the two variables in turn, and control on both of them and take a card count between minor breaks, which will then give the distribution. See also notes in Chapter 8, page 47.

Differencing

Differencing is a process of checking. For a rational integral function, the differences corresponding to the degree of the polynomial are constant; for other functions, some order of differences will be sensibly constant. For example, a table of cubes will have third differences constant:

1	6
7	6
8	12
19	6
27	18
37	6
64	24
61	6
125	30
91	6
216	36
127	
343	

While a table of 3-place square roots will have second differences small and sensibly constant:

n	\sqrt{n}	Δ	Δ^2	Δ^3
7	2.646			
		.182		
8	2.828		-.010	
		.172		.000
9	3.000		-.010	

		.162		+ .003
10	3.162		- .007	- .001
		.155		
11	3.317		- .008	.003
		.147		
12	3.464		- .005	
		.142		.001
13	3.606		- .006	
		.136		.001
14	3.742		- .005	
		.131		
15	3.873			

First (algebraic) differences can be produced on the tabulator (see Chapter 9, page 77) using two counters and a cycling scheme of two cycles. Assuming that the differences are formed by subtracting from the n th card the value on the $(n - 1)$ st card, the first counter should subtract on the first card, add on the second card, and then print (or summary punch) a total. The second counter should subtract on the second card, add on the third card, and then read out a total. The system then repeats, so that every other total (i.e., difference) is produced in one counter. The tabulator will take a total cycle for each card, and will print differences at the rate of 75 per minute or summary punch 30 per minute.

Second differences (page 78) are calculated as follows: if consecutive table values are denoted by a, b, c, d, e , etc., the difference array appears as shown below, and the second differences are built up in rotation in four different counters. A 4-cycle cycling scheme is set up. In the first counter c and a are added, a being read from the upper brushes. The term $- 2b$ is produced by subtracting b as the b card passes both upper and lower brushes.

Higher order differences may be calculated

(A)		
a		
	b - a	
b		c - 2b + a
	c - b	
c		d - 2c + b
	d - c	
d		e - 2d + c
	e - d	
e		f - 2e + d

f	f - e	g - 2f + e
g	g - f	h - 2g + f
h	h - g	

directly in counters on the tabulator by a process of building them up from higher order differences (E. C. Yowell, Sixth Differences on the 405, Proceeding of the Research Forum, 1948.) or may be calculated by taking first and second differences on the summary cards from a previous run in the process described above.

5 Chi-Squared Analysis

When a great many contingency tables of a uniform format are to be tested for association and independence by the chi-square test, an efficient calculation routine can be set up on punched cards, using a calculating punch, and a tabulator and summary punch.

The calculation proceeds entirely from the observed frequencies. The method can be extended to tables of almost any size, but proceeds best with tables $5 \times n$ or less. The chi-square value for the entire table is calculated; individual chi-square contributions from each cell may be exhibited if desired. For convenience, an example is carried through here of a 4×4 table.

	27	80	70	10
Table No. 273	35	75	75	20
	31	70	81	9
	21	63	81	19

The table as shown is punched in four IBM cards. Assuming less than 1000 such tables, of various sizes, to be computed simultaneously, we reserve columns 1-3 of the card for the table number (punched on all four cards). In column 4 the row number is punched; in this case running from 1 to 4 on the four cards. Subsequent columns must be reserved for the greatest cell frequency which occurs in any one table. If no cell frequency exceeds 99, the columns of the table will be punched in columns 5-7, 8-10, 11-13, 14-16, 17-19 of the cards. Three card columns are used, since the tabular column totals will probably be three-digit numbers. Note that provision is made here for 5 tabular columns. Since our sample table is 4×4 , columns 17-19 of the cards are either punched 000 or left blank. Blank columns are preferable, to avoid possible confusion with a true zero cell frequency.

The cards should now be subjected to some form of verification, either with an IBM verifier, or by repunching and comparing, or by print-

ing and reading back against the original data.

From this point on the calculation is completely mechanical.

Step 2. Sum the cards on the tabulator and out summary cards, showing the table number in columns 1-3, an X in column 4, and totals in columns 5-7, 8-10, 11-13, 14-16, 17-19, and the card count in 79-80. If the cell frequencies are high, or the number of rows is high, it may be necessary to allow for four-digit totals or more, in which case the columns on the row cards should agree with the columns reserved for the totals.

Step 3. The row cards and column total cards are now "crossfooted" on the calculating punch, producing in columns 20-23 the row totals and the sum of the cells of the table.

In our example, the summary card would be punched: 273 X 114 288 307 058 000, and the crossfooting operation puts the numbers 0187, 0205, 0191, 0184, 0767 in columns 20-23 of the five cards.

Step 4. The cards with X in column 4 are now sent through the calculator separately and the tabular column totals are changed to percentages of the grand total. In our example, we want the decimal fractions for 114/767, 288/767, 307/767, and 053/767 punched in the total cards, in columns 24-29, 30-35, 36-41, 42-47; and columns 48-53 reserved for tables 5 x n, will be punched 000,000.

Step 5. The total cards are now sorted ahead of the row cards by table number. The cards again pass through the calculating punch; the fractions computed in step 4 are used as group multipliers and the row totals on the row cards are the multiplicands. On each row card, then, will appear the theoretical frequencies. In our example, on card 1, the first theoretical frequency is 27.79400, which is punched 27.79. All theoretical frequencies are carried to two decimal places, the rounding being done by the machine by adding 5 in the third place, which is then dropped. The theoretical frequencies are punched in the row cards in columns 24-27, 28-31, 32-35, 36-39, and 40-43.

Step 7. The row cards now have both the observed and theoretical frequencies punched in them. In one run through the calculator, we obtain the five chi-square values: See laboratory exercise number 9.

$$\chi^2 = \frac{(f_o - f_t)^2}{f_t}$$

either punching all five or accumulating them in a counter and punching the sum of the five values for the row. (It is assumed that cell frequencies are sufficiently large to obviate the need for continuity corrections.)

Step 8. If the individual χ^2 values were punched, it is necessary to insert a cross-footing operation later. Let us assume that only the χ^2 for the whole row was punched. The cards are now summed on the tabulator the $\Sigma\chi^2$ being punched on the X-4 summary cards, which are sent through the summary punch in the same order they were removed in step 6.

Step 9. A listing is made on the tabulator of the summary cards, show-

ing the table number, the χ^2 , and R minus 1, and C minus 1. The latter figures are obtained as follows: the card count in columns 79-80 is the number of rows in the table. Taking this through a digit selector, each digit picks up a selector which selects from the emitter a number one less, to print R minus 1. The totals which were punched in step 2 are sent to one side of five sets of comparing relays, and the unequal impulses pick up selectors. These selectors also sift out the proper numbers from the emitter, to print. For example, our sample table here is 4 x 4. One total field, then, will be zeros; namely, columns 17-19. There will then be four unequal impulses, and just one selector will remain normal. Through the normal side of this selector we run a 3 from the emitter, to print C minus 1 = 3.

For a very large number of tables it would be expedient at this point to cut new summary cards with R minus 1, and C minus 1 on them, multiply them together for degrees of freedom, and print them together for degrees of freedom, for ease in referring to the χ^2 table.

It has been found efficient to calculate the χ^2 values as outlined here for groups of 100 tables or more. For less than 100 tables, desk calculation is faster and easier, since the punched card routine calls for four rather complicated 602A panels and two tabulator panels.

For the case where R = C = 2 and the two row totals are equal, the formula for χ^2 , including Yates' correction for continuity, reduces to

$$\chi^2 = \frac{N(|a - c| - 1)^2}{(a + c)(b + d)}$$

and may be calculated completely in one pass through the 602A. The diagram is shown in Chapter 9.

The floating decimal, all-purpose setup of the card programmed calculator, described in Chapter 10, allows for the calculation of Chi-squared directly from the values of the contingency table. Tables as large as 6 x 7 can be handled in one smooth pass, when two 941 storage units are available.

It is, of course, necessary to punch the tabular data, one cell per card, in the floating decimal notation. However, analysis on the CPC lends itself to handling a few tables efficiently.

6 Random Sampling

A problem of frequent occurrence in the small computing service is that of selecting a random sample of size n from a population of N punched cards.

Method 1. For N of the order of 500 and n of the order of 100, the simplest scheme is to use N cards from a master deck of random digit cards, bearing, say, 40 random digits per card, the cards being serially numbered from 1 to N . Sorting on sufficient columns of the random digits will effectively scramble the cards. A listing is then made of the first n of them, sorted in order on serial number. This list can be used to pull the desired sample by hand. With this method, the N cards of the population are not even handled until the drawing is made.

Method 2. For larger populations it is more efficient to use the N cards themselves. If blank columns are available, the quickest method is to machine random digits onto the N cards and use them, through sorting, as a means of scrambling the population; the first n cards are then the sample.

Method 3. If no blank columns are available, but the N cards are serially numbered, the first N cards of the random digit master deck may be scrambled by sorting on any convenient columns. The first n are selected after scrambling and sorted in order on serial number. The collator can then be used to match the decks on serial number. The random digit deck will fall in pocket 2, from the primary feed; the sample will fall in pocket 3, from the secondary feed; rejected population cards will fall in pocket 4.

Method 4. If the N cards are completely punched and not serially numbered, a sample can still be drawn provided the collator is equipped with the counting device and the gaps between selected cards do not exceed 99. The sample is selected by scrambling N cards of the random digit deck as before and ordering the first n cards after scrambling. The n random digit cards are then sent through the tabulator, wired to compute first differences on the serial numbers, which are summary punched in a new deck. This deck then bears on it the gaps between successive cards to be pulled. The collator can then be wired to select that card of the population dictated by the number of the gap. To be explicit, if the n random digit cards have serial numbers 7, 19, 23, 39..., first differences, starting with zero, would be 7, 12, 4, 16..., which would appear on successive gap cards. The collator then selects the seventh card, the twelfth card after that (which is the nineteenth card), the fourth card after that, and so on.

This last method is useful also when the N cards are serially numbered but unavoidable gaps in the numbering are present.

Method 5. The IBM sorter manual (number 52-3177-0) still lists a

collating device available on an O80 sorter, which can effectively scramble cards. It operates on the cards without the brush, sending them into consecutive pockets in rotation, the number of pockets being controlled by an external dial. This device is no longer available, but may be at some future time. Cards can be scrambled by sending them out to, say, 7 pockets with the device. At random intervals each pocket is emptied and re-inserted into the hopper as the machine runs. After any particular card has made several trips through the machine (the number of pockets being changed from time to time) the cards are considered scrambled and the first n cards constitute a random sample.

Method 6. Another method which, given N , aims at producing a given percentage sample with allowance for normal variation during sampling, is best described by an example. Suppose that a sample of 10 per cent is desired from a population of 6,340 cards. Using the collator, all cards having numbers less than 634 in any 3 columns of the random digit cards (using the first 6,340 cards of the random digit deck) are selected. These cards are then ordered on their serial numbers and used as a controlling deck in another collator run to match with the population cards.

Method 7. As a variation of method 4, the deck of random numbers might be used to create the sequence of gaps directly, without differencing. For example, if a 10 per cent sample is to be drawn from a population of 6,340 cards, 634 gaps are needed. These gaps must have an arithmetic mean of 10. Hence gaps of 9 and 11 will balance; also 8 and 12, and so on. Since the lowest possible gap is 1, the highest possible is 19. Thus from 6340 cards of the random digit deck, all cards having 19 or less on any two columns of the random digits will provide the gaps. Note that in this method the sample size is not fixed; moreover the method of sampling is not too good, since the possible gaps are held under twenty. This method has, however, the advantage of great speed.

Random Digits

The random digit deck used at the University of Wisconsin consisting of 10,000 cards, each having 40 random digits, was constructed in two parts. The first 1700 cards were keypunched directly from the first 68,000 digits of Kendall and B. Babington Smith's table "Tracts for Computers" No. XXIV (see footnote 5). The other 8300 cards were produced on the tabulator—summary punch by a chaining process described by Horton and Smith (see footnote 3).

Horton shows in his paper that the addition of random sets of digits modulo 10, without carry-over, results in a new random set. In fact, if the generating sets have a bias away from randomness, the generated set will test better for randomness. He suggests a chain of ten in this process. Twenty columns from the random digit cards already produced can be

read into counters on the tabulator. For the small counters, one column only can be added in each counter, to avoid carry-over. In the eight wheel counters, two columns can be added at the extreme wheels, since the carry-over from the units wheel cannot build up to the eighth wheel until some 200,000 cards have passed through the machine (the chaining is done progressively). The tabulator is set to take a total at convenient intervals (if the generating cards are serially numbered, minor control breaks can be taken on the tens digit of the serial number), and a summary card is cut in twenty columns. A second run is required for another twenty columns, reading a different twenty columns in the generating cards.

If the process of generating random digits is to be demonstrated, it is more dramatic to use random digits on the cards to dictate when the control breaks should be taken, inasmuch as they will then appear at more or less random intervals and the tabulator will appear to be making up its own mind. If a random digit is fed into the left hand wheel of a counter, a CI impulse is produced, on the average, every 2.2 cards. If two such CI impulses, produced independently, pick up selectors, an impulse can get through both of them to the minor control hub every 4.84 cards on the average. Three selectors in chain will lead to a minor control break every tenth card, though the breaks may come faster or slower at random.

Testing Random Digits

M. G. Kendall and B. Babington Smith have proposed four tests for local randomness to be applied to any set of supposedly random digits (see footnote 2).

The frequency test consists of the 10-way distribution of the ten possible digits, with theoretical frequencies of 10 per cent for each digit.

The serial test consists of the 100-way distribution of the two-digit combinations, taken in the same order as that in which the table is to be used. Theoretical frequencies are 1 per cent for each combination.

The gap test consists of the distribution of the gaps between (usually) successive zeros in the table. Theoretically, this distribution has a mean of 10.

The frequency distribution of the gaps is tested against the theoretical, using the chi-square test. Thus, the probability of a gap of one is $1/10$; that of a gap of two is $9/100$; that of a gap of three is $9^2/1000$, etc.

The poker test consists of the distribution of 4-digit combinations of digits, separated into the five possible poker "hands"—four of a kind, three of a kind, two pair, one pair, and none alike.

Chapter 9 shows the method of applying the poker test mechanically, using a tabulator, to a punched deck of random digits.

The other three tests of Kendall and Babington Smith may also be applied mechanically. (See *Mathematical Tables and Other Aids to Computation*, October 1950, p. 244).

A fifth test of local randomness has been proposed, especially for testing random digits to be used in the so-called Monte Carlo method. This is the d^2 test, in which groups of random digits are taken to be coordinates of points randomly located in the square having vertices (0,0), (0,1), (1,0), (1,1). The probability that the distance between two such points shall be less than an arbitrary distance can be computed; hence the distribution of distances computed on each card of a deck can be tested against the theoretical. In practice, twelve random digits from each card are selected to represent the four coordinates of two points (three digits being used to represent one coordinate).

It is generally a matter of some interest as to how a table of random digits is constructed.

1. The obvious method is that of drawing numbered objects from an urn. This is not only inefficient, requiring great patience to construct even a modest table of a few thousand digits, but the resulting table would probably not satisfy tests for randomness. As Karl Pearson says in his forward to Tippett's table: (see footnote 1)

"Drawing balls or tickets from a bag or urn, however pleasing in theory to the mathematician, transcends the powers of the practical statistician... Practical experience has demonstrated that it is impossible to mix the balls or shuffle the tickets between each draw adequately. The dice of commerce are always loaded, however imperceptibly... In short, tickets and cards, balls and beads fail in large scale random sampling tests; it is as difficult to get artificially true random samples as it is to sample effectively a cargo of coal or of barley."

2. More or less random statistical information, such as the last three digits of the population figures in census tracts, could be listed.

This was the source of data for Tippett's table (see footnote 1). Much the same objections to such a table can be made as in (1).

3. Kendall and Babington Smith (see footnote 2) set up a spinning wheel having ten equal sectors. The wheel was rotated rapidly in the dark, and illuminated at random time intervals, and the uppermost numbered sector recorded. This method is considerably faster, and the results are quite good.

4. The essence of method 3 is the random time interval. Whereas Kendall and Babington Smith achieved this by human means (an electric condenser was charged by moving a stylus at random over a maze of wires; the periodic discharge of the condenser illuminated the disc), it has been suggested that the random "noise" inherent in a vacuum tube be utilized for the same purpose. Alternatively, the random discharge of a Geiger tube, energized by stray cosmic rays, could be used. In all these methods, the human element involved in reading the spinning disc can be avoided by having the disc itself act as a distributor of an electric impulse, the output of the distributor going directly to a keypunch, if the impulse is amplified with a relay.

5. Horton and Smith (see footnote 3) have shown that any random sets, added together without carry-over, will result in a new random set. (See a previous section of this chapter.) Using Horton's scheme, any small table of random digits, no matter how constructed, can be expanded almost indefinitely.

6. If two 6-digit random numbers be multiplied together, the inner six digits of the product form a new random number. Thus, given A and B, two 6-digit random numbers, we can construct C; using B and C we can construct D, and so on. The sequence is not infinite; it will eventually degenerate, as groups of zero endings appear. However, the point at which the sequence degenerates may be delayed considerably by combining this process, due to Mauchly (see footnote 4), with that of Horton. At each stage, the three numbers involved may be added together without carry-over, to produce the next element in the sequence. Thus, given A and B, the product C is added to A and B and the sum is punched as the next element, C'. Then the process repeats, using B and C' whose product, D, is added to B and C' to produce D'. For example:

A	1	2	3	4	5	6	
B	9	8	7	6	5	4	
C	9	3	1	8	1	2	
C'	9	3	1	8	1	2	
D	3	0	7	8	4	9	
D'	1	1	5	2	0	5	etc.

7. Many cryptographic devices, which are designed to transform a highly skewed distribution (English plain text) into a random, perfectly

rectangular distribution (cipher text), could, merely through the modification of converting them from modulo 26 devices to modulo 10 devices, function as random digit generators. In fact, they are random digit generators, base 26, as they stand; Horton showed how the results can be converted to random digits base 10.

8. John von Neumann has suggested natural numbers (e.g., π , e , $\sqrt{2}$) as a source of random digits.

Footnotes

1. L. H. C. Tippett, Tracts for Computers No. XV, Cambridge University Press, 1927.
2. M. G. Kendall and B. B. Smith, "Randomness and Random Sampling Numbers," Journal of the Royal Statistical Society (1938), 101, and Supplement (1939), 6, 51.
3. H. B. Horton, and R. T. Smith, "A Direct Method for Producing Random Digits in Any Number System," Annals of Mathematical Statistics, XI, 1 (March 1949) 82.
4. John W. Mauchly, "Pseudo-Random Numbers," Eckert-Mauchly Computer Corporation, 1949.
5. M. G. Kendall and B. Babington Smith, "Tables of Random Sampling Numbers," Tracts For Computers. No. XXIV, Cambridge University Press, 1939.

7

Miscellaneous Operating Hints

General: Identification of Cards

When more than one set of cards is involved in a problem, each set should be positively identified. Although sets can be visually identified by color, card form, etc., it is important to identify them by punches, usually X punches. Rather than identify one set by the lack of an X, it is much safer to identify each set with an X in some column. When decks are separated after an interspersed operation, it will then be possible to sight through the identifying punch in each deck. It is also safer for purpose of instructing the machines to control on the presence of an X rather than the lack of it.

Because the machines can fail to read a punch, a set of cards is sometimes identified by X punches in two columns, and the two columns split wired to pick up selectors.

Tabulator: Back Circuits Through the SUP Bus

On a 405 (or 416) tabulator, when a control field, which is listed on the first card of a control group, contains numeric information plus Y's, which are to list as the special characters on the type bars, selectors must be used in the wiring to avoid a back circuit through the "subtract unit position control" bus bar. If the lower brushes were wired to list entry hubs, all the lower brushes would be common through the SUP bus and the machine would list special characters in all positions which are wired to list. The proper wiring is through selectors; common to type bars; normal to lower brushes; and transferred to SUP.

Incidentally, though back circuits are common enough in wiring, it is difficult to produce a good one for demonstration purposes. This is one such.

General

For identifying various decks of cards, three types of serial numbering offer different advantages.

Decimal numbering has the advantage of familiarity.

Duodecimal numbering offers more efficient use of card columns, especially on large decks. The number of columns needed goes up by powers of 12; that is, two columns are needed to number up to 144, three columns to 1728, etc. Moreover, when sorting on the serial numbers, the sorter utilizes 12 pockets. It doesn't run any faster, but it runs longer before a pocket fills up.

If cards in a deck are punched with digits of useable data on all 80 columns, the deck can still be serially numbered with a binary numbering system, which needs only X and Y punches. (In theory, binary numbering could be effected with only X's, the absence of an X being the zero of the system. However, it is more positive to have a hole in every column). If both X and Y are used, on the other hand, additional wiring is needed to distinguish X from Y. This can be effected by matching in comparing relays against X's or Y's from a digit selector used as an emitter. A binary numbering system will number up to card 2^N on N columns. Sorting is highly inefficient, and a master list may be needed for ready reference to convert to the familiar decimal notation.

A master deck of random digits is probably the best place to file serial numbering systems. If the deck of 10,000 cards bears 40 random digits per card, 4 columns will number it decimally, 4 columns are needed for duodecimal numbering, and 14 columns are needed for binary numbering.

Sorter: Mixed Alpha and Numeric Sorting

If a column on a deck of cards bears mixed alphabetic and numeric information, the normal order of sorting (first on the digits zero to 9, then on the zones 12, 11, zero) will result in the cards being in the order 1,2,3,...9,A,B,...I,J,K,...R,zero,S,T,...Z. The numeric zeros are out of sort, due to their sorting both as a field and a zone.

Correct order can be obtained in one of two ways. The usual sorting procedure outlined above can be followed, and the numeric zeros moved from the bottom of the zero pocket after the second sort to the front of the deck.

A more mechanical scheme would be to lock out the zero pocket on the first (field) sort. The numeric zeros then fall in the reject pocket,

where they may be left during the zone sort.

Tabulator

Selective Listing (Suppress Spacing)

Suppose it is desired to selective list only those cards having an X-71 and also NX-35. (The other 3 possibilities should not list: X-71 and X-35; NX-71, X-35; NX-71, NX-35.) It is desirable to suppress extra spacing on the X-71, X-35 cards.

X-71 is wired to selective list X,

X-35 is wired to hammerlock X,

and the switch set to X-suppression. Long hammerlock levers are raised in the proper fields.

X-35 picks up a selector also, through which an SUP impulse is wired from the transferred side to UP-SP, which suppresses spacing after an X-35 card.

Counting Specified Number of Cards

The 416 will count out a desired number of cards automatically by the following procedure:

Feed the reciprocal of the number to be counted from the DSC-emitter to a counter, and the CI impulse of that counter direct to minor control. Do not clear that counter, on minor total (the machine would then oscillate). For example, if a minor total is wanted every seventh card, a 6-wheel counter is wired 142858 from the emitter (note that one is added to make the sum unity after seven cards). The error will creep over after 100,000 groups, and can therefore usually be disregarded.

Minor Last Card Control

If a great many five-card decks are to be checked for the presence of an X on the last card of each deck, then with minor control on deck number, what is needed is the card count of the X cards, using last card control. Suppose that the X is in column 72; wired from LB to a selector. Last card control is effected by picking up a selector (digit hub) by the unequal impulse which dictates minor control. The card count impulse goes through the transferred side of both selectors (laced) and can reach a counter only if the X in column 72 is on the last card. Another counter

is controlled to add the card count impulse on all X-72 cards to insure that each deck has only one X-72 card.

The same result could be achieved by running the deck backwards; i.e., by putting the decks in the machine face up. Then first card control would do, using the usual minor first card control hub. However, the method outlined above is useful if other checking operations are to take place at the same time, and it is necessary to run the decks in the normal order.

The method outlined will, of course, work as well for intermediate or major last card control.

Cards to Test Tabulator Boards

Two cards are punched as follows:

Card 1: Columns 1-9 zeros
 Columns 10-19 ones
 Columns 20-29 twos
 Columns 30-39 threes
 Columns 40-49 fours
 Columns 50-59 fives
 Columns 60-69 sixes
 Columns 70-79 sevens
 Columns 80 eight

Card 2: punched cyclically with the ten digits; i.e., 1,2,3,4,5,6,7,8,9,0,1,2,3,...7,8,9,0. (That is, each column of card 1 is punched with the tens digit of the column number; each column of card 2 is punched with the units digit of the column number.)

These two cards, when listed or added, will print the column identification on two lines of all columns wired to list or add. For example, if a field in columns 28-29-30-31-32 is wired to list, the tabulator will print;

```

2 2 3 3 3
8 9 1 2

```

The zero of 30 will not normally list.

Producing Multiplication Tables

It is not unusual for a simple multiplication table to be needed in

research; for example, the first 100 multiples of the numbers from 2137 to 2146. A printed list of all 1000 of these numbers can be produced on the tabulator by wiring the ten base numbers to separate counters from a digit selector used as an emitter, by feeding a UCI impulse into DSC. All counters add every card total, clearing on major. A minor total is taken every card cycle by wiring the c.c. impulse to a comparing unequal impulse to minor control. All counters are wired to print totals on a minor control break. If an eleventh counter progressive totals the card count impulse, the multipliers of the table will also be printed.

Since all the information needed comes from the emitter, cards are not read but serve merely to keep the machine going. Hence any deck, inserted in the machine either edge first, face up or face down will serve.

Bivariate Distributions

When the tabulator is used to distribute one column of a deck (producing, in printed form, the same information as would appear on the counters of the 075 sorter), it is convenient both for testing the wiring and to print the columnar headings, to use a special test deck.

Since a 416 tabulator cannot print X's or Y's, and it is awkward to force printing of non-significant zeros, the numbers 12, 11, and 10 are used to indicate Y, X, and zero respectively. With the nine digits, there are then a total of 78 holes needed on the test deck; i.e., 12Y's, 11X's, 10 zeros, 9 nines, 8 eights, ..., 1 one. These may be combined, three per card, so that the test deck consists of 26 cards, as follows:

5 cards punched with Y, 9, 5
 5 cards punched with Y, 0, 7
 2 cards punched with Y, 0, 6
 4 cards punched with X, 9, 6
 4 cards punched with X, 8, 4
 3 cards punched with X, 8, 3
 1 card punched with 0, 8, 2
 1 card punched with 0, 7, 2
 1 card punched with 0, 7, 1

Over a period of time, any column of a deck may be distributed; therefore the test deck should be punched in all 80 columns. That is, the first five cards should have every Y, 9, and 5 punched out, etc.

The test could be made with as few as 12 cards, but since entire rows are punched out, more than three rows per card would materially weaken

the deck for extended use.

In running many distributions, it is well to run the test deck at periodic intervals, both for repeating the columnar headings and to insure that the control panel wiring remains fixed. All levels of automatic control used for the distributions are shut off while running the test deck.

In wiring the tabulator to distribute any single column all twelve ways, the column is read from the upper brushes, through a digit selector, to twelve selectors. There are then two possible choices of wiring. The selectors can be laced together; that is, the card count impulse can be taken to the common hub of selector 1, NX of selector 1 to common of selector 2, and so on to selector 12. The transferred points of the twelve selectors are wired to twelve counter groups. The NX point of the twelfth selector can be wired to a thirteenth counter group. With this scheme, the distribution will be correct only if no card is double punched. The thirteenth counter will record the number of blank cards. If the cards are known to contain no double punched cards, this method is slightly easier to wire.

The alternative method is to send the card count impulse to the common hubs of all twelve selectors separately, through split wiring or bus hubs. As before, the transferred points of the selectors are wired to the twelve counter groups. A thirteenth selector is wired directly to the upper brush hub; the card count impulse wired to common and out the NX point will record, in a thirteenth counter, the number of blank cards. Using this method, two holes in one card will add correctly in both counters. If the cards contain double punching, only this second method will result in the same distribution as would be produced on the counters of the 075 sorter. Note, however, that a card count of the cards between control breaks will not be the row total of the distribution. If the data is such that double punching indicates an error, then the errors will be revealed by the discrepancy between the card count and the cross-footed total of each row of the table.

In printing a bivariate distribution on the tabulator, the deck of cards is sorted on the column (or columns) which will be the left, or vertical margin of the table, i.e., the stub, and the other variable

is distributed among twelve counter groups as described above. The left marginal headings are printed by listing on the list cycle after each control break. The 416 tabulator normally prints nothing for Y's, X's, zeros, or blanks. Frequently a variable may include any or all of these categories. If all four are present, the indication for the first four lines will be blank, and are therefore identified. However, if the variable contains three, two, or one of these four categories, there would be no indication of which ones were present. This difficulty may be avoided by taking the cards out of the sorter in this order: rejects, Y, 1, 2, ...9, X, 0, and listing the symbol of the type bar for both Y and X. The four categories will then be clearly indicated.

Chain of Counters

Frequently, in wiring a tabulator board, one impulse is sent to many hubs. The commonest instance is when all the counters are impulsed from "plug to C" to their + hubs. It is a good practice to feed the chain of counters from both ends. "Plug to C" is sent to counter 8B; 8B is connected to 8A, and so on to 2A; from 2A to 2C, from 2C to 2D and so on to 8D; from 8D back to "plug to C" completes the chain. Thus each counter is fed from both sides, making a more positive connection in the chain. One weak connection will not interrupt the impulse from "plug to C" to each counter.

Tabulator and Reproducer: Repeated Passes of the Same Deck

When one deck is to be run through the tabulator many times, with only a minor change in wiring for each run, it is efficient to make several copies of the deck, with some single column differing between decks. Major control is taken on this deck number column, and major automatic total switch is shut off. The tabulator will stop, then, after taking a total at the end of the deck, and will idle while the necessary wires are shifted. A flick of the major automatic total switch, then, will restart it, after which the switch is again turned off. If no minor totals are taken within the deck, the minor automatic control switch could be used.

Much the same idea can be utilized when reproducing cyclically. For

(Text continued on page 52)

513 Operations and Switch Setting

Operation	Reproduce	S.R. and G.P. Compare	Master Detail	Impulse to PX Hub	Impulse to RX Hub
1. Reproducing and/or comparing. Reproducing with interspersed master gang punching; (X punched masters).	ON	OFF	MM	Punching and read feed suppressed on this cycle and comparing suppressed on following cycle.	No effect
2. Same as (1) but with X punched detail cards (No-X masters).	ON	OFF	DD	Punching and read feed operate on this cycle and comparing operates on following cycle.	No effect
3. Selective Reproducing (X masters)	ON	ON	MM	Punching suppressed on this cycle and comparing suppressed on following cycle.	No effect
(No-X masters)	ON	ON	DD	Punching operates on this cycle and comparing operates on following cycle.	No effect
4. Gang Punching (using punch feed only) (X masters)	OFF	OFF	MM	Punching suppressed	Comparing suppressed on all cycles after the RX hub has been impulsed once. Normally not used.
5. Gang Punching with gang punch comparing (X masters)	OFF	ON	MM	Punching suppressed	Comparing suppressed
(No-X masters)	OFF	ON	DD	Punching operates	Comparing operates
6. Reproducing without comparing, when control panel contains comparing wiring.	ON	ON	MD	Punching suppressed and comparing operates	No effect
7. Comparing without reproducing, when control panel contains reproducing wiring.	ON	ON	DM	Punching operates and comparing suppressed	No effect
8. Double punch and/or blank column	OFF	OFF	MM	No effect on DP-BC detection	No effect on DP-BC detection

Note: When the DP-BC hubs are wired and the blank column switches are OFF, double punch detection takes place. With the switches ON, double punch and blank column detection take place. Double punch blank column detection can be done simultaneously with any of the operations 1 to 5, in which case switch settings for that operation are used.

The reproduce switches are three ganged toggle switches in order to distribute the load. No unusual machine functions are obtained by splitting the settings of the three switches.

When the DP-BC hubs are impulsed, double punch detection always takes place. However, when the DP-BC switches are on, blank column detection can be selected for masters or details or both. With the Master Card Punching switch on, blank column detection functions for both masters and details. With the Master Card Punching switch off, the choice rests with the right hand Master/Detail switch. With the Master/Detail switch set to X - masters, blank column detection takes place only on the NX cards.

On more recent reproducers, the Master Card Punching switch may have a different function from that given above. If no explanation is given in the machine manual, consult the customer engineer.

example, if 10,000 cards are to be serially numbered, a serial master deck of 1,000 cards will punch the last three digits; the thousand number can be emitted. The master deck will be fed through the read side of the machine over and over. If the No. 999 card is X punched, in some otherwise blank column, that column is wired from the reproducing brushes to a comparing relay. The machine will stop, then, after punching —999 and the emitter can be changed to the next higher thousand number with minimum loss of time.

If a great deal of serial numbering is to be done, a special device for that purpose is obtainable on the reproducer. However, consecutive numbering can be done on the 602A (see Chapter 9) with the starting number dictated by an X card. Any number of starting numbers can be inserted in the deck to be numbered.

Similarly, the 602A can be used during otherwise idle time, if there is any, as a gang punch or as a summary punch.

Reproducer:

Operating Information

When the last card for either feed has left the hopper, any extra cards in the other feed must be removed before the three cards left in each side can be run out of the machine. To run these out, press the start key three times and no more. If the machine is run with cards standing in a stacker and no more feeding into it, the last card will be rubbed and wrinkled.

If the stackers are not full, and the comparing light is not on, look for a jam. Look at the cards in the stackers and at the feeds (at the bottom of the piles in the hoppers). If the cards are not obviously jammed, the machine may have missed a feed. There should be a card half-way into the machine on each side; if there is not, it has missed a feed. Replace the first two cards at the bottom of the pack because the edges will be nicked. To resume operation, it is not necessary to run the cards out of the machine. Put the cards back into the feeds and press the start key. The side that did not fail to feed will automatically hold up for one cycle while the other feeds, and then both sides will operate continuously. If it is necessary to run the machine out after it

has missed a feed, the switches must be changed before the machine will operate since the number of cards in the two sides of the machine is unequal. Set the Reproduce switch OFF and the Sel. Rep'd and G. P. Comp. switch ON. Then the feeds will operate independently and can be run out even though there are more cards in one side than the other.

Gang Punch Emitter

The gang punch emitter does not function until the first card reaches the punch brush station. In other words, the punching will start on the second card. A blank card should be placed in front of the cards in the punch feed so that the emitted data will be punched in the first detail card. If the gang punching is part of a reproducing run, a blank card must also be placed in front of the read feed cards so that reproducing will start on the second card in the punch feed.

Types of Gang Punching

The process referred to as "offset gang punching" is usually taken to mean punching common information in one field of a set of detail cards, the punching being set up from a different field on a master card. There are, however, at least four other types of punching on a reproducer, to which the term might have been applied.

1. Information in a field may be needed in another field (the second field blank to begin with), and it may not be important that the information be moved on the same card. For example, a card layout may be altered, so that what was formerly in columns 1-4 may now be needed in columns 5-8. To bring the old cards in line with the new layout, it is necessary only to transfer the four columns. This may be done by wiring from punch brushes 1-4 to punch magnets 5-8 and sending the cards through the punch feed. Each card's information appears, of course, on the following card.

2. Suppose that a deck of cards contains 20 two-digit numbers on each card, in columns 1-40 and it is desired to have the information formerly contained in one card reproduced into individual cards for each two digit number. Nineteen blank cards can be filed behind each card of the deck, and punch brushes 3-40 wired to punch magnets 1-38. The information will then be transferred from card to card in one pass through the reproducer, being offset one field in each transfer. Thus the first card contains all twenty numbers, the second card contains only the last nineteen numbers, etc., and the twentieth card (i.e., the nineteenth blank) bears only the twentieth number.

3. The process in (2) might be varied by wiring also from punch brushes 1-2 to punch magnets 39-40, in which case every card will con-

tain all twenty numbers in cyclic order. It is necessary, of course, to identify the original deck with X's, to prevent punching on each new master from the last of the nineteen detail cards.

4. If each master card is followed by only one blank, it might be desirable to make the gang punching reciprocal rather than cyclic. As an example, suppose cards are punched with digits (0-9) in columns 1-40 in various pretty patterns. Reciprocal wiring is then set up between punch brushes and punch magnets; by this is meant that if col. 17 of the punch brushes is wired to col. 38 of the punch magnets, then col. 38 of the punch brushes will also be wired to col. 17 of the punch magnets. This board, when wired more or less at random between pairs of columns, will then scramble the punching on any card and will restore the original pattern if the scrambled card is then sent through. A listing of the scrambled cards serves as ideal material to teach keypunching; when the original patterns are reproduced, key punch errors are vividly displayed. The whole process can serve as a rapid lesson in use of the key punch and reproducer.

Control for Interspersed Master Gang Punching

In this operation, X detail cards should be used for control, if possible, to avoid double punching cards if the machine fails to read an X. If an X is not sensed when gang punching with X details, punching will be suppressed (a detail card will be left blank) and the rest of the group will be blank. Later, the first blank card will cause a comparing light in the checking operation in the read side unless the machine fails to read the X again.

On the other hand, using X masters, if an X in a master card fails to be sensed, the information in the detail card preceding the master will be gang punched into the master. If the columns were already punched, the result will be double punches. These double punches in the master card will be gang punched through the detail cards of the next group. The error will be caught on the check run unless the machine fails to read the X again, but it is much more difficult to correct double punched than blank cards.

Comparing Decks

It is convenient to keep one reproducer board wired permanently for so-called 80/80 reproduction; that is, to read all 80 columns and punch all 80 columns. Thus a deck of cards which is nearly worn out may be exactly duplicated speedily. Moreover, it is frequently desired to re-

produce out a few columns of a deck; that is, reproduce the deck completely except for a field of a few columns. The 80/80 board may then be used with the corresponding wires pulled. This board, fully wired, may also be used to compare two supposedly identical decks. For this purpose the reproduce switches are set to "reproduce", the SR and GPC switch is "ON", Master/Detail switches are set left "detail" and right "master". Thus even though the board is wired to read and punch, punching is suppressed, since every card is treated as though it were a gang punch master card. In comparing decks (for example, to check key punching twice of the same data), the reproducer is efficient provided that not many errors are expected. If the decks differ on many cards, so that the machine will stop frequently, it is more efficient to compare the decks thirty-two columns at a time on the collator. A wiring diagram for this operation is found in Chapter 9. In using the collator to compare decks, it is necessary to make a preliminary matching run to select mated cards on the identifying information. During the comparing runs, it is essential that the collator deal only with mated cards; if one mismated card exists in either deck all subsequent cards will be rejected as not comparing, since the board is wired to feed cards continuously from both feeds.

If the reproducer is equipped with forty-five comparing relays, two decks may be compared completely in two runs, the second run having the decks turned over so that column 80 of the cards passes the column 1 brush.

Calculating Punch:

Checking by Re-running

The simplest system of checking calculations on the 602A is that of re-running. This checks only for intermittent machine troubles, but such troubles are well worth looking for. If the machine functions properly on both runs, the same answer will be punched twice, and the answer field on the cards will not show double punching.

Consider using the calculating punch for summary punching. Suppose that five cards pass through the machine, each punched with an amount in columns 10-14 and each group of five followed by an X80 trailer, originally blank in columns 9-14, on which the sum is to be punched. If

the addition is performed on the read cycle (after which NX 80 cards are skipped out), there is no harm in adding on the read cycle of the X80 card, since the amount field is blank on the read cycle. However, if checking is now attempted by re-running, without the precaution of selecting out the addition on the read cycle of the X80 card, the previously calculated sum will also be added, and the new answer will be just twice the correct answer.

Squaring a Number

It is not necessary to store the number anywhere except in storage 1R. On the multiplication step, storage 1R is impulsed to read out, the product counter is impulsed to add, and storage 1R exit is wired to the product counter.

Constant Multiplicand or Multiplier

Storage space is not needed for a constant multiplicand. The number can be emitted to the product counter through a selector picked up on the multiplying step. If a multiplier is constant, it may be interchanged with the multiplicand and emitted to save storage space unless multiplying time is lengthened and is an important factor.

Nines

If a counter or storage unit contains all 9's, it will read out or punch all 0's. If a true answer of 9's is possible, the counter or storage unit used should be at least one position larger than the answer.

Multiplication on Successive Program Steps

It is not possible to multiply by 1R on successive program steps, unless 1R contains only one digit. On the second multiplication, the shift to the highest order multiplier digit does not operate, and the machine multiplies only by the units position of 1R.

A X2 or X5 multiplication can take place on the program step immediately preceding or following a regular multiplication using 1R.

AB/C

The product of A and a quotient B/C can be obtained in one division step. The divisor C is read into storage unit 1R, dividend B into coun-

ters 1-3, and multiplicand A into another storage unit. On the next program step (divide) A is added into a counter, automatically being multiplied by the quotient as it develops, thus yielding AB/C .

Wiring is as usual, except that A instead of the quotient exit is wired into the answer counter. The number of decimal places in the answer will be the number of places in A plus the number in the unrounded quotient.

Identifying Trailer Cards

When punching an accumulated result (such as a sum of squares) on a trailer card, identified by an X, the machine may make two types of error if the trailer is not sensed correctly (due to off-punched cards, or an extraneous X). A trailer may be missed, in which case the next trailer will contain the accumulated result of two sets of detail cards. This would, of course, show up, due to the first trailer being blank. Or, a detail card may be sensed as a trailer, in which case the detail card will be punched and, if the fields overlap, will be ruined. In addition, the next trailer will contain insufficient information. This second type of error may not be noticed.

It is better to wire the control panel to punch only on an X trailer which has no digit in some column for which every detail card contains a digit, and wire the panel to skip out detail cards on the basis of No-X and digit. Thus the machine will stop (and the compare light come on) if either a trailer card contains a digit or a detail card contains an X. See example, page 74.

Testing

When trouble appears in work done on the calculating punch, the usual method of testing is to wire the machine for 8 x 22 multiplication, punching out all thirty digits of products. With a deck of assorted factors, to give the multiplier unit all possibilities in every position, the same cards are run over and over and the results inspected for double punching. The IBM customer engineers can furnish a special test deck for this purpose (using 8 x 8 multiplication) which is of particular value when the trouble lies definitely in the multiplier unit. If, however, the trouble lies in the counters, the 8 x 22 deck is preferable, since it

tests all thirty counter wheels at once.

The balance test unit on a calculating punch may be conveniently and rapidly tested by subtracting random digits into a counter and punching them out in the same field, balance tested. The cards will then come out of the machine with no change except the addition of an X, which must appear on every card.

Shifting a Card Field

Information in field A of a deck is needed in field B. This operation can be performed on the 513 by reproducing field A onto a second deck and then reproducing it back onto the original deck in field B.

Provided the field is six columns or less, the 602A will do the same operation at forty cards per minute, which is 80 percent as fast but wastes no cards. For fields of larger size, the operation will be somewhat slower. The wiring on the 602A is as follows: read in to Punch storage on the read cycle; wire "read" and punch on program one.

Other Operations on Multiplying Steps

No other operations, such as transfers, counter resets, or negative balance testing, can be programmed on a multiplication step.

Obviously any counter wired to add or subtract during a multiplication step will have the multiplication performed on the information being added or subtracted.

Counters are reset by adding the complement of the number contained in the counter. The counter will not be reset to zero if the reset is wired on a multiplication step.

A counter can turn negative during a multiplication even though the final result is positive. Hence a negative balance test programmed at the same time as a multiplication may lead to false results.

Used as a Gang Punch

While the 602A is not usually as efficient as the reproducer for gang punching, since its maximum speed is 3000 cards per hour, it is more efficient if an interspersed master gang punching operation is to be done in which the master and detail cards are not distinguished by X punches.

For example, master cards might be identified by the digits 35 in

columns 56-57. If the gang punching operation were done on the reproducer, the master cards would have to be sorted (or collated) out, X punched, and then merged back in before gang punching could begin.

Assume that the information in field A of the master cards is to be punched in field B of the subsequent detail cards.

If control brushes are set to read columns 56 and 57, the presence of a master card can be detected as the card passes the control brushes, using the two digit selectors. If the card is a master card, field A is read into storage and the card is skipped out without punching. The subsequent detail cards are then punched out of storage.

If the reading of the identifying field must take place at the read brush station, it is then necessary to read field A on every card, and store the information. As before, the presence of master cards is detected by wiring the two columns through the digit selectors to two pilot selectors. Master cards are ejected without punching (see below), and the information read from field A is transferred to punch storage, where it is available for punching on every subsequent detail card.

If the identifying information is a number of more than two digits, or if the master cards are identified by having the controlling field less than a given amount, the master cards may be detected by testing the control field information in a counter. As before, this information may be read at the control brush station if control brushes are set on the proper columns. If the reading is done at the control brush station, the calculation, explained below, to distinguish master from detail cards, may be programmed any time after the reading of the previous card.

The calculation to distinguish the cards is the same in either case. Assume that master cards are those punched 567 or less in columns 56-57-58 and that this field is to be read at the read brush station. (This is, perhaps, the more usual case, since it is awkward to have the control brushes shifted for a short run.) Columns 56-57-58 are subtracted into a counter on the read cycle. At the same time field A is read into storage. On the first program, 567 is added into the counter from the emitter. If, at the end of program one, the counter tests negative, the card is a detail card, and should be punched with the information held

in punch storage from the previous master card. If the negative balance test at the end of program one is non-negative, the card is a master card. The card should be ejected, without punching, and the information stored from reading field a should be transferred to punch storage. The ejection may be effected by wiring a skip impulse through the transferred side of the selector picked up by the NB impulse, to the first punching column; the highest order digit from punch storage goes through the normal side of the same selector.

Clearing the Machine at the Start of a Run

Turning the machine off, or running out all the cards, does not reset counters or drop out pilot selectors if they have been left picked up by an impulse to the X or D hub. Thus it can never be assumed at the beginning of a run that the machine is restored to normal (as can always be assumed with the tabulator, reproducer, or collator except for the collator counting device).

For most operations in which the cards are independent (e.g., multiplication of $\underline{+} A \times \underline{+} B = \underline{+} P$, punched on each card), the counters will be wired to reset either during the read cycle or on some program step. Selectors used in sign control which are picked up by X punches read at the control brushes are wired for read drop out. Before the first card is calculated, the machine goes through the entire sequence of program steps wired on the control panel, performing, in general, all operations wired from program steps. In the example given, if the counter used for the multiplication is wired to reset on program 5, this reset operation will take place before card 1 is read at the reading brush station. If the selectors used in sign control are latched up from some previous run they will drop out as the first card feeds into the machine.

In short, for this particular operation, the condition of counters and selectors before the start of the run is immaterial. Consider, however, another example. Suppose field A on a group of No-X cards is to be added in counter 1. The sum is to be multiplied by the amount in field B of a following X card, using counters 5 and 6, and the result punched in field C of the X card. Counter 1 must read out as a multiplicand on a program step of the X card, and must be reset before more No-X cards

are read. Counters 5 and 6 are read out and punched on the X card, and must be reset before the next X card appears (the simplest way being to reset them after read out on the X card).

In this second example, all the counters involved will not be reset until after the passage of an X card. Any amounts standing in the counters from a previous run will cause errors on the first X card.

Often, as in this example, the difficulties may be obviated by preceding each run with dummy cards bearing X punches in the columns which may contain X's for the run.

In some cases it may be necessary to wire extra selectors (which insure counter resets) controlled by an impulse from the reading brushes on every card; for example, any digit in column 3, all cards being serially numbered in the first three columns. These extra selectors will then effectively sense the condition that cards are passing or have passed the reading brushes. Special resets and suppression of such operations as digit emission can be controlled through the normal side of these selectors.

If extra selectors are not available to control counter resets and selector dropouts, or if the wiring is too complicated, it may be more practical, though more awkward, to clear the machine by using a special reset board. This is a control panel wired to reset every counter and "Read in" every storage unit on a read cycle impulse with every pilot selector wired for read drop out. Read cycle is wired to the read hub. Skip impulses are wired to those punch hubs for which skip inserts are in the skip bar. With this panel in the machine, any card passed through the machine will restore all counters, pilot selectors, and storage units. In fact, all that is necessary to effect all resets is to insert the board, press the start key, and hold down the hopper card lever until the feed knives operate.

Page 82 is intended as a novel test of ability to correct a badly wired panel for the 602A (i.e., "debugging"). There are 24 things wrong in the wiring, if the panel is to do what the printed directions state.

8 Electronic Calculation

Two contrasting modes of operation are possible with the card programmed calculator (CPC). A particular problem may be handled by wiring special control panels, one for each of the three component machines.

For example, panels may be wired to cause the machine to test successive odd numbers for factorability and list each number which cannot be factored; that is, the machine will print a list of prime numbers. Each number is divided by every odd number less than its square root; if any division results in a zero remainder, the number being tested is increased by two and the calculation starts over. For numbers of the order of 80,000 the machine tests odd numbers at the rate of one every 2.4 seconds.

Alternatively, semi-permanent "all-purpose" boards have been designed which leave the programming for a particular problem to the punched cards themselves. As a single card passes through the tabulator, the machine will perform one of the arithmetic operations, receiving and transmitting eight significant digits of numbers in the range 10^{-50} to 10^{49} . For example, an instruction card punched 00-2-xx-38-3456677846 tells the machine to take the result from the preceding operation (the xx), multiply (operation 2) by .00034566778 and send the result to storage unit 38. All numbers used by the machine in this mode of operation are in scientific notation. The number in this example is 3.4566778 times 10 to the minus fourth power; the exponent on 10 has 50 added to it arbitrarily, to avoid having to store a sign for the exponent. The 00 part of the instruction code tells the machine to read from the card.

As another example, if an instruction card is punched 00-3-xx-yy-12 34567855 the machine is instructed to divide (operation 3) the previous result (xx) into 123456.78; the result of the division will be available for the next operation and is not stored (yy is punched in the card field reserved for storage assignment).

The initial numbers needed for a problem are first stored in the machine (there is capacity for storing thirty-two numbers, each with a

sign), after which a deck of instruction cards is passed through. Each instruction card may bear one new number and one operation instruction.

The all-purpose setup offers complete flexibility with modest speed. It is hoped that persons having problems for the machine will do their own coding of instructions, since by this means the equipment will be used to capacity.

To illustrate the all-purpose operation further, there are listed here the nine instruction cards to calculate the value of the function,

$$Q(x) = \sum_{n=1}^5 \frac{x^n}{n! + n} = \frac{x}{2} + \frac{x^2}{4} + \frac{x^3}{9} + \frac{x^4}{28} + \frac{x^5}{125}$$

where x is in storage unit 23 and the value $Q(x)$ is to be developed and stored in unit 24. Operation 0 is addition; operation 2 is multiplication; operation 3 is division.

factor A	operation	factor B	send result to	factor A entry from card
00	2	23		8000000047
00	0	XX		3571425748
23	2	XX		
00	0	XX		1111111149
23	2	XX		
00	0	XX		2500000049
23	2	XX		
00	0	XX		5000000049
23	2	XX	24	
00	0	00		

Modern high speed computing equipment does nothing that cannot be done with pencil and paper—it simply does it faster. All machines so far constructed, wheter electronic or not, perform only the four operations of addition, subtraction, multiplication, and division. These operations are performed in some sequence. A machine can discriminate (i.e., can determine the answers to such questions as "Does the result at this stage exceed 23.7?" or "Do the results of the last two trials agree to four decimal places?") and thereby select one of two possible sequences of operations to follow. However, such a function of a machine reduces to subtraction followed by a zero test of a counter or a negative balance test (i.e., does the counter now contain zero or a number less than zero?).

The advantages of automatic computing equipment, then are only speed and accuracy. Machines can make mistakes, but it is assumed that a mach-

ine avoids the common human errors of misreading (it is very common for human computers to read 4693 as 4963) and forgetting.

The speed and accuracy of automatic machinery is, of course, offset by high cost in comparison to human computers. Machines must be backed up by an organization to run them. Suppose that a human computer using a good electric desk calculator can be maintained for two dollars per hour, on the average. The same work might be performed 30 times as fast on automatic machines, but at an average cost of, say, eight dollars per hour. Unless a large volume of work is to be done, so that the automatic machinery can be kept occupied, it might be cheaper, in the long run, to hire several human computers, for most computing work.

Now there is a type of problem where automatic machinery is vital and the work cannot be speeded up by having more people work on it. Such a problem is one where successive steps depend on the previous steps, and must be done in sequence.

For example, suppose we define a function

$$Q(i) = \frac{Q(i-1)R(i-1)}{R(i-2)}$$

and define

$$R(i) = \left(1 + \frac{i}{1,000,000}\right)^2 \frac{R(i-1)R(i-1)}{Q(i-1)}$$

and, starting with the values $Q(1) = .99999999$, $R(1) = 1$, $R(0) = 1$ we wish to calculate the values of $Q(i)$ from $Q(2)$ to $Q(500)$. (What sounds like a simpler problem is: at what value of i does $Q(i)$ first reach ten?)

$$Q(2) \text{ is easy.} \quad Q(2) = .99999999$$

To reach $Q(3)$ we will first need $R(2)$.

$$R(2) = \frac{(1.000002)^2 (1) (1)}{.99999999} = 1.0000040$$

$$\text{Then } Q(3) = \frac{(.99999999) (1.0000040)}{1} = 1.00000399$$

It is clear that each successive value of Q depends on the previous Q and the two previous values of R . And each R value depends on the previous R and the previous Q . There is no shortcut to the calculation. Working even to slide rule accuracy (three significant digits) at each stage becomes extremely tedious.

The arithmetic operations at each stage are precisely the same. Hence if an automatic machine first has its memory loaded with the appropriate starting values and is given the sequence of operations to perform repetitively, successive values of Q will flow out. The CPC can be set up to calculate the values Q at the rate of 150 per minute, to eight significant digits, which is easily 300 times as fast as a human computer. (Incidentally, the value of Q reaches ten at Q(410); Q(746) is slightly over one million).

The Card Programmed Electronic Calculator

Instructions for Coding for All-Purpose, Eight Significant Digit, Floating Decimal Operation.

All numbers used by the CPC in this mode of operation (as input, during calculation, or in punched or printed output) are in scientific notation: eight significant figures followed by the exponent on ten. The exponent is arbitrarily increased by 50. Since only two digits are allowed for exponents, all numbers used by the machine must be within the range from 10^{-50} to 10^{49} . Examples of the notation are:

Number	Scientific Notation
12345.678	1234567854
- 12.345678	1234567851X
1.2345678	1234567850
- .12345678	1234567849X
.000012345678	1234567845

Each card passing through the 417 tabulator contains the following punched information:

(1) The addresses of the two factors to be used for the operation dictated by the card. These are the directions for channels A and B. There are three possible types of addresses: the number of a storage unit containing a factor; the result of the calculation on the preceding card; and, in the case of channel A, a number punched on the instruction card.

(2) An operation number, to instruct the machine what operation to perform on the numbers A and B.

(3) The address to which the result of the operation is to be sent (usually a storage unit number). If the result is to be printed only or is to be used in the next calculation without being stored, this address is left blank.

In addition, each instruction card may contain

- (1) a serial number or other identification
- (2) a special operation number.

The card layout is as follows:

Columns	Contents
1-3	serial number
4-5	address of factor A
6	operation
7-8	address of factor B
9-10	address of result, C
12	special operation
14-23	card entry into channel A.

An X overpunch in column 23 signifies that the number in columns 14-21 is negative.

There are 32 auxiliary storage registers, numbered 11, 12, 13, 14, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 43, 44, 45, 46, 47, 48.

Columns 4 and 5, or 7 and 8, can be punched with any storage register number, or punched XX to use the result of the calculation on the preceding card. Columns 4 and 5 can also be punched 00 to indicate read-in to channel A of the number punched in columns 14-23.

The operation code for column 6 is as follows:

X	Print result of the calculation directed on this card
0	Add, $A + B$
2	Multiply AB
3	Divide, A/B
8	Subtract, $A - B$
9	Summary punch the result of the calculation directed on this card. The punching will be in columns 14-23 of the summary card, with column 23 X overpunched if the result is negative.

The X, 8, and 9 can be combined singly or in combination with one of 0, 2, or 3. The effect of operation 8 is simply that of changing the sign of factor B. Several examples of instruction cards follow:

4 - 5	6	7 - 8	9 - 10	Remarks
23	3	47	15	Divide the number in register 23 by the number in register 47; send the

				quotient to register 15.
00	X0	99	11	"Load" storage register 11 and also print. The 99 in channel B is a dummy figure to fill the columns.
46	2 8	17	12	Form the negative of the product of the numbers in storage registers 46 and 17; send result to register 12.
00	3 9	XX		Divide the previous result into the number read from this card; summary punch the result.
XX	X 8	21	48	Subtract from the previous result the number in register 21; print the result and send it to register 48.
XX	2	XX		Square the previous result.

The special operation code for column 12 is as follows:

1. Causes the platen to advance one extra space before printing the result of the calculation called for on this card, if this card is punched X in column 6 also.

2. Same as (1) but two extra spaces.

5. The number entering channel A is changed to the negative of its absolute value.

6. Same as 5 for channel B.

7. Causes CPC tabulator counter number 1 (2A and 6A) to add.

8. Causes CPC tabulator counter number (2A and 6A) to clear during the reading of the following card. (Operations 7 and 8 are primarily for the purpose of transferring information to the summary cards.)

During any calculation, subroutines for the calculation of elementary functions of numbers placed in storage register 27 may be indicated without being programmed; the value of the function is available in register 28 for calculation on the next card. For example, if the calculation on card 267 produces a number B whose square root is needed on card 268, it is necessary only to send the result on card 267 to register 27 and indicate "square root." The code 28 on card 268 in either channel A or B will proceed with \sqrt{B} . Other elementary functions, such as $\sin X$, e^X , etc., may be called for similarly by subroutines which are on file.

It is not particularly important to seek the simplest program routine, unless the routine is to be repeated many times, in which the saving of one card results in a considerable saving of time. For example, given X in register 35, the evaluation of $X^2 - 3X + 17$ may be effected as follows:

A	0	B	C	
35	2	35	36	
00	2	35		Read -3 from this card
00	0	XX		Read 17 from this card
36	0	XX		

or as follows:

00	0	35		Read -3 from this card
XX	0	XX		
00	0	XX		Read 17 from this card

Both routines produce the same result. The first uses one more card than the second and also calls for the use of an extra storage register.

One precaution is necessary. The result of a calculation, sent to storage, can be used on the succeeding card with the XX code. It cannot, however, be used on the second card following, since the operation of storage read-in, due to the lack of synchronization between the tabulator and the storage units, may take two card cycles to complete. On the third card following, the number may be recalled from storage.

Reading into a storage register automatically sweeps out any number previously held in it. Reading out of a storage register leaves its contents unchanged.

If a given set of instruction cards is to be sent through the machine repeatedly and certain of the cards are to be replaced for each pass, it is well to indicate on the chart that the cards to be replaced should be "right corner cut" to afford a visual distinction between them and the balance of the deck.

It is possible to print every card of a deck, including the instructions and the numbers in the three channels, without any special punching. An asterisk will then be printed next to the card number of any card bearing an X in column 6.

It is important that tests be devised for any calculation, covering the range of magnitudes involved, with known answers.

Printed sheets ruled for the card layout we use, are available on request.

Before coding a long routine, it is helpful to try a few very simple routines on the machine to get the "feel" of it. The all-purpose mode of operation effectively places at your disposal a tremendous "desk calcu-

lator." With a few minutes of instruction, nearly anyone can write out the solution to a problem, without having to know anything of the internal workings of the machine.

Generally, instruction cards pass through the tabulator at the rate of 150 per minute. Thus, calculations to be controlled by an instruction deck of 750 cards will be completed in five minutes.

If, inadvertently, division by zero is called for, the result will be zero; no delay is involved.

In practical use, all you need to do is write out the instruction code to solve your problem—one line per arithmetic operation—and bring the written sheets to the Computing Service. Trained operators will keypunch your cards. The tests you devise are first run off to insure that the programming is correct; then the problem itself is run off. In many cases, the results can be finished while you wait.

CAUTIONS

There should be no blank cards in any instruction deck. If it is necessary to insert a dummy card for delay purposes, it should be punched 99099 in columns 4 - 8.

00 in channel B control (columns 7 - 8) will cause trouble. 99 in columns 7 - 8 has no effect and should be used to fill these columns when no other instructions for channel B are used.

9 Diagrams

POKER TEST OF RANDOM DIGITS ON AN IBM TABULATOR

Selectors	Trf's						Wire c.c. Impulse through the Indicated Positions (i.e., side) of six 10- Position Class Selectors						Type	Type Group
	1	2	3	4	5	6	1	2	3	4	5	6		
1							N	N				N	A A A A	Four of a kind
2			*	*	*			N		N		X	A A A B	Three of a kind
3	*		*	*	*		N				N	X	A A B A	
4	*		*	*	*			N	N		X		A B A A	
5	*	*	*	*	*		X				N	N	B A A A	
6	*	*	*	*	*		N		X			N	A A B B	Two pair
7	*	*	*	*	*			N			N	X	A B A B	
8	*	*	*	*	*		X		N	N			A B B A	
9	*	*	*	*	*	*	X		X	X		X	A A B C	One pair
10	*	*	*	*	*	*		N	X	X	X		A B A C	
11	*	*	*	*	*	*	X	X	N	X			A B C A	
12	*	*	*	*	*	*		X	X	N	X		B A A C	
13	*	*	*	*	*	*		X	X	X	N		B A C A	
14	*	*	*	*	*	*	X		X	X		N	B C A A	
15	*	*	*	*	*	*	X	X	X	X	X	X	A B C D	None alike

Complete wiring is not shown. The above chart is the key to the wiring.

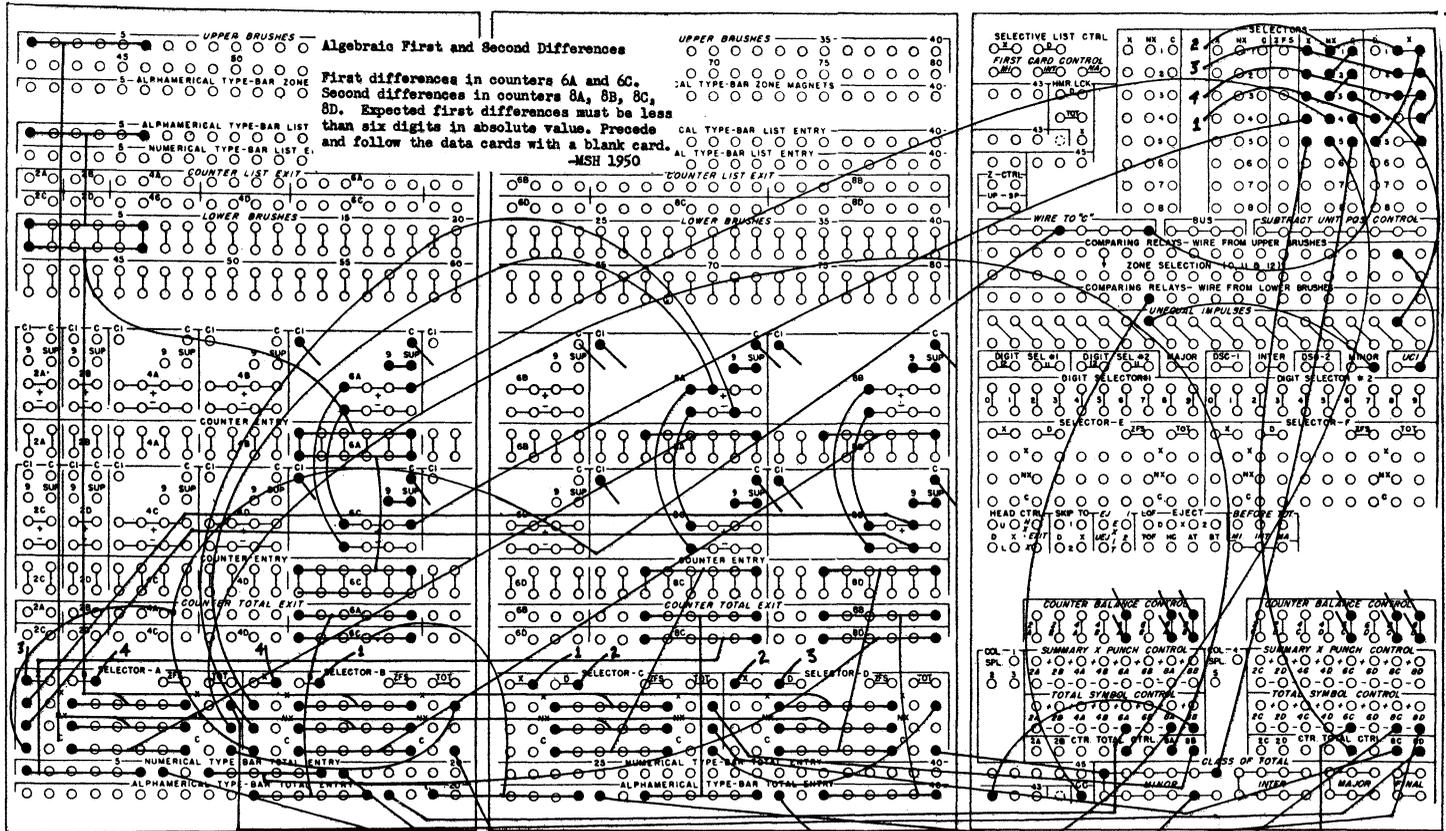
EXAMPLE:

The 4 digits to be tested are shown on the diagram as Cols. 1-4. Suppose a card is punched 2727, which is two pair, type 7. Class selectors 1, 3, 4, and 6 will be transferred. Type 7 is uniquely identified if a card count impulse is sent to counter 6A via the following path: into a common hub of selector 2, out the corresponding NX hub to a common hub of selector 5, out the corresponding NX hub to a common hub of selector 6, out the corresponding X (transferred) hub to counter entry.

There are only 15 possibilities to sift out; for example, "one pair" can occur six different ways, types 9 to 14.

The 6 class selectors, numbered here from 1 to 6, are usually identified on control panels with letters A to F.

The wiring through the selectors for type 7 is shown. In actual wiring, the card count impulse must be split 16 ways: 15 to enter the common side of the selectors, and one to enter counter 8B directly, for the counting of cards.



Algebraic First and Second Differences

First differences in counters 6A and 6C.
 Second differences in counters 8A, 8B, 8C,
 8D. Expected first differences must be less
 than six digits in absolute value. Proceed
 and follow the data cards with a blank card.
 -MSH 1950

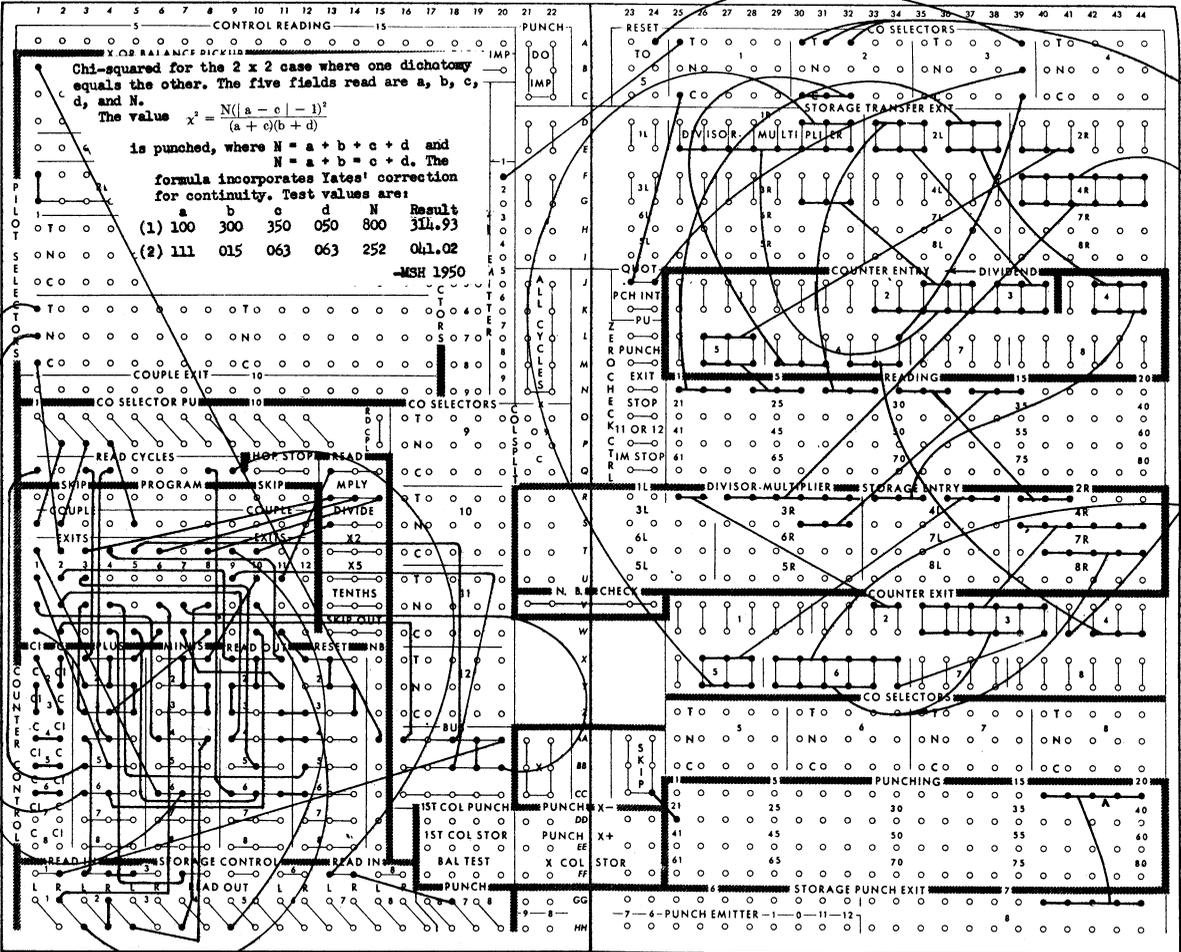
- HAMMERLOCK LEVERS
- AUTO HAMMERLOCK LEVERS
- HAMMER SPLIT LEVERS
- RECOUNTABLE TYPE
- INFORMATION LEVERS
- INFORMATION TERMINAL SWITCHES

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

INTERNATIONAL BUSINESS MACHINES CORPORATION
IBM
CALCULATING PUNCH
TYPE 802 A CONTROL PANEL

FORM 24-2326-0

PRINTED IN U.S.A.



Chi-squared for the 2 x 2 case where one dichotomy equals the other. The five fields read are a, b, c, d, and N.

$$\chi^2 = \frac{N((a - e) - 1)^2}{(a + c)(b + d)}$$

The value χ^2 is punched, where $N = a + b + c + d$ and $N - a - b = c + d$. The formula incorporates Yates' correction for continuity. Test values are:

	a	b	c	d	N	Result
(1)	100	300	350	050	800	311.93
(2)	111	015	063	063	252	041.02

—MSH 1950

NOTE

X OR D CODE

CARD NAME OR FUNCTION

ELECTRO. NO.

Setup Change, 602A

Setup A: Plug pickup of selector 17, have no dropout.

Group multiplication with X80 masters, which are skipped out, with the multiplier (columns 1-5) read into 1R. The multiplicand is read into 2R. The product is punched in columns 11-17 of each NX80 card, rounded.

Setup B: Plug dropout of selector 17, have no pickup.

Division, with divisor in columns 63-65, dividend in columns 22-26, with two decimal places, no rounding.

The extent to which the two setups may differ is limited only by the selector capacity to switch the setups. A manually operated selector, using a toggle switch, may be used to effect the change, and the board could then be sealed. Such a toggle switch can be installed for a small charge by IBM.

-FG 1952

Program decks for CPC floating decimal operation may be checked on the 405 or 416 tabulator for three kinds of error. Channel A address is in columns 4-5, channel B address in columns 7-8, and channel C address in columns 9-10. The Wisconsin CPC has two 941 storage units and uses card read-in to channel A only.

Type 1 error consists of channel C addresses to the same storage unit or counter on successive cards. During listing, an error card will list a 1 in TB 19.

Type 2 error consists of Channel C address to non-existent storage unit or counter, and an error card will list a 2 in TB 21.

Type 3a error consists of channel A or B address of a storage unit on the first or second card following the card bearing the channel C address to that unit.

Type 3b error is similar to 3a except for counter readout on the first card following the reading. Type 3 errors result in a 3 listing in TB 23.

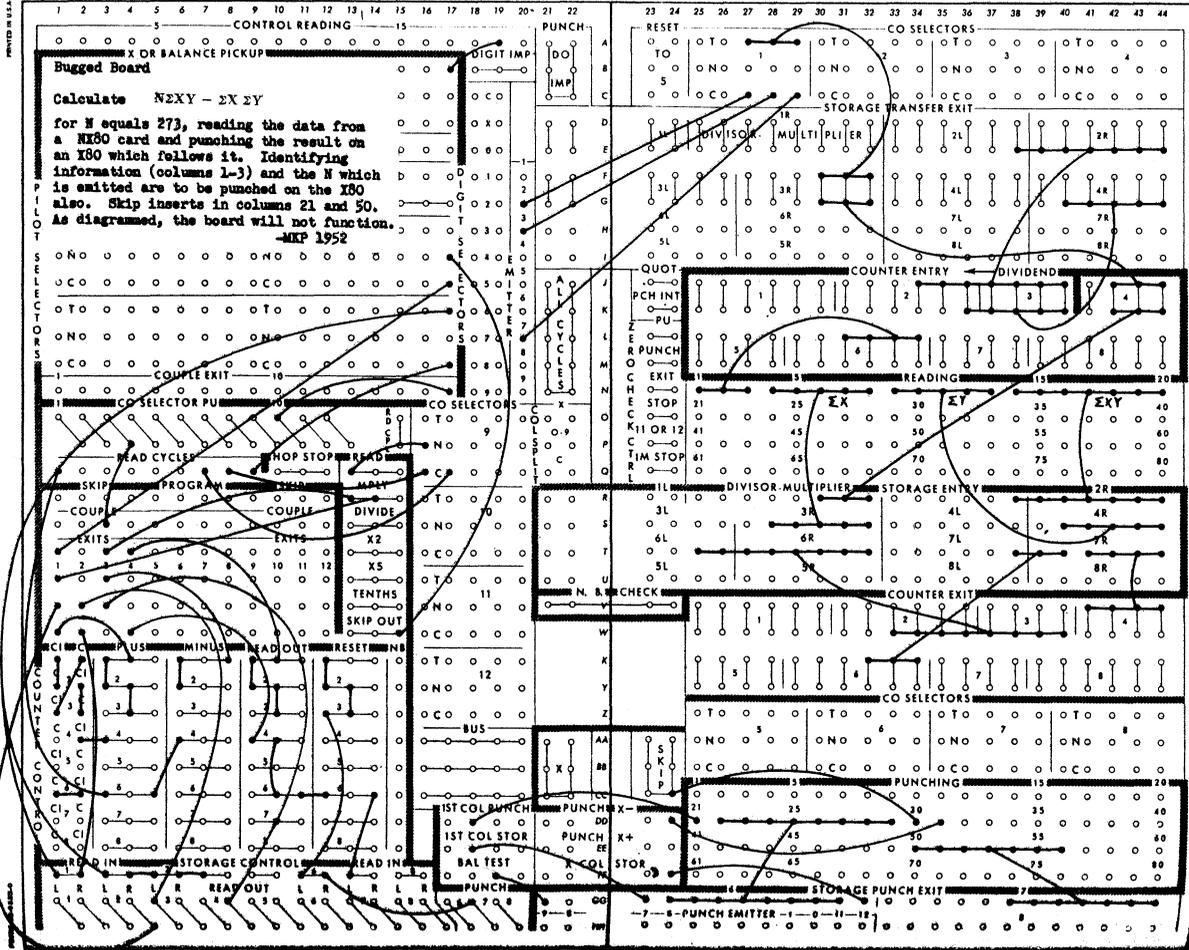
The three wires to TB's 19, 21, and 23 may be split wired to selective list, if it is not desired to list all instructions.

The wiring shown requires 16 single-position selectors, six 10-position selectors, two digit selectors, 20 comparing relays, and the card cycle total transfer device. The checking operation takes place at full speed of the tabulator.

While there are other possible coding errors, the three tested are of the type which produces intermittent errors in the final results; that is, the deck may work, but not consistently.

TYPE 402 MAY BE PUNCHED FOR TESTING IN SERVICE

INTERNATIONAL BUSINESS MACHINES CORPORATION
IBM
CALCULATING PUNCH
TYPE 402 A CONTROL PANEL



NOTE

1 OR 0 CODE

CARD NAME OR FUNCTION

ELECTRO NO.

98

part II
laboratory work in
punched card computing

Laboratory Work

Preliminary Information for Laboratory Work

The IBM card may be punched with holes in any of eighty columns and twelve rows. The eighty columns are numbered on the card, usually at the bottom. The ten digit rows are usually printed. The two rows above the zero row are denoted by X or 11 (the row just above the zero row), and Y or 12 (the top row). The printing on the card has no bearing on its use in the machines, but serves merely as a convenient guide to the punching.

The short edge ($3\frac{1}{4}$ inches) is used by the knife and throat of the keypunch only; in all other machines the knives and throat work on the long edge ($7\text{-}\frac{3}{8}$ inches). Therefore, in joggling cards for use in any machine except the punch, the cards should be hit only on the short edge. The long edges are distinguished as "9 edge" (next to the 9 row) or "12 edge" (at the top of the card, next to the Y row). On most machines there is a label on each feed hopper as to how cards are to be inserted. For example, the sorter feed hopper is labelled "face down, 9 edge" which means 9 edge toward the throat. These labels refer to normal operation; on occasion cards are inserted in other ways.

The term "deck" refers to any group of cards. A given problem may involve five decks, suitably distinguished by punching; the five sub-decks together may also be referred to as a deck.

On a given deck, a group of columns may be reserved for a particular variable; for example, columns 6-7-8 may have a score on the same test for each person (each person's attributes being punched on a single card). Such a group of columns is called a "card field." (Note: the term "field" is also used in connection with alphabetic punching to distinguish rows 1 to 9 of the card from rows 0, X, Y which are called zones.)

If certain cards in a deck are X punched in column 79, these cards are referred to as X79 cards. The others in the same deck are then

No-X79, cards (or NX79). Similar reference is made to the D23 cards of a deck; i.e., cards which bear some digit, from 0 to 9, in column 23.

It is common practice to number the cards in a deck with punched numbers. For example, in a deck of 1037 cards, columns 1-4 could be used for numbering from 0001 to 1037. Note that the entire field is used on every card. This is "serial numbering." If the deck is in ascending order on its serial numbers, it is said to be in sequence (or "in sort") on columns 1-4. This is not necessarily the same as being in consecutive order. Cards punched as follows

1234

1235

1237

1389

on a given field are in sequence on that field but are not in consecutive order.

Suppose a deck of 1000 cards is serially numbered from 000 to 999 in columns 1-3 and the deck is out of sort on that field. To put it in order, sorting normally begins on column three, the units digit of the field. The cards fall into the pockets from 9 to zero and are removed from the machine with the zero cards at the front of the deck, followed by the ones, twos, ... nines. The entire deck is now sorted on column 2, the tens digit. The order of the previous sort on column three is maintained within the groups falling into each pocket on this sort. The deck is now in order on columns two and three. The cards are again removed in the order 0, 1, 2, 3, ...9 and sorted once more on column one.

This is normal sorting procedure and appears to be reversed from the method most people use in hand sorting. The hand sorting procedure (sorting first on the hundreds digit; then keeping the hundreds groups separate and sorting each on the lower order digits) is block sorting, and is used in machine sorting of very large decks.

The standard machine sorting procedure (sorting on the lowest order

digit first) affords a good example of levels of control. Considering the hundreds, tens, and units digits of the serial number as distinct classifications, the final result shows the cards in order on hundreds digit; in order on tens digit within each hundreds group; and in order on units digit within each tens group. We have, then, three levels of control on the order of the deck; call these levels major, intermediate, and minor. It is worth repeating that the cards are sorted on the minor control level first, then the intermediate, then the major.

These levels of control can be card fields, instead of card columns. Thus, a deck can be ordered on field C within field B within field A. Field A is the major classification. Sorting any one field may necessitate several column sorts in sequence.

To take an example from industry: cards relating to total sales for a month could be ordered by states; by cities within states; and by salesmen within cities. The normal order of sorting would be on the field identifying the salesmen first (the minor classification or control).

There are differences between the plugboard diagrams in the IBM manuals and the plugboards for particular machines. For example, the 405 manual shows 8 3-position X-distributors; many machines have these replaced with 16 single position selectors. When using any machine, check to find out the differences from standard, both in wiring and for special devices which may be present or absent.

Each machine has its own main line power switch and, except for the punch, a start and stop key. In addition, each wall outlet is switched from a main power panel. In case of machine trouble, such as a jam, stop the machine immediately, and call the instructor. Before attempting to remove the cause of the trouble, shut off the power at the machine.

Cards which are to be used at a subsequent lab period should be filed and properly identified. Cards left lying around tend to disappear.

Do not disturb other people's work. Do not tear down a board unless you are certain it is no longer needed. Conversely, tear down each of your own boards when you are through with it and (almost without

exception) tear down your boards at the end of a laboratory period. (Boards which are to be held should be clearly labelled.)

Do not remove cards from a machine and use the machine, even though it appears to be idle.

Come to lab each week fully prepared. Preparation usually includes a review of the problem for the week, preparation of wiring diagrams, and review of the mathematics involved. Be sure to bring up questions in lecture the preceding week if the directions are not clear to you.

MACHINE OPERATING INSTRUCTIONS

Cards must be joggled before being placed in a hopper. Place one side of the pack against the joggle plate of the machine, hold the deck loosely with one hand exerting gentle pressure on the top (long edge) and holding the deck together. Slap the other end of the deck with easy upward strokes until the cards are completely in line.

Do not remove the pressure plate or place more cards in the hopper while the machine is running, unless there are at least 300 cards (two inches) still in the hopper.

Do not remove cards from a stacker while the machine is running. This is especially dangerous with the sorter, reproducer, and collator.

If the machine jams, press the stop button immediately. Call for help; do not attempt to remove the jam yourself unless you have been specifically instructed in how to do this. More harm can be done in removing a jam than the jam itself could do.

The following instructions apply particularly to the 075 sorter. These instructions are to go with a personal demonstration of its use.

The brush is set on the desired column by raising it from the brass roll with the column selection handle and sliding it to the desired column. Turn handle down before starting to sort. Be sure the brush is all the way down; it can ride on the top of the positioning ratchet. Use the worm drive to move the brush one column in either direction; for more than one column always lift the brush and slide it.

Reset the counters, if they are to be used, before starting to sort; never reset while the machine is running. If counting is not necessary, turn the counters off. Resetting counters during operation produces missorting and damages the machine.

Check the sorting operation by sighting through the holes.

Every stacker has an automatic cutoff which will stop the machine when any pocket becomes full (roughly 400 cards). Do not remove cards from the pockets while the machine is running. The machine can be stopped at any time and will pick up correctly for sorting and counting when restarted. When starting the machine, it is necessary to hold the start key down until the first card has passed the second card latch lever; this means that the key must be held down for about half a second.

Neither sorting or counting will take place unless the corresponding switches are turned on. It is possible to count without sorting, sort without counting, do both, or neither. In the last case, the machine merely moves cards from the hopper to the reject stacker.

The selector switches on the commutator control the sorting for each of the twelve card positions. When off (moved toward the center), cards bearing only the corresponding punch will reject; the corresponding counter will add, however. The machine sorts on the first hole it meets of any card (i.e., if a column is double punched with a 7 and a 3, the card will sort into the 7 pocket unless the 7 selector switch is off, in which case it will sort into the 3 pocket); the counters will tally every punch in the column. The twelve counters corresponding to the card rows add at the time the hole passes the brush and are controlled from the brush. The two total counters add as the card passes the first card latch lever, provided that none of the other twelve counters have already added.

When any card or cards in a deck appear nicked or damaged in any way, have them duplicated or reproduced immediately. Cards are always cheaper than jammed machines.

Lab. I

Keypunch at least twenty cards, not all on the same machine. The card layout is as follows:

<u>Columns</u>	<u>Contents</u>
1-2	your identification number
3-4	line number of the data
5-34	30 digits of data
35	X punch

using the data printed below. The data is printed with a space between each five digits for ease in reading only.

1	00139	03436	88742	51794	66281	52759
2	33204	30907	55691	82649	77152	81684
3	42175	69816	46508	93758	82047	12373
4	11152	65403	72395	41374	38026	90842
5	44315	41018	66702	93750	88263	92795
6	33263	86615	94417	52486	50247	02953
7	33374	87625	94517	63596	50248	12064
8	11240	14547	99853	62805	77392	63860
9	55426	52129	77813	04861	99374	03806
10	44374	97726	05528	63597	61358	13064
11	55485	08837	16639	74608	72469	24175
12	33462	36769	11075	84027	99514	85082
13	22351	25658	00964	73916	88403	74971
14	66537	63230	88924	15972	00485	14917
15	77648	74341	99035	26083	11596	25028
16	44403	90152	83260	14281	27539	65713
17	55514	01263	94371	25392	38640	76824
18	44573	47870	22186	95138	00625	96193
19	55625	02273	94471	36402	38641	86935
20	55684	58981	33297	06249	11736	07204

When using the electric punch (type 016 or 031), an uncut low skip

bar is to be used. A master card is inserted in the duplicating rack, bearing your identification number in columns 1-2 and an X in column 35. The machine will duplicate the X in column 35 and automatically eject the card. If the O24 punch is used, the action of the skip bar is replaced with appropriate punching in the drum (program) card.

Wire a control panel for the interpreter, printing columns 1 and 2 of the card in type bars 37 and 38; columns 3 and 4 of the card in type bars 40 and 41. Interpret part of your deck on "upper line print"; the balance on "lower line print."

Familiarize yourself with the location and type number of the various machines, the location of power switches, and the files of cards.

File your deck, suitably labelled.

While half the lab group is keypunching, the other half will be shown the operation of the sorter. Read over the information on the sorter before coming to lab.

Assignment:

Read over the information on use of desk calculators and calculation of bivariate tables. Prepare the rule charts similar to page of the information on bivariate tables, on which to record the data in lab. 2.

All written assignments are due in laboratory the following week.

Lab. 2

You will be shown the operating features of the Monroe, Friden, and Marchant electric desk calculators and the Peerless, Brunsviga and Comptometer manual desk calculators. Use the electric machines to extract square roots, correct to 10S, of the numbers suggested in the section on desk calculators, using the Newton-Raphson method. Be sure to extract at least one root on each of the three electric machines.

A deck of 76 cards (serially numbered in columns 1 and 2) is available, bearing two single-digit variables; variable A in column 3 and variable B in column 4. Using the card counting sorter, prepare

two bivariate tables from the data on this deck, as described in the section on bivariate tables.

Assignment: 513 manual (edition 52-3180-0, or 52-3180-1) pp. 1-9, 11-17, 22, 26.

Chapter 8, relating to the 513.

Complete the problem on bivariate tables and hand it in the following laboratory period.

Diagram the 513 panels to be wired in lab. 3.

Lab. 3

Using the decks punched in lab. 1, compare the punching on the 513, using the so-called 80/80 board. This need only be done once for the entire group, to illustrate the method.

Reproduce onto blank cards the deck you punched, using this wiring scheme:

Read	Punch	Read	Punch	Read	Punch
1	1	13	24	25	31
2	2	14	11	26	21
3	3	15	19	27	5
4	4	16	29	28	9
5	27	17	10	29	16
6	7	18	23	30	22
7	6	19	15	31	25
8	34	20	32	32	20
9	28	21	26	33	12
10	17	22	30	34	8
11	14	23	18		
12	33	24	13		

Wire the comparing circuits as well as the reproducing. Examine the new deck, after which the new deck may be discarded.

Using cards 01 to 10 of your original deck, hand file three blank cards behind each card. Wire a panel to gang punch columns 1-4 of each X35 master into columns 1-4 of the NX detail cards which follow. On the same panel, wire to offset gang punch columns 5-14 into columns 15-24. Emit the current date (e.g., 031452) into columns 25-30. The PX and RX brush settings of the 513 are on the bulletin board.

Sort out the X35 cards and return the entire original deck to file. Hand in the gang punched cards.

Assignment: Collator manual, pp. 1-24, 32-35. (Edition 52-3185-1), and:

1. Information in columns 5-8 of each successive group of ten cards is needed in ten 4-column fields of one card. The 10-card groups are group identified in columns 1-3 and further identified by a card number (from zero to 9) within the group in column 4. The identification in columns 1-3 is to appear in columns 1-3 of the summary card. Describe a method, using the sorter and reproducer.

2. Conversely, information in ten 4-column fields on one card is needed on ten separate cards. Describe a method.

3. Diagram some of the collator panels to be used in lab. 4.

Lab. 4

A deck of cards is available, serially numbered from 001 to 300 in columns 1-3. Two cards will be out of sort and there will be two duplicates. Sequence check the deck on the 077 collator; remove the duplicates and put the cards in order. Note that you have not checked for consecutive numbering. See problem 3 below.

Break the deck on column 9 on the sorter (column 9 is randomly punched with 1's and 2's) and merge the two decks together again on the collator.

As time permits, do the following operations. It is not necessary to perform each operation for the entire deck, but only as far as necessary to demonstrate that the panel is properly wired.

1. Insert a blank card behind each punched card of the deck. If the blanks are placed face up in the secondary feed, the alternating corner cuts will reveal correct operation quickly.

2. Remove the blank cards, using diagram 37 in the collator manual.
3. Insert the number of blanks behind each card, according to the punching in column 52. (Diagram 50 in the 077 manual.)
4. Insert 3 blanks behind each X80 card. The control panel is a modification of diagram 48 in the manual. Column 80 of the primary brushes goes to PX-PU. Control input impulse goes to common of the primary X selector. NX of the selector goes to a selector pickup, as does the 3 hub of the counter. The X side of the primary X selector goes to units common of the counter. All other wiring is as shown in diagram 48.

At the end of the laboratory period restore the 300 card deck to its original condition; i.e., with two cards out of sort and two duplicates.

Assignment: 405 manual, pp. 1-38, 70-71, 74-77. Pay particular attention to auto control, p. 16, and subtraction, pp. 30-33.

Problems:

1. How would you sequence check a file of cards which is in descending order?
2. A card X punched in any one or more of columns 16-23 of a deck is to be removed. Describe the collator wiring. If the error cards were punched 5 instead of X, could they be removed on the collator?
3. Describe at least three methods of consecutive number checking.
4. Diagram the tabulator panel needed in lab. 5.

Lab. 5

Sort the 300 card deck for a tabulation with major control on column 49 and minor control on column 51. (Minor control breaks will occur about every 50 yards.) Columns 52-55 are punched with random digits; this field can therefore be considered to average 4999.5 per card.

In a counter group of suitable size add the information in columns 52-55 of NX79 cards; subtract on X79. In another counter group reverse these controls; i.e., add columns 52-55 of X79 cards and subtract on

NX79 cards. Take a card count and print out all three counter groups on minor control breaks. (Note: when counter capacity permits, take a card count on every tabulation you make.)

Balance convert the totals from both counters which are adding columns 52-55. Note that both totals for each control break should be the same in absolute value, but one of them will be indicated as negative by printing the extra character (impulsed from "counter symbol control") on the type bar to the right of the total. Consult the bulletin board for indication of what character is present on each type bar.

Column 51 contains extraneous X punches. Control will be broken on cards having extraneous X's unless the wiring to the comparing relays is sent through the counter list exits of a spare counter, or the wiring of Pointer 9-470-A is used.

Count the number of minor control breaks in a fourth counter group, and print this count at each major control break.

List, on the automatic list cycle following any control break, all identifying information. (See wires marked "4", p. 19 of the manual on the 405.)

Hand in your tabulator tape. Except for choice of type bars, everyone's results should be identical. Throughout the course, whenever you produce printed results, be sure to include all errors on the final tape; in other words, hand in all the tape you use on the machine. If a test deck is used, be sure to show a listing of it, properly labelled as "test".

For a few weeks, set all toggle switches of the outer row on the tabulator, whether or not the switch applies to your work. For example, since intermediate control is not used in this tabulation, it is immaterial to the action of the machine whether the switch is on or off. However, turn it off.

Customarily, type bars are assigned from the left (i.e., beginning with number 1 alphameric) for ease in adjusting the tape. Identifying information is usually listed to the left of totals.

Label your tape carefully.

Assignment: Sections on cycling (on the tabulator), first differences,

and bivariate tables. 405 manual, pp. 56-57, 62-65

Diagram, for Lab. 6, the 416 panel for bivariate tables.

Lab. 6

Part I

A 41-card deck is available, bearing data in columns 10-12 to be tested for smoothness by computing first algebraic differences. 112 cards are negative. Wire a panel for the tabulator to take differences, making the necessary changes from the lithoprinted diagram as dictated by the size and position of the field being read. Perform the differencing, locate and correct the errors in the data, and hand in your tape.

Note: Differencing is an important process in machine computation. Although the complete wiring scheme is furnished in this exercise, be sure you are able to wire a differencing panel by yourself.

Part II

Reproduce both bivariate tables (which were produced on the sorter in Lab. 2) from columns 3 and 4 of the 76-card deck. Directions for producing the non-cumulative distribution are found in the text. The cumulative distribution uses the same panel, with only the progressive total clearing wire changed from minor to major. Using the same order for the variables as in Lab. 2, produce the main body of both tables, label and hand in the tape. Do not recalculate the values of Lab. 2.

Assignment: Chapter on "Digiting". Review the 405 manual and also pp. 60, 66, and 78.

Problem:

Diagram a tabulator panel for a 5-cycle scheme. Information in columns 1-4 is to add in counters as follows:

cards 1, 6, 11, 16,	in counter 6A
cards 2, 7, 12, 17,	in counter 6B
cards 3, 8, 13, 18,	in counter 6C
cards 4, 9, 14, 19,	in counter 6D
cards 5, 10, 15, 20,	in counter 8A

with all counters wired to print totals at the end of the deck only (i. e., on the automatic control break at the runout of the deck). Diagram

the tabulator panel for digiting in lab. 7.

Lab. 7

Two 2-digit variables are punched in a deck of 300 cards; variable X in columns 4-5 and Y columns 6-7. The deck is to be digitized on all 4 columns, to produce the simple sums of X and Y, the sums of squares of X and Y, and the sum of cross products XY. Since there are no missing cells in the array, and since the data has been selected so that all ten digits are present in all four columns, there is no need in this exercise for special wiring to take care of unpaired variables, nor for dummy digit decks.

The following panels will be needed:

1. A tabulator panel. add X in counter 8A; Y in counter 8B; card count in counter 6B; digitizing digit in counter 2A; progressive digitizing digit in counter 2B. Wire printing of all totals, including two digits of the progressive digitizing digit. (Note: In actual digitizing work, printing is usually not wired). The lower brush connection of the column being digitized goes to a type bar, a comparing relay, and counter 2B; use a bus.

2. Two summary punch panels for cutting summary cards. Cut sums on X in columns 1-9; sums on Y in columns 10-18; card count in columns 19-22; digitizing digit in column 80; progressive digitizing digit in column 79; summary board number in column 78. (Board 2, for tens digit sums, will use columns 1-8 and 10-17; board 1, for units digit sums, will use columns 2-9 and 11-18.) Emit into column 77 the number of the variable being digitized (e.g., 1 for X, 2 for Y).

3. A tabulator panel for final summarizing, using counters 6A and 6B (coupled) for adding the information from columns 1-9 of the summary cards; counters 6C and 6D (coupled) for adding information from columns 10-18. Wire a card count in counter 8A.

It will be necessary to work as a group on this exercise, with each of these four panels wired by a different person. The steps in the operating procedure are as follows:

1. Sort the deck on column 4; remove cards in reverse order (i.e., 9's first). The digitizing panel is set for minor control on column 4.

Summary board #2 is in the summary punch. Ten summary cards will be cut and the totals listed at the same time. In addition to testing the wiring with the usual test cards, use a special test deck of ten cards punched in columns 4-7 as follows:

9999, 8888, 7777, 1111, 0000.

2. Sort the deck on column 5; change control to column 5 on the tabulator; insert board #1 in the summary punch. Cut ten summary cards; compare the zero cards from both passes.

3. Repeat, making necessary changes, for the digiting on variable Y.

4. Remove the four zero summary cards; add the remaining 36 cards on the tabulator, controlling on column 77. The zero summary cards provide the simple sums and the card count. List them, using the same panel. This can be done either by sending them through the machine one at a time or by wiring the card count impulse to a comparing relay and unequal impulses to minor control.

Calculate, to 3D, the value of r , the product-moment correlation between X and Y; hand in your result next week.

Assignment:

602A manual, pp. 1-19, 26-27, 29, 41, 83-86.

Problems: The 602A diagram for lab. 8.

(The following problems on digiting are due the week of lab. 9.)

Each of the following items is an error in the digiting process. Explain where its effect would normally first be noticed and the proper procedure (other than re-running, unless that is the only remedy) to correct the trouble.

1. Cards are removed from the sorter in ascending order.
2. A card of the data deck is dropped on the floor and is not noticed.
3. A wire from lower brushes to counter entry on the digiting panel works loose.
4. The #2 summary board is used for a digiting run on the units digit of one variable.

5. A wire to punch magnets on a summary punch panel works loose.
6. The sums of cross products XY and YX do not agree in one case.
7. An extraneous X punch is present in column 5 of the deck, on a card for which variable X is punched 38.
8. After the sort on column 7 is made, the cards are put in the tabulator but the control wires are left on column 6.
9. The factor $[N\Sigma Y^2 - (\Sigma Y)^2]$ in the correlation formula comes out negative.
10. Counters are not wired to reset on a major control break (i.e., the wiring from previous use of the panel, to reset on minor control breaks, was not changed).
11. The digiting on one column produces eleven summary cards and the sequence of progressive digiting digits on these cards is:
9, 7, 4, 0, 3, 9, 4, 8, 1, 3, 4, 4.

Lab. 8

We will calculate with the 602A the same sums of products produced by digiting in lab. 7. A control panel similar to p. 74 will be wired, to punch the results on an X76, ND4 trailer card. X^2 and XY can be calculated on the same program step; Y^2 must be done on a separate program. (Note: These cannot be successive programs.) Counters 1, 2, and 3 can be coupled and accumulate the first two products; counters 5 and 6 can accumulate the third product.

Only two pilot selectors are needed. They are impulsed from the control brushes set on columns 4 and 76; read drop outs are wired.

Using the counter assignment suggested, 24 digits of results are punched in columns 57-80 of the trailer card (i.e., punch 16 digits from counters 1-2-3 and 8 digits from counters 5-6. The results should, of course, agree with the results from digiting in lab. 7.)

The 602A manual specifies that the skip out hub is wired from reading brushes. This means that the skip out hub can accept an impulse only at read time. It is quite common to send a read cycles impulse, through a selector picked up on an X at the control brushes, directly to skip out.

Assignment:

Review the 602A manual. Read the sections in chapters 4 and 6 on chi-square calculation and cycling (that part of the section on cycling relating to the 602A).

Following discussion in lecture, prepare for lab. 9 a tentative analysis chart for calculation of the chi-squared formula (page 35), as though the calculation would be done once per card. Also prepare a wiring diagram for a 5-cycle cycling scheme.

Lab. 9

As a group we will prepare an analysis chart for a 602A panel to calculate the chi-square formula for five pairs of numbers which are punched on each card, and punch the sum of the five chi-square values on the same card.

The observed values, f_o , are punched in columns 13-14, 18-19, 23-24, 28-29, 33-34. The theoretical frequencies, f_t , which correspond, are punched in columns 15-17, 20-22, 25-27, 30-32 and 35-37.

Test cards of the following types are available:

Test card number	f_{o1}	f_{t1}	f_{o2}	f_{t2}	f_{o3}	f_{t3}	f_{o4}	f_{t4}	f_{o5}	f_{t5}
1	16	299	16	299	16	299	16	299	16	299
2	16	299								
3			16	299						
4					16	299				
5							16	299		
6									16	299
7	29	166	29	166	29	166	29	166	29	166
8	29	166								
9			29	166						
10					29	166				
11							29	166		
12									29	166

Test card number 1 has all 5 pairs of values the same. The result should be five times as great as

$$\frac{(16 - 29.9)^2}{29.9} = 6.461$$

Cards 2 through 6 have a pair of values in a single position on each card to isolate trouble to a particular cycle of the cycling scheme. Card number 7 is like card number 1 except that the relative size of the pair of numbers is reversed, to check the differencing wiring. Cards 8 to 12 isolate the trouble to a particular cycle, similar to cards 2 to 6.

Punch the accumulated chi-square value in columns 57-61, with three decimal places. Only one panel will be wired for each lab. group.

Assignment:

"Sign Control" in the 602A manual. Prepare a 602A diagram for lab. 10. Note that the sign control procedure must be modified since the two factors are read from different cards.

Lab. 10

Columns 64-65 of a deck are punched with values + A on odd-numbered cards; + B on even-numbered cards. The signs are indicated by an X overpunch in column 65. Even numbered cards are punched X72. + Q, the quotient of + A/+ B, is to be punched in columns 66-70 of the X72 cards, in "true" form, with an X punched over column 66 for negative Q.

The NX72 card is skipped out without punching. The principle modification in the sign control procedure is that the drop out of the two selectors picked up by the X in column 65 must be wired so that both of them will be up together until just before punching begins. The X pickups of these selectors must also be selected, since both are wired to the same column of the cards.

As in lab. 9, one panel will be wired for the lab. group. Wire the panel as far as possible and label it to hold until next week.

Assignment: 604 manual, p. 1-28, 66-70.

Note: Labs 11 and 12 deal with specific problems on the 604 electronic calculator. It is expected that before the semester is over you will become familiar with the operation of the combination card-programmed calculator, particularly the all-purpose floating decimal setup.

During the last 2 weeks of lab, each student or team of students should be working on an individual problem, preferably of his own choosing and related to his own subject field. If you prefer, a problem will be assigned to you. The primary purpose of the problem is to have you learn as much as possible about the use of the machines. The problem should be large enough to cover several weeks of lab. work and should be a new problem if possible.

Lab. 11

Use of the 604 Electronic Calculator

Calculation of e .

$$e = \sum_{n=0}^{\infty} \frac{1}{n!} = 1 + 1 + \frac{1}{2} + \frac{1}{2 \cdot 3} + \frac{1}{2 \cdot 3 \cdot 4} + \dots$$

For computational purposes, the work can be arranged as shown below, in which each line is obtained from the previous line by division by the line number. The remainders after each 5 digits of quotient are noted.

line #	Q_1	R_1	Q_2	R_2
001 1	00000	000	00000	000
002	50000	000	00000	000
003	16666	002	66666	002
004	04166	002	66666	002
005	00833	001	33333	001
006	00138	005	88888	005
007	00019	005	84126	006
008	00002	003	48015	006
009	00000	002	27557	007
010	00000	000	02755	007
011	00000	000	00250	005
012	00000	000	00020	010
etc.				

Each pass through the machine is terminated when both Q and R reach zero, as on card 010 of the first pass. Note that after the first pass there is no need to use cards 001 and 002, since the divisions by those serial numbers terminate immediately. All other divisions produce repeating decimals.

The process can be started by punching a deck with serial numbers in columns 1-3, starting with 003. Columns 4-6 are punched with the R_1 values, extending to at least card 014.

Read columns 1-3 into FS-1 on card cycles. Read columns 4-6 into FS-3. The division is set up by reading out FS-3 to positions 6-7-8 of the counter (counting positions from the right). The previous quotient, which will be in GS-4, is added into the counter, in the right hand 5 positions. After the division by the number in FS-1, the 5-digit quotient in the MQ unit is read out to GS-4 for punching. The new remainder is punched directly from the counter into columns 12-14. The counter should be reset on program 1.

The simplest method of clearing the machine at the start of a run is to pass several cards punched 999 in columns 1-2-3 through first.

When the pass through the calculator is completed, the wiring of the 521 is changed to read R_2 and punch Q_3 and R_3 . Be sure there are enough cards in the deck to continue the calculation to its terminating point. There is space on the card to continue through Q_{10} and R_{10} , thus carrying the calculation through the 55th decimal place. The final summation is made on the tabulator. If you wish, a second deck may be machined, reproducing R_{10} into columns 4-6 of the second deck; another 50 digits may then be calculated on the second deck.

Lab. 12

NUMERIC INTEGRATION

References: Scarborough, Numerical Mathematical Analysis, pp. 119 et seq.; Milne, Numerical Calculus, pp. 120 et seq.

Simpson's One-Third rule for numeric integration (obtained by integrating Newton's formula for forward interpolation term by term over n equidistant points, n even) is:

$$\int_{x_0}^{x_0+nh} y \, dx = \frac{h}{3} [y_0 + 4(y_1 + y_3 + \cdots + y_{n-1}) + 2(y_2 + y_4 + \cdots + y_{n-2}) + y_n]$$

h is the width of the interval ($= \Delta x$).

Simpson's rule is to be applied to a definite integral whose value is known; namely,

$$\int_0^1 \frac{dx}{1+x^2} = \frac{\pi}{4}$$

taking $h = .01$ for $n = 100$.

The quantity in brackets in the formula represents a sum of products in which the multiplicands are the ordinates of the curve being integrated and the multipliers are 1, 2, or 4 depending on the position of the ordinate in the interval. [The product of the summation and $h/3$ = .133333333 should produce π .]

The ordinates have been calculated and are available on a deck of 101 cards, numbered from 000 to 100 in columns 1-2-3. The ordinate values are punched in columns 4-13. The selection of the proper multiplier is to be done as the cards pass through the calculator (either 602A or 604), based on whether the card number is odd or even (except for the first and last cards).

Note: In practice the ordinates are frequently computed during the integration.

Lab. 13

A deck of cards will be furnished, punched for CPC all purpose operation, which will load storage units 11, 12, 13, 14, 15 with the coefficients a, b, c, d, e of the quartic equation

$$ax^4 + bx^3 + cx^2 + dx + e = 0 .$$

We want to follow these cards with a deck which will solve for all four roots of the quartic. The scheme is as follows: use Newton's method

to locate one root; then reduce to a cubic by dividing out that root; solve for a root of the cubic; reduce by division to a quadratic; then solve the quadratic either by formula or by extending the method one step further.

Newton's method corrects an approximation to a root by working along the tangent. The formula is:

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$$

As with all iterative systems, the better the first guess, the quicker the process converges. Since the location of the roots is unknown here, zero is probably the best first approximation. The first iteration will thus be:

$$x_2 = 0 - \frac{e}{d}$$

and the second iteration will be

$$x_3 = x_2 - \frac{f(x_2)}{f'(x_2)} \quad \text{and so on}$$

In order to handle the various types of quartics which may be met, there should be at least seven iterations for the first root and at least five for the second root. Print the result of each iteration.

If the quadratic is to be solved by formula, evaluate and print the discriminant and send it to storage unit 27. The square root subroutine, which is on file, will extract the root of the number in storage unit 27; the root may be printed or stored as you choose.

Use of the Card Counting Sorter

In addition to its nominal use (sorting), the card counting sorter can be used for a wide variety of basic calculations.

Responses to questions can be tallied, item by item, by counting without sorting.

A simple bivariate table may be produced by sorting on one variable and, keeping each group resulting from that sort separate, counting the other variable.

Simple sums, sums of squares, and sums of cross products can also be calculated, for use in such formulas as:

$$\sigma = \frac{1}{N} \sqrt{N \sum X^2 - (\sum X)^2}$$
$$r^2 = \frac{[N \sum XY - \sum X \sum Y]^2}{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}$$

Sum of X - one digit number

Method 1. Count; multiply the counter readings by the digit value and sum the products.

Method 2. Sort; then turn sort switch off. Count, but do not clear counters until the end of the operation:

9's

9's and 8's

9's, 8's, and 7's

.

.

.

9's, 8's, 7's 1's. Omit zeros.

The total in the counter will be the sum, since the 9's have been added in nine times, the 8's eight times, etc. . . . the 1's one time.

Method 3. Sort. Then count the 9's, do not clear the counters but record the total. Count 8's, record total (of 9's and 8's). Continue to the 1's. Add the nine totals together; this will be the sum of X.

Sum of X: two digit number

$$X = 10 A + B$$

$$\Sigma X = 10\Sigma A + \Sigma B$$

Use one of the above methods to obtain ΣA , ΣB . The method extends to variables of any size.

Sum of X²: one digit number

Method 1. Count; multiply the counter readings by the square of the digit value and sum the products.

Method 2. Sort; then turn sort switch off.

Count the 9 cards, record c.c., do not clear.	= cf ₉
Count the 8 cards, record c.c., do not clear.	= cf ₈
.	= .
.	= .
.	= .
.	= .
.	= .
Count the 1 cards, record c.c.	= cf ₁

Form the sum of products cf₁ x 1

cf₂ x 3

cf₃ x 5

cf₄ x 7

.

.

.

cf₉ x 17

= ΣX^2

Sum of X²: two digit number

$$X = 10 A + B$$

$$\Sigma X^2 = 100\Sigma A^2 + 20\Sigma AB + \Sigma B^2$$

ΣX^2 for a two digit number, or the data for the correlation formula for two single digit variables can be produced through a cumulative frequency table. In the example shown on a separate sheet, the simple frequency distribution is shown first.

Take the deck of 76 cards and produce first the simple frequency distribution. Columns 1-2-3 are serial numbers; A is in column 3; B is in column 4. Sort on A. Keeping the 10 groups separate, count on B and record the counter readings for each group, clearing counters between groups.

Then, keeping the 10 groups on A separate, and starting with the 9's, make the cumulative frequency distribution as follows:

Using the 9's from A, count B, and record the counter readings including the total, which is the column labelled cf_A . Do not clear the counters. Using the 8's from A, count B, and record the counter readings which are now cumulative frequencies. Continue through the zeros on A.

Following the pattern of the 41 card deck given here, calculate ΣA , ΣB , ΣA^2 , ΣB^2 , ΣAB and considering columns 3-4 of the deck as a single two-digit variable, M, calculate also ΣM and ΣM^2 . Hand in the results of this work at the next lab. session.

The zero row of the cumulative frequency table is f_B . Grand total in that row is $N = 41$.

$$\sum_{i=1}^9 cf_A = \Sigma A$$

$$\sum_{i=1}^9 cf_B = \Sigma B$$

$$\sum_{i=1}^9 (2i - 1) cf_B = \Sigma B^2$$

f_B row accumulated to the right is cf_B . Directly under it are the odd numbers in reverse order, from 17 to 1. The last row of figures is the sum of cf_A , accumulated by columns. The last entry in the zero column is ΣA . The sum of the last row from 1 to 9 is ΣAB . All answers are given in the example.

Sample Table

A/B	9	8	7	6	5	4	3	2	1	0	N
9			1		2		1		1	1	6
8	2			3		1		1		1	8
7		1	2				2		1		6
6				2	1						3
5	1					1		1			3 c.c. = 41
4		2					1			2	5
3			1			1			2		4
2	1				1						2
1								3			3
0		1									1
	4	4	4	5	4	3	4	5	4	4	41 = N

A/B	Cf _A											
9	0	0	1	0	2	0	1	0	1	1	6	17
8	2	0	1	3	2	1	1	1	1	2	14	15
7	2	1	3	3	2	1	3	1	2	2	20	13
6	2	1	3	5	3	1	3	1	2	2	23	11
5	3	1	3	5	3	2	3	2	2	2	26	9
4	3	3	3	5	3	2	4	2	2	4	31	7
3	3	3	4	5	3	3	4	2	4	4	35	5
2	4	3	4	5	4	3	4	2	4	4	37	3
1	4	3	4	5	4	3	4	5	4	4	40	1
0	4	4	4	5	4	3	4	5	4	4	41	
	4	8	12	17	21	24	28	33	37	41	← Cf _B	
	17	15	13	11	9	7	5	3	1	← odd numbers		
	23	38	64	100	126	142	169	185	207	232		

$N = 41$ $\Sigma A = 232$ $\Sigma B = 184$ $\Sigma A^2 = 1602$ $\Sigma B^2 = 1164$ $\Sigma AB = 1054$

$\Sigma M = 10\Sigma A + \Sigma B = 2504$ $\Sigma M^2 = 100\Sigma A^2 + 20\Sigma AB + \Sigma B^2 = 182,444$

Square Root

Square root of numbers may be calculated by one of a number of different methods. Aside from calculations by logarithms, most of these involve the binomial theorem in one form or other. However, considering square root as the solution of the equation:

$$x^2 = A$$

suggests well known methods for locating the roots of polynomials, such as Horner's method, the Newton-Raphson method, or the method of false position.

Most automatic computing machinery uses Newton's method. The process is easily programmed and, being an iterative process, can proceed from an arbitrary starting value (or, if the numbers A are in sequence, the root found for any one of them is an excellent first approximation for the next in sequence).

Newton's method uses the following formula to locate any root:

$$A_{n+1} = \frac{1}{i} \left[\frac{N}{A_n^{i-1}} + A_n(i-1) \right]$$

where N is the number whose root is sought; A_{n+1} and A_n are two successive approximations, and i is the index of the root.

As adapted to square root, however, it is easier to understand in the form in which it was used long before Newton.

If $p^2 = A$ and $p < q$, then p is less than the square root of A and q is greater. $\frac{p+q}{2}$ is generally a closer approximation to A than either p or q.

Thus, to seek $\sqrt{5}$, any number, such as 3, can be used to start the process. We form $\frac{5}{3} = 1.67$. The root is now located between 3 and 1.67 and the next trial divisor will be $\frac{3 + 1.67}{2} = 2.33$. Then $\frac{5}{2.33} = 2.146$ and the next trial divisor is $\frac{2.33 + 2.146}{2} = 2.238$. One more division gives

$$\frac{5}{2.238} = 2.234146.$$

The following points are worth noting:

1. Any number can be used to start. Generally, the closer it lies to \sqrt{A} , the fewer steps will be required.
2. Any error in arithmetic is self correcting in subsequent steps.
3. The method roughly doubles the number of correct significant

digits at each step. In the example given, it is clear that the root must be correct at least as far as 2.23, since those digits have re-
curred in two successive steps. The next interpolation, then,

$$\frac{2.238 + 2.234116}{2} = 2.236073$$

is nearly correct to six significant digits. Using a desk calculator which gives 10-digit quotients, and a one-page table of square roots to 4 significant digits, any root can be calculated to 10 significant digits with no more than three divisions and interpolations. If the starting values are merely guessed, four or five iterations may be necessary, but this is still extremely rapid.

Exercise. Compute, correct to 10 significant digits, the square roots of:

2.00000000

3.00000000

5.00000000

10.00000000

3.141592653

2.718281828

familiarizing yourself with the features of the desk calculators available.

IBM Terminology

LEFT CUT, RIGHT CUT: Cards are usually furnished with a corner cut off along the 12 edge. In our work, we reserve right cut cards for masters, trailers, clear cards, leading cards, or for any other purpose in which a few cards should stand out from the bulk of the deck, which is on left out cards.

HUB: The holes in the control panels into which wires are plugged.

BUS HUBS: Groups of hubs which are internally common, so that any impulse entering any one of them is available at all the rest. Bus hubs are not connected to anything inside the machine.

SELECTOR: A switching device consisting of one or more sets of three points (common, normal, and transferred) controlled together by pickup hubs. On the 416 tabulator, the D pickup accepts any impulse from 9 to Y, and the selector transfers during the entire next card cycle. The X pickup accepts only X's and Y's, but acts the same way.

TRANSFERRED SELECTOR: A selector in the transferred state (the circuit from C to NX being broken, and the C to X being made) is said sometimes to be "up" or at "X". On some machines, selectors have the points labelled C, N, and T.

CARD CYCLE: The period of time on any machine between the passage of a given part of one card and the corresponding part of the following or preceding card. Usually applied to the tabulator, reproducer, collator, and interpreter when cards are feeding at the maximum rate.

JACKPLUG, BOTTLEPLUG: Common names for a short wire whose ends are mounted together to facilitate plugging adjacent hubs together.

GROUP WIRES: Four wires fastened together to facilitate rapid wiring of 4-digit fields on tabulator, reproducer, and collator panels.

BACK CIRCUIT: Refers to errors in wiring through the use of split wiring or bus hubs. The idea is that a bus is a two-way device, and impulses can travel both ways. For example, on the 602A, if R1 to storage

- 1 and 2 is jackplugged, then a R1 to either storage unit on another program will sweep out the other.
- PLUG TO C:** A steady impulse, on tabulators, available during digit time on all card cycles, used normally to roll counters for addition or subtraction.
- CARD COUNT:** The C.C. hub on a tabulator emits an impulse at "one" time. Usually sent to a counter to tally one during card cycle. C.C. emits only while cards are passing the lower brushes.
- LIST CYCLE:** On the tabulator, a card cycle in which the type bars are impulsed to print as the card moves.
- TOTAL CYCLE:** On the tabulators, the time involved (usually during a control break) when cards are not moving and counters are impulsed to read out.
- DIGIT TIME:** The portion of a card cycle when digits 9 through zero are passing the brushes. On the 602A, the portion of a machine cycle during which digits can be handled by counters.
- BACK COUPLING:** Wiring counters from CI to C.
- CI TO C:** The method of back wiring counters, used with 9's complements. On the tabulator, the SUP hub is then impulsed with a 9. On the 602A, CI to C of a counter or group of counters is always wired, since only 9's complements are used.
- 405-416:** The 405 is the old standard alphabetic tabulator. The 416 is the numeric version, lacking the alphabetic characters on the left hand type bars and corresponding zone magnets.
- 402-417:** The 402 is a modernized version of the 405. Most of the external switches of the 405 are incorporated in the control panel; several new switches are added; the carriage can be tape controlled. The 417 is the numeric version.
- 407:** The latest tabulator, featuring among other things 120 type wheels, each having 47 characters.
- ALPHAMERIC TYPE BARS:** Those which contain alphabetic as well as numeric characters. On the 416 the term is retained for the left hand 44 type bars even though they are the same as the right hand 45 (numeric) type bars.
- EXTRA CHARACTER:** Each numeric type bar contains the 10 digits and one extra character, usually an asterisk or credit symbol on numeric

machines.

ZERO SUPPRESSION: The 416 and 417 tabulators tend to print zeros to the right of any type bar which prints a non zero digit (including the extra character). Normally the zero suppression lever (referred to in the manual as a hammersplit lever) of the right hand type bar of a field is raised to suppress printing of non significant zeros to the right of that type bar.

UNEQUAL IMPULSES: Intermittent impulses emitted by the comparing relays on the same card cycle in which an unequal situation is sensed. Normally used to cause the machine to stop and take a total cycle.

UCI: On the 416 tabulator, intermittent (digit) impulses. Normally used as the input to a digit selector to change it into an emitter.

FIRST CARD CONTROL: On the 416 tabulator, if minor first card control, a plug to C impulse which occurs on the card cycle following a minor control break. Major and intermediate first card control impulses are quite different; see the timing chart.

AUTO CONTROL: The use, on a tabulator, of two reading stations and comparing relays, to sense a change in a card field, and cause a total cycle to be taken.

BALANCE CONTROL: On the tabulator (net balance machine), the device which enables the machine to convert a negative (complement) figure in a counter to the corresponding positive ("true") figure before read out.

PROGRESSIVE TALLING: Reading out a counter without resetting.

DIGITING: The process of obtaining sums of products without obtaining any individual product. Sometimes referred to as progressive digiting.

CYCLING: A method of controlling a machine in repetitive cycles, usually through selectors. For example, the tabulator can be cycled in groups of cards (in a 3 cycle scheme, cards 1, 4, 7 ... act the same; cards 2, 5, 8 ...; and cards 3, 6, 9 ...). On the 602A the cycles refer to sweeps of the program levels.

MACHINE CYCLE: On the 602A, the basic cycling speed of the machine, which is 200 cycles per minute.

PROGRAM SWEEP: On the 602A, one passage across those program levels which are wired. For example, if programs one through six are wired, a four cycle scheme causes the machine to go through programs

one to six four times (for a total of 24 programs); that is, four sweeps.

- CROSSFOOTING:** Horizontal addition. If numbers A, B, C, and D are punched in a card, obtaining their sum is a crossfooting operation.
- SUMMARY PUNCHING:** The process whereby sums contained in the counters of the tabulator are punched in a card on another machine.
- CONTROL PANEL:** The wired boards inserted into every machine except key-punches and sorters, to dictate the machine's operations.
- PLUGBOARD:** Same as control panel.
- HOPPER:** The "in" receptacle for cards on any machine.
- STACKER:** The "out" receptacle for cards on any machine.
- COUNTER:** An accumulating device. Counters on tabulators are rotating wheels; on the collator they are stepping relays; on the 604 the counter consists of a collection of vacuum tubes.
- BALANCE TESTING:** The process of examining the number contained in a counter to determine whether or not it is less than zero (as indicated by a complement nine in the high order position).
- BALANCE CONVERSION:** The process of changing a negative (complement) number to its absolute value.
- COLUMN SPLIT:** A device (consisting of an internally operated relay) to separate the impulses occurring during one card cycle, usually between zero and X time.
- OVERPUNCH:** Usually an X or Y punch in the same column of the card with a digit (zero to nine).
- DOUBLE PUNCH:** Two holes in the same card column.
- MULTIPLE PUNCH:** Two or more holes in the same card column.
- LACED CARD:** A card in which one or more columns have all twelve holes punched out.
- LACING:** Wiring counters or selectors in sequence. Selectors are usually laced by wiring from the normal point of one to the common point of the next, as in a cycling scheme.
- SIGN CONTROL:** The process whereby a machine is wired to furnish the proper sign in an operation dealing with signed factors or terms.
- VERIFICATION:** Usually refers to a process of checking keypunching. The most positive method consists of repunching and comparing the two decks by machine.

GANG PUNCHING: The process of punching common information in a group of cards.

MASTER CARDS: The cards in a deck which bear information to be used with the cards which follow.

DETAIL CARDS: The cards in a deck which are not master cards, trailer cards, or precede cards.

TRAILER CARDS: Cards following a deck or subdeck, usually to receive results of operations on the cards preceding it.

PRECEDE CARDS: Cards at the beginning of a deck, usually used for special control or setup operations.

80/80: The common name for straight reproducing, in which all 80 columns of one deck are punched into all 80 columns of a new deck. The 513 panel for this operation (usually permanently wired) is called the 80/80 board.

TEMPORARY, PERMANENT BOARDS: Temporary (or manual) plugboards can be readily torn down and rewired. Permanent boards are constructed so that their wires cannot be removed without pliers or a special tool.

BLANK COLUMN: Any column of a card which has no hole punched.

9's COMPLEMENT:

10's COMPLEMENT: Methods of expressing a negative number in a counter. For example, using a 6-wheel counter, the 9's complement of 123 is 999876; the 10's complement of the same number is 999877.

TEST DECK: A deck of cards punched to simulate as far as possible all conditions to be met in a problem, run through the machines before the problem itself to test the wiring. It cannot be emphasized too strongly that a test deck is vital for any machine operation on machines other than keypunches and sorters.

SPLIT WIRING: Three or more hubs wired together, either through split wires, through plastic connectors, or through a bus.

INTERLOCKS: Safety switches to prevent you from doing something you shouldn't do. Nearly all machines have interlocks to stop all operation when a cover is removed. Summary punching is interlocked to prevent the tabulator from feeding when the summary punch has not fed cards. The CPC has a pluggable interlock to prevent operation until the 941 units are turned on.

RUNIN, RUNOUT: The operations of getting the first cards into a machine

and the last cards out of the machine. On some machines special wiring is necessary to insure correct operation on the runin and runout.

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