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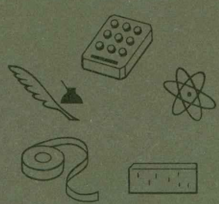
Introduction to data processing;

Haskins & Sells;

INTRODUCTION TO DATA PROCESSING



HASKINS & SELLS

INTRODUCTION TO DATA PROCESSING

An Outline of

Basic Data-Processing

Operations and Methods

HASKINS & SELLS

Table of Contents

Page

FOREWORD 5

A GENERAL SURVEY 7

BASIC DATA-PROCESSING OPERATIONS 16

RUDIMENTS OF PROCESSING METHODS 23

PUNCHED-CARD METHODS 60

ELECTRONIC DATA PROCESSING 84

INTEGRATED DATA PROCESSING 96

ORGANIZATION AND CONTROL OF
DATA-PROCESSING ACTIVITIES 102

FOREWORD

The need to process data is rooted in two basic circumstances: the limitations in the capacity of the human mind to assimilate and remember, and the requirement, in a modern society, for written evidence of actions and agreements.

Data originates in the human mind. Data is information – a piece of intelligence. The purpose of processing data is to guide or facilitate action by some individual or group, now or in the future.

When the activities of man, as an individual or group, passed the point where reliance upon memory became an insecure basis for action, the need for data processing was born. The data then had to be recorded. Soon, data had to be manipulated, and presently, complexities in application became superimposed upon the basic needs. Thus, in its primary forms, data processing is truly an activity of ancient origin.

Data processing requires human effort and human effort must be compensated. The core of the data-processing problem long has been the insistent pressure to minimize the cost. Ascending trends in the level of cost of human effort, coupled with growth in the complexity and volume of data-processing activities, have stimulated the replacement of human effort by mechanical, and, more recently, by electronic processes. The response has been, therefore, to transfer work once done by human beings to machines: the same response, in principle, as that which lies at the foundation of modern industrial progress.

In this continuing transition in data processing, the role of human effort has been raised to a higher plane. More and more, the role of the people in the activity has passed from the performance of directed routines to the execution of functions calling for the making of decisions and the exercise of judgment.

The evolution of data processing has produced an ever-growing multiplicity of processing methods and devices – manual, mechanical, and electronic. All these have played a vital role in the improvement of data-processing efficiencies.

Amid the dramatic strides in methodization, however, there is a basic fact which tends to become obscured. This is, that the essential nature of data-processing operations has remained simple and unaltered. The purpose that pervades nearly all areas of data-processing operations is change: change in the form of data, in their content, or in both. The operations that are necessary to effect change are essentially the same, however performed.

The operating features of data-processing methods and devices, many of them bordering on the spectacular, have been well explored in the available literature. On the other hand, the nature of data-processing operations – a relatively prosaic subject but nevertheless always intertwined in the consideration of data-processing objectives – has received somewhat secondary consideration. Nowhere, apparently, has a concerted attempt been made to bring the two together.

The approach to data processing, in this study, is directed at finding a balanced perspective, by seeking to correlate the principal methods and devices with the basic operations they serve to perform. Basic operations are described in elementary terms in the first three chapters of the study, as a foundation for discussing their performance by mechanical and electrical methods in succeeding chapters. Parallel in importance to the matter of operations and methods in modern data processing are the concepts of integrated data processing and the subject of organization and control of data-processing activities. Principles and problems in these two areas are reviewed in the concluding chapters.

In this way, the field of data processing is broadly covered in its entirety, focusing attention upon fundamental principles and practices and eliminating details wherever practicable. The objective of the study is to convey to the reader a grasp of the basic concepts in the processing of data.

Such an understanding has a practical usefulness. There is need for a better understanding and appreciation of fundamentals in the solution of data-processing problems.

Appreciative acknowledgment is made to those manufacturers of equipment who have permitted the use of material in various illustrations.

HASKINS & SELLS

February 1957

A GENERAL SURVEY

	Page
Needs for Data	8
Sources of Data	8
Processing Methods	9
Nature of Processing Operations	9
The Means of Accomplishment	10
Early Developments – Accounting Machines – Punched-Card System – Electronic System	
The Data-Processing Problem	14

A GENERAL SURVEY

Knowledge, so runs a familiar truism, is of limited usefulness unless communicated. Broadly, the function of data processing is the communication of intelligence.

Framed in this purpose, the task of data processing becomes one of determining the needs for data, the sources of data, and the methods of processing.

Needs for Data

Needs for data may originate from external sources or from within the enterprise. External needs include the requirements of customers, suppliers, creditors, owners, government, and the general public. Needs in relation to these same groups usually have their counterparts as internal needs of the enterprise. Without reference to the requirements of outside groups, however, internal needs fall broadly into two classes: the needs for data purely as a record of past actions and needs having to do with actions of the future.

Illustrations of all such needs are legion, extending into all functions of the enterprise. Closely related to the needs themselves is the matter of timeliness. Time is vital. Money may be gained, or lost, depending in part upon availability of data at the time needed.

Sources of Data

The sources of data likewise may be external or internal. A point of considerable importance, at times, in connection with processing is that the recipient usually has limited control, or no control, over the form and content of data received from others. On the other hand, the enterprise itself usually has a large measure of control over form and content of data originating internally.

Within various enterprises there are inconspicuous, as well as prominent, areas in which data are originated or processed. Data are usually reduced to written form. Data in written form comprehend all information from the simplest to the most complex — for example, from the notations in someone's "little black book" to the detailed sales forecasts, production schedules, and financial statements.

By no means all of such data originate, or are processed, in accounting and statistical departments, the areas most prominently associated with data processing. Many persons in other departments of the enterprise — secretaries, clerks, supervisors, even executive personnel — may devote all or part of their time to these same operations. In many cases, the sum total of effort devoted to originating or processing data, in all phases of the business, is materially greater than is generally realized.

The element of time also enters into the consideration of sources of data. Some data are received, or originate within the enterprise, at regular intervals whereas other data arrive sporadically. The volume of data, and time of receipt, are important factors in connection with the organization of the processing operations.

Processing Methods

Processing consists of performing upon the data such operations as are necessary to meet the requirements, as to form and content, of the user of the data. To do this involves consideration of the nature of processing operations and the means by which the operations are accomplished.

Nature of Processing Operations

If data, in the form originated, served the purpose of the user, processing of course would not be necessary. The purpose, therefore, that dominates a great part of processing operations is change in the form of data, in their content, or in both form and content. Processing also includes bringing the data into tangible form by writing them down, as well as duplicating them.

The accomplishment of these purposes requires the application of one or more of the following basic procedures:

Writing or rewriting the data.

Rearranging the data.

Reconstructing the data, by performing computations upon them.

Writing or rewriting is always necessary, singly or in combination with other basic procedures in processing.

These basic procedures comprise what is required to be done, essentially, with the data to produce the results required. To actually do what is required to be done, and thus to implement the basic procedures, six basic operational steps have been evolved. These are – classifying, sorting, calculating, summarizing, recording, and communicating. From the viewpoint of operational procedure, all processing of data involves one or more of these six basic steps.

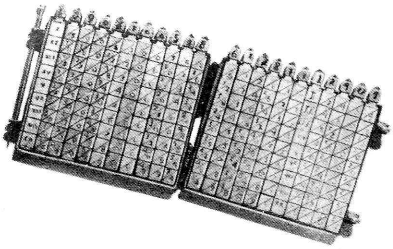
The Means of Accomplishment

Processing may be accomplished manually, mechanically, or as a result of more recent developments, electronically. Manual processing, of course, is always at least partly mental as well. Similarly, mechanical and electronic processing involves some mental and manual activity.

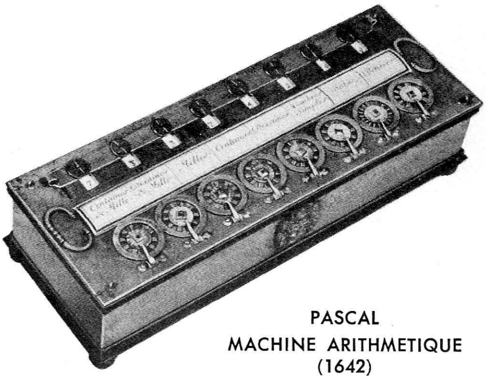
Early Developments

The trend, from the earliest beginnings of processing, has been continually toward the replacement or amelioration of mental and manual effort. The devices first developed had the common purpose of assisting in the function of calculating. The earliest of these is the abacus, invented over 2,000 years ago and still more widely used, in the world as a whole, than any other calculating device. Among the other early calculating devices were Napier's "bones" (1617), Pascal's calculator (1642), Grillet's calculator (1678), Thomas arithmometer (1820), Parmalee calculator (1850), Webb adder (1868), Fuller spiral scale slide rule (1879), and the Felt early comptometers and Edmondson calculator (1885). These devices were used mainly in scientific and other computations and only secondarily as an aid in the calculating operations of data processing.

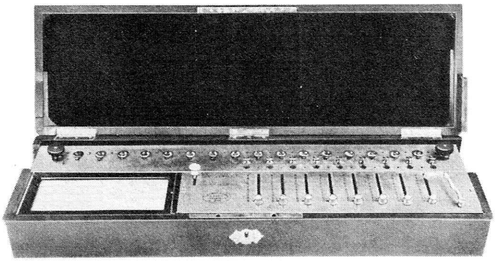
The letter press and the typewriter were the first devices brought forward to aid in the basic procedure of writing which, in terms of the six basic operational steps, becomes the function of recording. Somewhat later, the advent of multi-purpose mech-



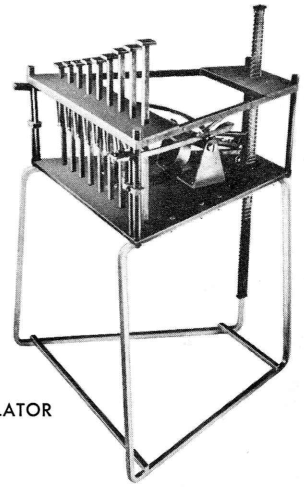
NAPIER'S "BONES"
(1617)



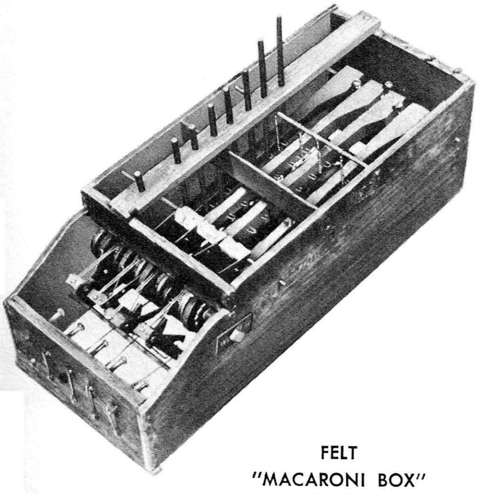
PASCAL
MACHINE ARITHMETIQUE
(1642)



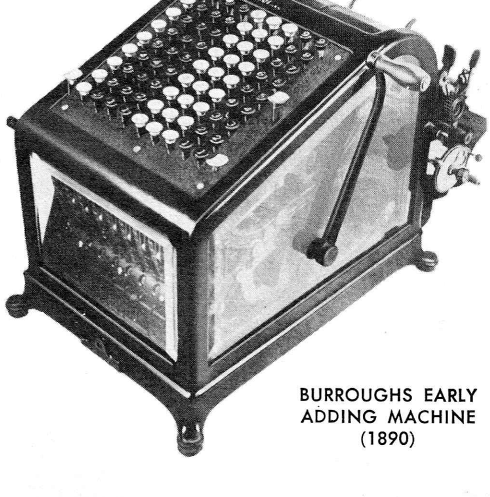
THOMAS
ARITHMOMETER
(1820)



PARMALEE CALCULATOR
(1850)



FELT
"MACARONI BOX"
(1885)



BURROUGHS EARLY
ADDING MACHINE
(1890)

anisms marked the beginning of a new era in data processing. Among the first of these were the Burroughs adding devices, invented in the 1880's. In earlier calculators, the result was read from a dial or similar indicator, then written manually. By incorporating the now familiar feature of the adding machine tape, the Burroughs device became a mechanism capable of recording and summarizing as well as calculating. A similar effect was obtained when tape mechanisms were incorporated in cash registers, again imparting the ability to record and summarize, as well as calculate.

Accounting Machines

Shortly after the close of World War I, there came into use a group of devices, commonly referred to as accounting machines, which broadened still further the application of mechanization by combining, in one machine, four of the basic operational steps: recording, summarizing, and calculating, as well as a limited ability to assist in sorting.

The appearance of the calculators, accounting machines, and the like, removed much of the work of data processing from the manual area. However, all of these machines, being key-driven devices, required some form of action by an operator — such as depressing a key, bar, or lever — to perform each processing operation. All such machines operated only with manual aid, not automatically.

Punched-Card System

Beginning as far back as the early 1900's, and with increasing impetus starting in the 1920's, there came gradually to be extended into the field of data processing a new concept, the punched-card system. In this system, data are "written out," in the form of holes in cards, arranged in a planned pattern to represent the equivalents of data. Working upon the card as the common medium, the machines of the system perform four basic operational data-processing steps automatically: recording, sorting, calculating, and summarizing. All that remains for human beings to do in the operation of the system is to classify the data before their entry into the system, to transport the cards from one machine in the system to another, and to set up the machines to perform the processing routines. All else – the vast complex of detailed operations – is automatic. This, surely, has been a tremendous contribution to the reduction of human effort as well as a great advance in the efficiency of data processing. The time requirements for processing have been shortened and greater assurance of accuracy has been provided in the punched-card system.

Electronic System

From the viewpoint of automatic operation, however, the punched-card system still falls short of the ideal in two respects: first, being mechanical, the speed of processing in the system is tied to the movement of mechanical parts and devices, and second, each of the machines in the system has specialized abilities and hence the chain of processing is not continuous. The card media must be transferred between machines for the performance of the various operations.

These limitations are overcome in the electronic system of data processing. In the equipment of the electronic system, data are represented, in a scheme of equivalents, mainly as patterns of electrical pulses or magnetic spots. The equipment may be completely interconnected, thus affording a continuous flow of processing. Processing itself takes place by the movement of the pulses through the circuitry. The speed of processing is many times faster than that attainable in mechanical systems.

There is left, therefore, only the planning of the operating routine as the principal function for human beings in the operation of the electronic system. This is a complex task requiring specialized skill. The machines in the electronic system must be directed, in minute detail, in their operations. The directions, like the data, are translated into patterns of electrical pulses, and these, moving through the system, cause the equipment and circuitry to be activated in the manner required.

Without question, enormous savings in human effort have been achieved by the transfer of work in data processing to machines. Yet the fact remains that, even today, there are still large numbers of people engaged in the data-processing activity: putting marks on paper or causing equipment to put them there, or supervising the process. Why is this so? There appear to be two reasons. One is the ever-increasing demands of the users of data — business, government, and others — for more information. The other reason, one which also suggests the greatest promise of solution of the problem, is that substantial areas still remain in which the potentialities for mechanization have not yet been fully explored.

The Data-Processing Problem

The data-processing problem is two-fold. It involves determining the needs for data, and fulfilling them. To determine the needs, it is necessary to ascertain what data are required, by whom they are needed, and when, where, and in what form they must be furnished.

The most difficult of these determinations usually is the first — the problem of reaching agreement on the data required, particularly as to internal needs. The needs should be real, not fancied, and supported by obvious or reasoned justification. On the other hand, opportunities to furnish data for constructive purposes should not be overlooked. The situation as to needs is seldom static. Changing conditions create new needs or abolish old ones, requiring reappraisal of the data-processing program, in relation to needs, from time to time.

Fulfilling the needs involves the determination of where, when, by whom, and in what manner the data are to be processed. In resolving these matters, it is necessary to consider the organization for data processing and the choice of data-processing methods.

Organization and methods are subjects of broad importance in data processing. In general, however, the managements of business enterprises, including financial and accounting executives, have not applied to these subjects the degree of study warranted. The choice of methods, particularly, has been left largely to the specialists in techniques. Management personnel naturally tend to emphasize data analysis — the interpretation of the results of processing — in the exercise of their functions and to give secondary consideration to the problems of data processing itself. The recent stir of interest in electronic data processing has tended to place these two aspects of the use of data — data analysis and data processing — in better perspective.

Data-processing methods, even the electronic method with its exciting possibilities, will not change the basic purpose in doing business. Neither will they supplant the need for judgment in the difficult decisions that must be made. But data processing, used wisely, can narrow the area of uncertainty by providing better guides to action. To use it wisely, there must be a broad understanding of the capabilities found in the available methods. Only in this way can the possibilities for benefit be fully visualized in relation to needs.

Undoubtedly, from the viewpoint of volume — the volume of data to be processed and the volume, or extent, of the processing operations — the data-processing problem often is a formidable one. But the basic processing procedures, applicable to all volumes of data, large and small, are not complex. Similarly, without attempting to penetrate into the physical principles underlying the operation of the mechanical and electronic devices used in data processing, the manner in which these devices perform their operations is not difficult to comprehend.

BASIC DATA-PROCESSING OPERATIONS

Page

Classifying 17

Alphabetic Codes 18

Numeric Codes 18

Alpha-Numeric Codes 19

Mnemonic Codes 20

Sorting 20

Calculating 21

Summarizing 21

Recording 22

Communicating 22

BASIC DATA-PROCESSING OPERATIONS

Data processing, while complex in the aggregate, is composed of only a few basic operational steps. All data-processing routines consist of one or more of the following basic procedures:

Classifying
Sorting
Calculating
Summarizing
Recording
Communicating

These basic operations serve to implement the three basic procedures in data processing: writing or rewriting, rearranging, and reconstructing the data.

Sometimes the basic operations are performed as separate steps while in other instances a single step in the routine represents, in one operation, a combination of basic steps. For example, sorting is usually a separate operation whereas recording is frequently linked, in one operation, with summarizing or other basic operations.

Classifying

The purpose of classification is mainly to facilitate writing and rewriting of data, by minimizing the work required. The central idea in classification is abbreviation. To facilitate processing, data are classified, or identified, in a scheme of shortened and uniform equivalents.

The system of classification may be either natural or artificial, or a mixture of both. In the natural system, data are identified according to their essential nature. A chart of accounts, in which items are identified according to their accounting nature, is a natural classification.

In the artificial system, data are represented, more or less arbitrarily, in a scheme of equivalents known as codes. Of these, there are three basic types: alphabetic, numeric, and alphanumeric.

Alphabetic Codes

In alphabetic codes, specific characteristics or ranges of characteristics are designated by alphabetic symbols. Familiar examples of alphabetic codes are the designation of shoe widths by the symbols A to E, ratings of bonds (Aaa, Aa, A, etc.), and credit ratings (A, B, C, D, E, etc.). The use of alphabetic codes in data processing is very limited.

Numeric Codes

In numeric codes, characteristics or ranges thereof are designated by numbers. There are several types. In the group classification code, the numeric type most commonly used, major and minor categories are indicated by succeeding digits. For example:

3000	Inventories
3100	Raw materials
3110	Steel
3120	Copper

A variation of the group classification code is the arrangement of code numbers in order of magnitude corresponding to the alphabetic sequence of the data. For example:

Code	*Data*
1–20	A–Ab
21–40	Ac–Ad
600–650	Ma–Me

This type of code is used principally in coding names, titles, or subjects.

Another type of numeric code is the significant digit code, in which all or part of the digits are associated with a characteristic of the data. In the following example, the last two digits represent drum capacity:

10000	Drums
10050	Drums–50 gal.
10075	Drums–75 gal.

A variation of the significant digit code is the final digit code. Strictly speaking, the final digit code is not a complete code scheme; rather, it is a coding device, or practice, that may be used in conjunction with various classes of codes. A final digit code is an arrangement of coding symbols in which the same symbol is uniformly applied to a common characteristic of data in several categories. For example:

500	Sales
510	New York office
511	Product A
512	Product B
513	Product C
520	Chicago office
521	Product A
522	Product B
523	Product C

In this example, the final digit "1" distinguishes Product A, the final digit "2" distinguishes Product B, and so on, in all the categories where these sales are found.

Decimal codes are used principally for filing purposes. The structure of these codes, to the left of the decimal point, is similar to that of the group classification code. For example:

30.	Inventories
31.	Raw materials
31.1	Steel
31.2	Copper
31.21	Copper wire

Decimal codes are highly flexible, since they may be expanded without limit. However, their use in mechanical data processing involves certain difficulties in adaptation, since the machines do not recognize decimal points.

Alpha-Numeric Codes

Alpha-numeric codes make use of both numbers and alphabetic characters. For example:

30	Inventories
30A	Raw materials
30A1	Steel
30A2	Copper
30A2a	Copper wire

Mnemonic Codes

A mnemonic code embodies characteristics of one or more of the basic classes of codes. A mnemonic code is one in which there is some assistance to the memory in the combinations of numbers or letters, or both, employed. For example:

Code	*Data*
FLG4	4″ flange
BRG12	12″ bearing

Other variations of the basic types of codes also are employed in data processing. The construction of codes is an important feature in formulating the data-processing plan. The coding requirements depend upon the range of characteristics of the data desired to be known and hence to be followed and maintained in the processing operations. The objective in code construction is to find the simplest code scheme that will lend itself most conveniently to the classification of data in accordance with the characteristics to be noted and reported.

Sorting

The purpose of sorting is to facilitate arrangement of data. Sorting is a process of arrangement or selection of data according to order, rank, or common characteristic. Sorting according to order or rank, known as sorting in sequence, occurs when a body of data is arranged in alphabetic or numeric sequence.

Sorting according to common characteristics, known as sorting by classification, occurs when a body of data is arranged into groups of data, each having a common characteristic: for example, the arrangement of a file of customers into groups, by states.

A variation of sorting by classification is the process of merging, in which two or more files are rearranged into one file. For example, receipts and withdrawals of inventory items may be merged with inventory balances, each item of receipt and withdrawal being arranged in combination with the related inventory balance. The common characteristic on which the sorting is based is the inventory item.

Another variation of sorting by classification is the operation of extraction, or matching. In this process, a portion of data from one group is removed from the group in order to supplement data filed in another group. For example, from a master file of customers there might be removed the addresses of those customers to whom statements are to be sent for a current period. The common characteristic is the customer's name. The extracted addresses would be arranged in parallel with the related invoices and other groups of data evidencing activity in the customers' accounts for purpose of preparing the statements.

Obviously, sorting is greatly facilitated by expressing data in codes.

Calculating

Calculating is related to the reconstruction of data. Calculating consists of the application of a mathematical process, usually arithmetical, to data. Calculation creates new data in the processing routine.

Summarizing

Summarizing also aids in the reconstruction of data. The purpose of summarizing in data processing is essentially the compression of a body of data into more concise form.

Summarizing is not far removed from sorting or calculating. Nevertheless, there are distinctions. Data may be sorted into categories but this operation, in itself, merely achieves a separation — usually a meaningless one until the results of the separation are summarized. Calculating is a mathematical process in which the objective is a mathematical result. Summarizing may occur as an incident of calculating but it is not the primary purpose of calculating. Summarizing may occur at various stages of the processing routine. It also creates new data.

The familiar baseball box score is a summarization of the game, supported by underlying calculations.

Recording

Recording is linked to the basic procedure of writing and rewriting of data. Recording is the expression of data upon a vehicle used in the processing routine. Usually, many recording operations are performed in the processing of data, beginning with the expression of raw data in record form and ending with entry of the results of processing in various records or documents.

Communicating

Communicating is the process of transferring data from one point to another in the processing routine and of bringing the final results of processing to the user's location. Thus it serves as an adjunct in the accomplishment of all three of the basic procedures in processing. Communicating is the transporting of data. The processing routine may require that data be transported over various distances.

RUDIMENTS OF PROCESSING METHODS

	Page
Classifying	24
Sorting	26
Pegboard Equipment	26
Edge-Notched Cards	28
Reverse-Digit Sorting	30
Block Sorting	32
Avoidance of Sorting Operations	33
Calculating	34
Key-Driven Calculators	34
Rotary-Type Calculators	36
Summarizing	37
10-Keyboard Adding Machine	37
Full Keyboard Adding Machine	37
Supplemental Features	38
Recording	38
Transcription	39
Reproduction	39
Stencil Process — Multilith Process — Hectograph Process — Photographic Processes — Offset Printing Process — Addressing Machines	
Filing	44
Microfilm — Filing Objectives	
Multi-Purpose Equipment	47
Accounting Machines	47
Special-Purpose Machines	48
Devices to Broaden Flexibility	
Communicating	51
Modes of Transportation	52
Teletype Equipment	52
Transceiver	54
Teledata	55
Codes	55
Teletype Code — Possible Disadvantages — Transceiver Code — Codes Used in Teledata Equipment	

RUDIMENTS OF PROCESSING METHODS

To again reiterate: the basic procedures in data processing are the writing or rewriting, rearrangement, and reconstruction of data, and the basic procedures, in turn, are carried out by the application of six basic operational steps – classifying, sorting, calculating, summarizing, recording, and communicating. All data processing – in enterprises both large and small and in simple as well as highly complex routines – is essentially the application of one or more of these basic operational steps. It is next appropriate to consider the specific methods and devices through which the basic operational steps are accomplished.

The conditions or circumstances under which data processing is performed are of infinite variety. It has been necessary, therefore, to devise methods and equipment to meet the varying conditions. As a consequence, the field of data-processing methods encompasses a multitude of methods and machines, ranging from broad to specialized areas of application. To describe all of the methods and devices presently available is impracticable. The present discussion therefore will be limited to some of the basic methods and equipment, illustrating, in this way, the fundamental features involved in a broad understanding of data-processing methods and devices.

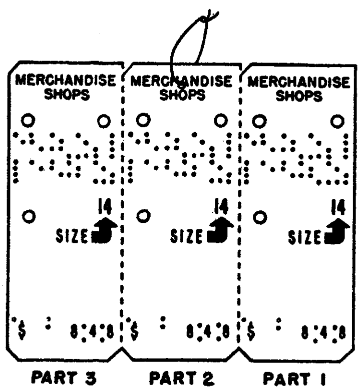
Just as the basic operations in data processing sometimes overlap, so also do methods and machines frequently serve more than one function. The functions of methods and machines therefore cannot be described entirely in parallel to the basic operational steps.

Classifying

To permit rapid processing of data, there must be a system of classification. Moreover, the classification must be applied to and thereafter remain associated with the data throughout the processing routine.

The original record of data received from outside sources, or prepared internally, is known as a source document. Classification is usually applied to source documents but may be deferred until some later point in the routine. Data are usually classified in code form.

Classification by mental process is time-consuming and expensive. Not too infrequently, in fact, coding is a bottleneck since coding necessarily precedes processing. To meet this problem, various practices and devices have been evolved to provide automatic coding, such as pre-coded printed or perforated garment tickets, attached to merchandise, which provide automatic coding of sales; and charge plates, used by various concerns, including airlines and retail establishments.

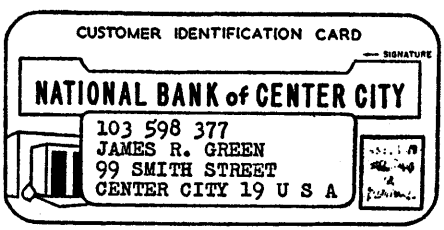


PART 1 – Removed at time of sale and used as a means of recording the details of the sale.

PARTS 2 and 3 – Remain with the merchandise. If merchandise is returned, Part 3 is used in recording the details of the returned sale.

PRE-CODED GARMENT TICKET

Charge plates show the customer's name, account number, and other information. When presented by the customer, the plates are inserted in a recording device, thus obviating the need for effort in mental coding.



CHARGE PLATE

Point-of-transaction recorders, involving the use of pre-coded documents, have recently been developed and promise to yield important economies.

Accuracy in coding is of paramount importance. The application of codes should be verified, either by someone assigned to the task of verification, or by other corroborative process. An example of the latter is the matching of account numbers between those placed on purchase orders by the purchasing department and those later placed on vendors' invoices by the accounting department.

Sorting

Sorting, like all other basic operations, may be performed manually, mechanically, or electronically. In sorting by classification, the volume of the sorting operation depends upon the number of classifications into which the data are to be segregated and the number of items to be sorted. On the other hand, in sorting a body of data into sequence, the volume depends only upon the number of items to be sorted.

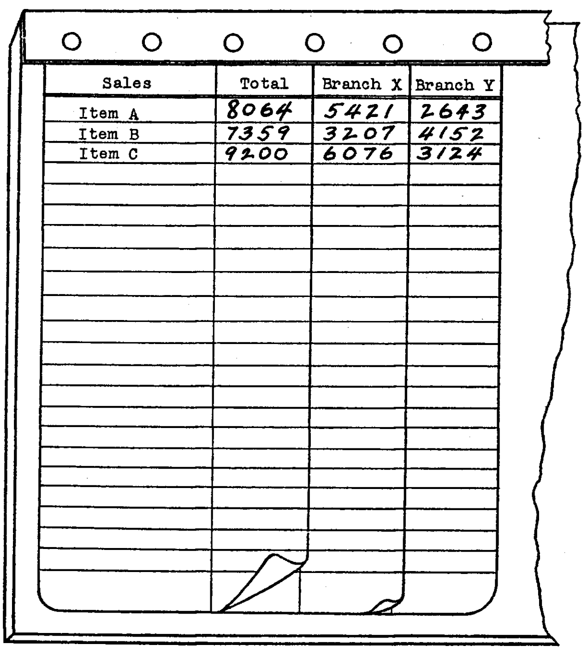
Manual sorting of course is a familiar process. Within the manual area, however, there are various practices and devices which aid in sorting. The entry or transcription of data on columnar work sheets is a sorting process in which data are grouped in accordance with the columnar headings. Sorting racks and trays provide receptacles for the manual segregation of data in designated categories. Mailing racks and the "in" and "out" baskets used in most offices are perhaps the simplest illustrations of this principle.

The sorting operation may be facilitated by the structure of the source document. For example, the document may consist of detachable strips, with one item entered on each strip. The strips are then separated and sorted by classifications. Sorting also may be facilitated, if the number of items in each source document be small, by preparing multiple copies of each document, for subsequent sorting by classifications.

Pegboard Equipment

A device which assists in sorting is the pegboard. Pegboard equipment consists of pre-planned forms and a board of special design. Essentially, the equipment sorts data by making use of the method of columnar arrangement.

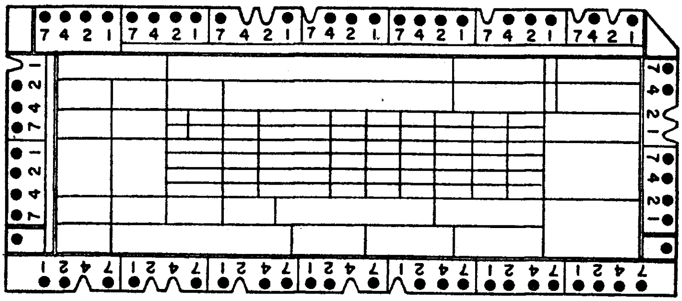
The pegboard device is particularly useful in situations where the objective is to bring together data prepared, in a uniform pattern, at more than one point or source. The data are classified, at each point or source, on forms of uniform design, each line of the form representing a certain classification. The magnitude (quantity, dollar value, or other measure) of each classified item is entered in a column opposite the item. Upon completion of the forms, the completed columns showing magnitudes of the respective items of data are overlapped or detached and assembled on the pegboard. Assembling is accomplished by placing the sheets or the detached columns in pegs upon the board, so aligned as to bring each item into exact juxtaposition to all others of the same classification. In this way, the pegboard equipment performs a sorting operation by grouping items of data having common characteristics.



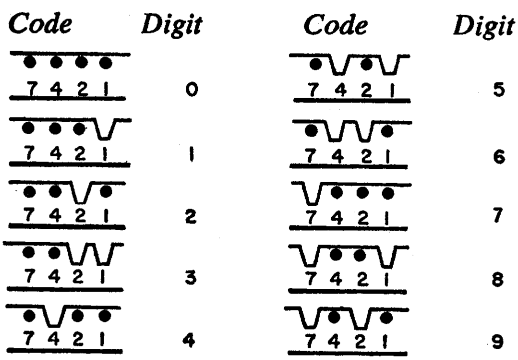
PEGBOARD

Edge-Notched Cards

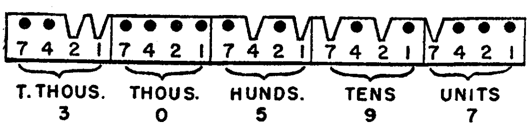
One of the fastest means of sorting is a system which utilizes specially designed edge-notched cards and a "key", or needle. The card ordinarily is used both as a source document and a sorting device, thus serving a dual purpose. The appearance of the card is illustrated below.



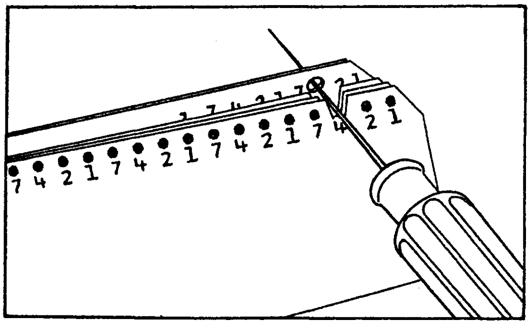
The holes spaced along the edges of the card are used in coding data. Classification codes are indicated by notching the holes in accordance with a special card-code system. In this system, the digits 0 to 9 are represented by the following pattern of notched holes.



Thus, the classification code 30597 might be indicated on the card as follows:



Sorting of edge-notched cards is accomplished by inserting a needle through the position of the digit to be sorted. The needle of course passes through all the cards being sorted, by means of either the hole, or notched hole, in the position. The needle is then lifted upward, carrying with it all cards having holes in the position selected and leaving at rest all cards having notches in that position. In this way, the notched cards become sorted, as desired, into a separate group. The procedure is illustrated below.



Because of the code system employed, the insertion of the needle in the "4" position in the preceding illustration will drop out not only the 4's in the group of cards but the 5's and 6's as well. The procedure to eliminate the 5's and 6's might be as follows:

Insert the needle in the "1" position, thus lifting the 4's and 6's from the group and leaving the 5's at rest;

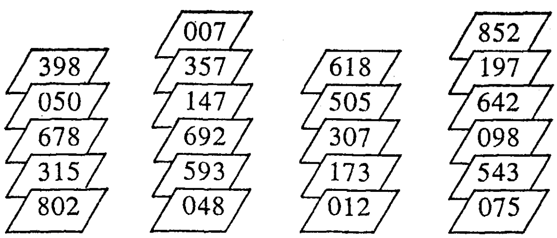
In the portion of the cards lifted in the preceding step, insert the needle in the "2" position, thus lifting 4's only and leaving the 6's at rest.

The high speed of sorting is based upon the ability of the system to sort a large number of cards with one, or a few, thrusts of the needle – as compared with the time involved in individual handling of each card as required in manual and other mechanical methods of sorting.

Code schemes other than the one shown in the preceding illustration may be used, including codes covering some, or even all, of the alphabetic characters. While highly useful, to the present time the system has been employed only as a means of recording and sorting. Devices that would provide for printing and summarizing by the direct use of edge-notched cards are under development but are not presently available.

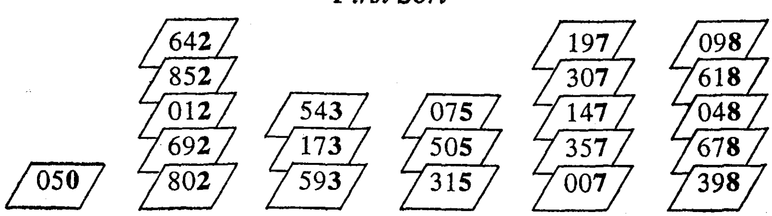
Reverse-Digit Sorting

The predominating operation in many sorting routines consists of the arrangement of data classified in numeric codes into numeric sequence. This procedure is often necessary in rearranging data from one classification into another; for example, the rearrangement of sales data, previously arranged by product codes to accumulate sales information, into customers' numeric name codes in order to prepare for posting to customers' accounts. Particularly if the volume of sorting is substantial, the fastest method of sorting frequently will be the reverse-digit method. In reverse-digit sorting, the coded digits are sorted from right to left. To illustrate, assume the following codes are entered on documents which are to be arranged in numeric sequence:

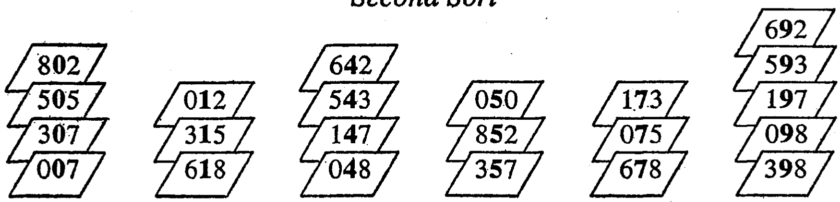


Sorting successively from right to left, the results are as follows:

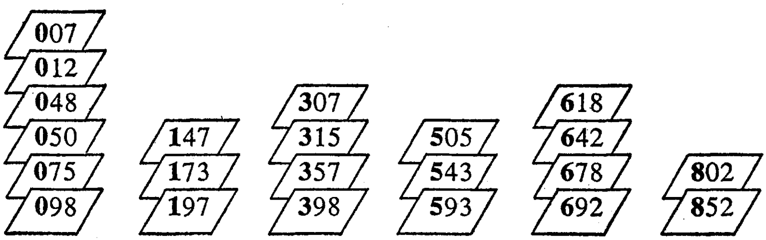
First Sort



Second Sort



Third Sort



Thus, at the conclusion of the third sort, the codes are in numeric sequence. Study of the illustration will show that, to maintain the sequence of the digits, the order of sorting the documents, in the second and succeeding sorts, must be from the bottom of the right-hand stack to the top of the left-hand stack.

In the foregoing illustration, involving only a few codes, obviously it would have been easier to sort from left to right, i.e., by first arranging the codes in groups by hundreds and then in sequence within each such group. Thus the sorting, in this elementary example, would be accomplished in two sorts instead of three.

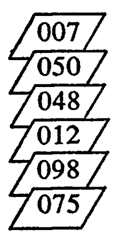
However, in situations where the sorting involves a large volume of codes, the reverse-digit method is a faster process, mainly because the number of groups into which the data are segregated in the course of the sorting operation never exceeds ten in the case of numeric sorting or twenty-six in alphabetic sorting. For example, if 5-digit codes were to be sorted, the comparison of the two methods is as follows:

	Maximum Number of		
	Groups		*Items Handled (Both Methods)*
Sorting Operation	*Reverse-Digit Sort*	*Straight Sort*	
10,000's to 1,000's	10	10	100,000
1,000's to 100's	10	100	100,000
100's to 10's	10	1,000	100,000
10's to units	10	10,000	100,000
Total	40	11,110	400,000

Block Sorting

A sorting procedure often employed is block sorting. This is a combination of the straight sorting and the reverse-digit sorting methods. Block sorting is used in connection with relatively long sorting routines when it is desired to start work on other operations without waiting for the completion of the entire sorting operation. By sorting the first block, the other operations may be commenced and continued as the sorting operation is completed.

Referring back to the illustration of reverse-digit sorting, assume the codes there shown are to be sorted in blocks. The first step would be to select all codes having "0" as the first left hand digit. These are, in the illustration:



The remaining sorting operations, as to these items, are then performed by the reverse-digit method, whereupon the items are arranged in sequence, namely: 007, 012, 048, 050, 075, and 098.

Having been sorted, the items in this group could then be released for other processing, whereupon the sorting routine would be resumed upon the remaining items.

Avoidance of Sorting Operations

In some situations, sorting operations may be avoided by good planning of procedures. A typical example occurs in connection with the control of tags used in taking physical inventory. Assume that 10,000 tags are issued. At the completion of the inventory counts, all tags issued must be accounted for, either as having been used, unused, or lost. In practice, tags are occasionally lost, and the problem therefore is to identify the lost tags. If the 10,000 tags are issued in one series and 5 are lost, it will be necessary to sort 9,995 tags to determine the missing numbers.

However, if the tags are issued in blocks of, say 500, in separate numeric series, sorting at least three-fourths of the blocks in numeric sequence will not be necessary since at least 15 of the blocks will have been returned intact. Of course, the number of tags that will be lost cannot be known at the time of issuance and hence the selection of the size of the blocks is a matter of judgment based on past experience. If issuance is made in blocks, there is always at least a possibility that some sorting in sequence will be avoided.

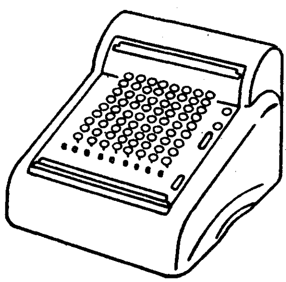
A similar principle is often followed to avoid the sorting of returned payroll checks in numeric sequence. Separate bank accounts are maintained for successive weekly payrolls. There is deposited in the account the exact amount of funds required to meet the payroll for that week. The payroll checks are marked as being invalid if not presented for payment within, say, thirty days. At the end of thirty days following issuance, the checks as returned by the bank or known to be unclaimed usually will be equal, in aggregate amount, to the amount originally deposited to cover the payroll. If this proves to be the case, it will be unnecessary to sort the payroll checks in sequence or, unless auditing considerations indicate otherwise, to reconcile the payroll bank account. Should there be a balance remaining in the account, however, sorting and reconciling would be necessary.

Sorting usually represents a substantial part of the workload in the processing routines of a business. While planning of the sorting operation is not a difficult matter, the planning should be carefully done, to avoid bottlenecks and unnecessary operations.

Calculating

Of all the operations in data processing, calculating is usually the easiest to organize and manage. The computations required, in most of the processing of business data, seldom are complex. While the volume of computations is sometimes impressive, the speeds of mechanical aids have made it possible to handle volume without impeding the flow of the routine.

On the other hand, in making simple calculations, the manual method is sometimes the most efficient. To reduce the work involved in calculating, precalculated tables are widely used as aids in making computations involving fixed factors, as in computations of interest and withholding taxes. Slide rules are sometimes used in connection with analysis of data but rarely in the processing functions.

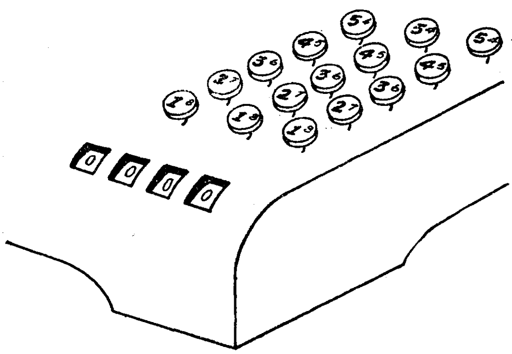


KEY-DRIVEN CALCULATOR

Key-Driven Calculators

Mechanical calculators are of two types: key-driven and rotary. The key-driven calculator is operated by depressing keys which actuate the mechanism.

To illustrate the operation of addition on this calculator, assume that the numbers to be added are 125 and 689. Since the addition of these numbers will require use of only a few of the keys, the performance of this operation of addition may be illustrated by showing only a portion of the keyboard, as follows:



The number 125 would first be placed in the machine as follows:

Number	*Inserted by depressing the:*
1	(1^8) key, left column, once.
2	(2^7) key, middle column, once.
5	(5^4) key, right column, once.

Next, the number 689 would be placed in the machine in the following manner:

Number	*Inserted by depressing the:*
6	(3^6) key, left column, twice.
8	(4^5) key, middle column, twice.
9	(5^4) and (4^5) keys, right column, once.

The accumulator dial would then show the sum of the two numbers, 814.

Subtraction is performed on the calculator as a process of addition, using complements for the minuend. Assume that 475 is to be subtracted from 863. Referring to the foregoing section of the keyboard, the subtrahend 863 would first be placed in the machine as follows:

Number	*Inserted by depressing the:*
8	(4^5) key, left column, twice.
6	(3^6) key, middle column, twice.
3	(3^6) key, right column, once.

The minuend 475 would next be placed in the machine as follows:

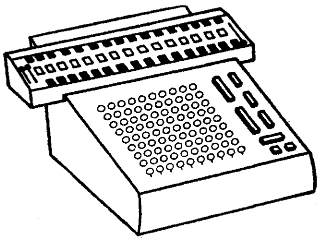
Number	*Inserted by one depression of:*
4	(5^4) key, left column.
7	(2^7) key, middle column.
5	(4^5) key, right column.

By these operations, there would have been placed in the mechanism the numbers 863 and 524 (complement of 475). The accumulator dial would register the total of the two numbers, 1387. To adjust for the use of the complement, the left-hand digit is ignored and 1 is added to the right-hand digit, thus producing the correct result of the subtraction, 388.

Multiplication and division, being essentially repeated additions and subtractions, are performed on the key-driven calculator by similar operations. Because of the importance of manual dexterity in the operation of the machines, the more efficient use of these key-driven calculators is in computations involving limited numbers of digits. In the newer models of these calculators, the mechanism is driven electrically.

Rotary-Type Calculators

In the rotary-type calculators, numbers are entered by single depressions of the keyboard. The machine is actuated by tripping or rotating the mechanism, rather than by driving the keys. Rotary calculators are the work horses in the calculating function. They perform all the arithmetic operations. The modern types, electrically driven, operate at high speed.



FULL KEYBOARD TYPE

10-KEY KEYBOARD TYPE

ROTARY-TYPE CALCULATORS

Accuracy, of course, is highly important in the calculating operations. In many situations, to afford reasonable assurance of accuracy, it is necessary to check all calculations; in others, accuracy may be established by proofs of over-all results.

Summarizing

The principal mechanical device used in summarizing is the adding machine. Adding machines are basically of two types: 10-key keyboard and full keyboard.

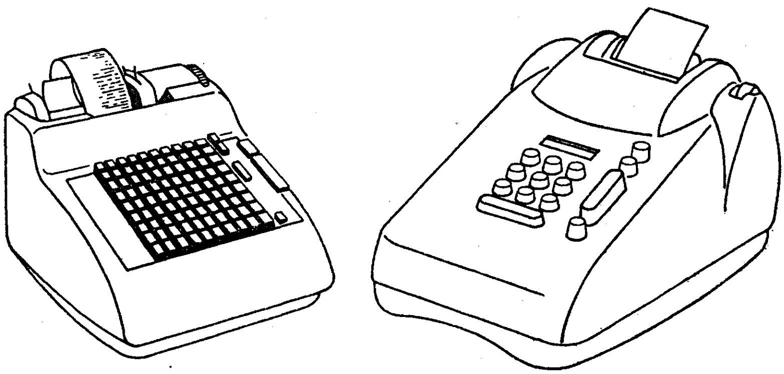
10-Key Keyboard Type

The 10-key keyboard adding machine has only ten numbered keys. The full number is entered by depressing first the key for the left-most digit, then proceeding with all subsequent digits, including zeros, to the right.

The 10-key keyboard adding machine resembles the 10-key keyboard calculator; in fact, 10-key keyboard calculators are essentially adding machines coupled with auxiliary devices to provide for multiplication (repeated additions) and division (repeated subtractions).

Full Keyboard Type

The full keyboard type has a number of rows of nine keys. In operating the machine, the keys are depressed to form a visual interpretation of the number. Zeros in the number are recorded by not depressing keys. Rows of numbered keys are sometimes replaced by symbols for specialized purposes.



FULL KEYBOARD TYPE

10-KEY KEYBOARD TYPE

ADDING MACHINES

Supplemental Features

Variations to increase flexibility can be obtained by supplementing adding machines with movable carriages and dual accumulators. Movable-carriage adding machines will register in successive accumulators as the carriage is moved, thus permitting the listing and simultaneous totaling of two or more amounts from the same document. If the numbers are small, a similar effect can be obtained, on the full keyboard type only, by utilizing the keyboard in sections, so that two or more columns can be totaled at the same time.

Recording

The variety of methods and devices employed in the recording phase of processing is far greater than that found in other processing operations. The operation of recording is common to most processing routines. Naturally, therefore, there is a tendency to combine that operation with others, in a unified operation. Some methods and devices are applicable to recording only, but many others have a multiple purpose in the scheme of processing.

Recording encompasses the transcription, reproduction, and filing of data. Transcription is the act of writing or rewriting, or the equivalent for processing purposes. Reproduction is the act of making facsimiles of data in order to facilitate reference by more than one user or to assist in other steps in the processing routine. Strictly speaking, filing comprehends only the act of storing data in assigned locations. As a matter of practical operation, however, the function of storage usually is coupled with that of locating data previously stored.

Again, within these three subdivisions of the recording operation, some methods and devices tend to overlap, thus assisting in more than one sub-function. In short, the recording area is a broad one, replete with methods and devices having a multiplicity of applications.

Transcription

One of the very earliest aids in the processing of data is the typewriter, which permits transcribing by keystroke. Among other mechanical devices which assist solely in the transcribing operations are check writers, card punches, rubber and metal stamps, and the family of printing devices connected to calibrating mechanisms such as flow meters and scales. Many other devices assist, in combination, both in transcribing and in one or more other operations.

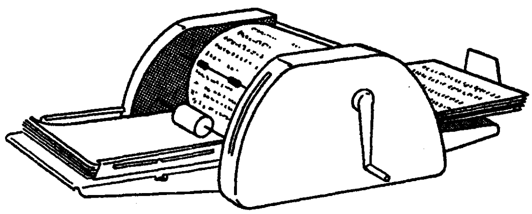
Reproduction

Probably the simplest reproduction device is carbon paper. By the use of this device, reproduction is obtained by impressing the data upon the first copy. Even here, however, ingenuity has recently produced a seeming paradox: carbon copies without the use of carbon paper. In this process, invisible chemical impregnations in the paper make possible the reproduction of copies from a single impression.

A means of data reproduction equally as common as reproduction by direct impression is the method of producing copies from a master form. Among the processes employing this method are the stencil, multilith, hectograph, and photocopy.

Stencil Process

In the stencil process, the stencil itself is first prepared, usually by typing. The stencil is then attached to the surface of a drum. An ink solution, placed inside the drum, passes through the impressions in the stencil. Copies are produced by bringing paper into contact with the stencil. Given proper care, stencils may be re-used. Reproduction in various colors is possible but usually only one color is used in each run.



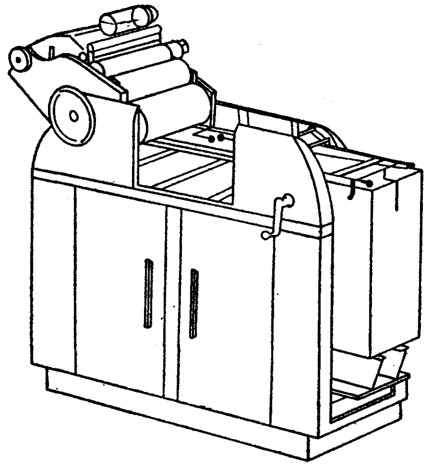
STENCIL DUPLICATING MACHINE

Multilith Process

The multilith process is based upon the properties of oil and water to repel each other. A master copy is first prepared upon specially coated paper or a thin metal plate. By typing or other impression process, the copy text is placed upon the master with a *water-repellent* chemical.

The master is then covered with a very thin layer of *water-soluble* chemical which instantly separates, being repelled from the field of the copy text and adhering to the remainder of the master's surface. Next, a roller covered with oil-base *(water-repellent)* ink is passed over the master. The ink adheres to the copy text but not to the remainder of the master surface covered by the layer of *water-soluble* chemical. The master, now having been inked, is thus ready for reproduction of the copy text.

The copy text is transferred from the master by contact with a blanket or mat. Finally, the copy text is printed by bringing paper into contact with the blanket or mat.



MULTILITH

Hectograph Process

In the hectograph process, reproduction is accomplished either by the gelatine or the spirit method. The gelatine method involves the preparation of a master copy on special paper, by typing or otherwise. The master is then placed upon a base of gelatine material. Copies are made by placing special paper in contact with the gelatine base. While the gelatine process is still rather extensively used, it is now considered to be obsolete. New equipment for the process is no longer produced.

In the spirit method, the master copy itself is the reproducing medium. A small amount of liquid is applied to special paper which is then brought into contact with the master to produce duplicate copies. Master copies may be re-used. The simultaneous use of several colors is possible.

Photographic Processes

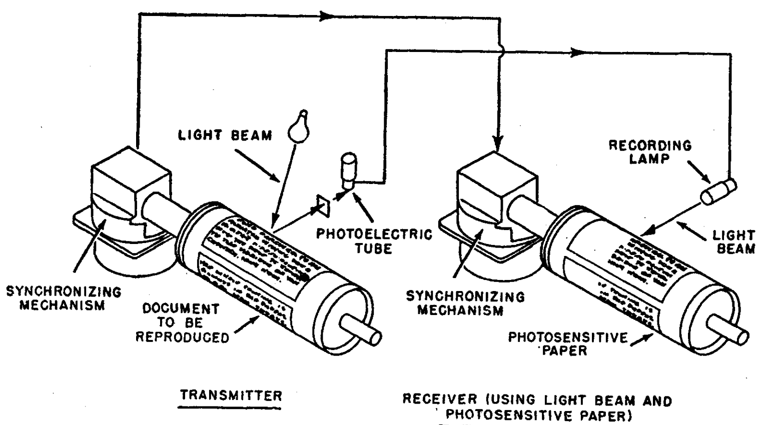
Reproduction of original copy can be obtained from various photographic processes, covering a wide range of costs. All such processes have the inherent advantage of avoiding errors, which are always possible when reproduction involves transcription. The availability of photocopies of original documents reduces the risk of loss or damage to the documents themselves. Reductions in the size of material can be accomplished by photographic processes and, conversely, enlargements by photographic means are useful in presenting data to groups.

Photographic records of high quality, when required in small quantity, are rather expensive. For many purposes, however, high quality in reproduction is not a necessity.

There are two basic photographic methods: wet process and dry process. All photographic methods involve the use of materials sensitized to various combinations of light, heat, chemicals, or electrical charges. There are two types of wet process: contact and intervening negative. In the contact type, sensitized paper or other material is brought into contact with the copy, then immersed in a bath, to obtain the reproduction. In the intervening negative type, the copy is photographed on a film, or plate. Sensitized material is then brought into contact with the film or plate, and immersed in a bath to obtain the reproduction.

There are also two types of dry process: contact and electronic scanning. Because of greater convenience of the dry process, the more recent advances in photographic reproduction have been in that type of processing.

In the contact method, the sensitized material is brought into contact with the copy to be reproduced, or the intervening negative, and reproduction is obtained by the application of light, heat, chemicals, or electricity, or a combination thereof.



ELECTRONIC SCANNING DEVICE

In a common method of electronic scanning, copy to be transmitted is wrapped around a drum. As the drum rotates, a photoelectric eye, moving slowly from one end of the drum to the other, generates electrical impulses corresponding in strength to the shading of the copy being transmitted. At the receiving end, the electrical impulses are converted to copy on paper attached similarly to another drum, the copy being formed by the conversion of the impulses of varying strength into similar variations of light or dark. Recording may be accomplished either by the use of a stylus which removes, in varying degrees, a white top coating on black or colored paper, or by directing a light beam of varying intensity upon photosensitive film or paper.

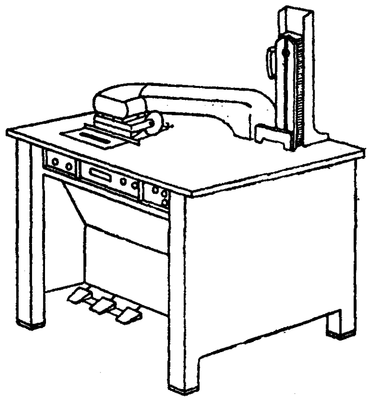
The new xerographic process utilizes paper sensitized to electrical charges, in combination with the application of heat to a dry resinous powder, to obtain reproduction. This process is adaptable for use in electronic printing devices.

Offset Printing Process

Another photocopy process is that of offset printing, of which there are various methods. In one method, the data are first photographed on a metal plate. The plate is bathed in a chemical solution which etches and brings into raised relief the negative of the image of the data. The etched plate is then mounted upon a bed, or drum, and reproduction is obtained by printing from the mounted plate. Offset printing provides high-quality copy and is used, in fact, more extensively in merchandising and selling functions than in data processing. The use of color in offset printing requires the preparation of separate plates and individual runs for each color in the composition.

Addressing Machines

Printing – the oldest, yet one of the most common means of data reproduction – may be done by the use of movable type or by the use of metal slugs, usually prepared from movable type. A device widely used, which employs the principle of printing from a metal slug, is the addressing machine. The master form in this instance is a metal plate upon which the data to be reproduced have been embossed. The plates, together with the documents upon which the reproduced data are to be impressed, are fed into the machine and the impression is made as the machine automatically inserts an inked ribbon between the plate and the document.

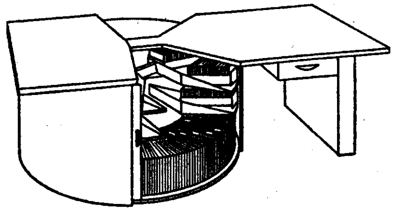


ADDRESSING MACHINE

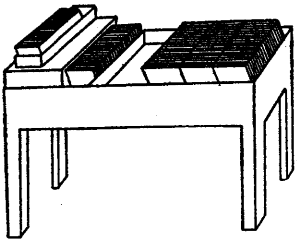
Other types of addressing machines use master forms which incorporate the use of other reproduction methods – usually a stencil process. As the name implies, the principal use of these machines is the reproduction of addresses in mailing and other operations. However, the machines may be used for other purposes, such as heading-up various record forms and statements.

Filing

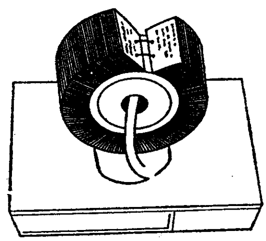
Filing consists of the operations of storing data and finding data previously stored. Filing is largely a manual operation. Moreover, it is unique among the processing operations in that a substantial part of the work involved in the performance of filing is sheer physical effort – for example, in the more elementary filing systems, bending, reaching, opening and closing drawers, and so on. Most of the mechanical aids to filing are designed to reduce the physical effort required. The objective, in general, has been to provide maximum visibility – thus facilitating identification of the location where data are to be filed or obtained – and a minimum of effort to file or remove data, once



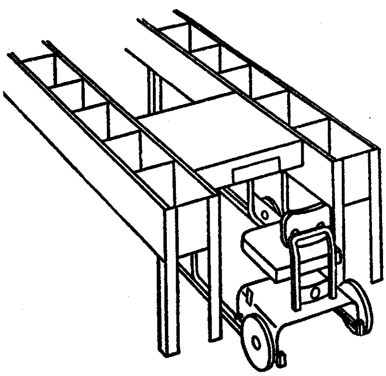
ROTARY FILE
(HORIZONTAL PLANE)



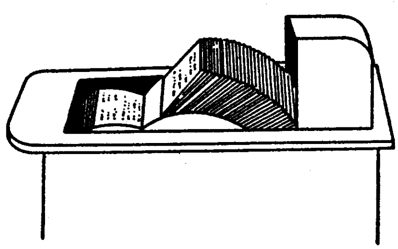
TUB FILE
(WITH REMOVABLE TRAYS)



ROTARY DESK FILE



FILE WITH
MOVABLE CHAIR



ROTARY FILE
(VERTICAL POSITION)

FILING AIDS

the location is known. Space requirements, of course, also have influenced the design of filing systems.

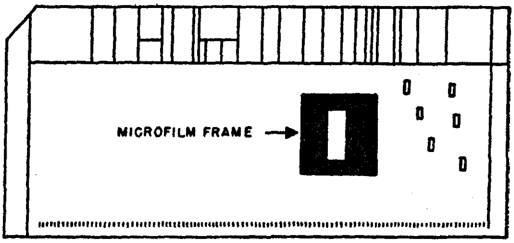
One such aid is the tub file, which is an open file with the data arranged in a single horizontal plane. A posting tray follows the same principle. Another common arrangement is the revolving file, containing visible data arranged on either a horizontal or vertical plane.

Various types of filing cabinets permit the movement of component trays, without removal of the trays from the cabinet. The placing of filing devices on wheels provides flexibility and assists in ready reference to data. Chairs constructed on special rails enable clerks to move easily from one file location to another.

Microfilm

Microfilm, a photocopy process of reproduction, has found increasing usage in recent years, especially as a medium for the storage of permanent and semi-permanent data. Its principal advantages lie in the saving of storage space and ease of handling. Against these advantages are the cost of arranging the data for the preparation of the film and the cost and time involved in obtaining access to the filmed data. Microfilmed data are usually filed in reels. Access to data is obtained by a reading machine, which produces an enlarged image of the data.

Speed of access to data on microfilm is increased by the use of the microfilm card, a relatively new device. The microfilm is framed into the card, which contains a coded reference to the data. This device permits quick identification of location of the stored data. On the other hand, the required storage space is increased.



Filing Objectives

Obviously, the one reason that data are filed (stored) is that they may be needed later; otherwise, having served their immediate purpose, data would be discarded. To store the data quickly and to locate them readily, there should be a logical scheme of classification covering the identification of file location and contents. The importance of accuracy in filing is self-evident; misfiling may involve costly search for needed data. The physical arrangements should facilitate the convenience of filing. The filing routine should provide for prompt storing of data in order that they may be in current form when required and for prompt destruction when no longer required.

Multi-Purpose Equipment

Much of the equipment used in data processing performs two or more of the other basic processing operations. There are numerous items of equipment in this category. For example, the basic cash register is essentially a cash drawer, coupled with an adding machine with tape. Some of the present types of cash registers will distribute data into more than one classification, thus becoming sorting mechanisms as well as performing their traditional operations of calculating, summarizing, and recording. Cash registers of this type are commonly used in supermarkets.

Accounting Machines

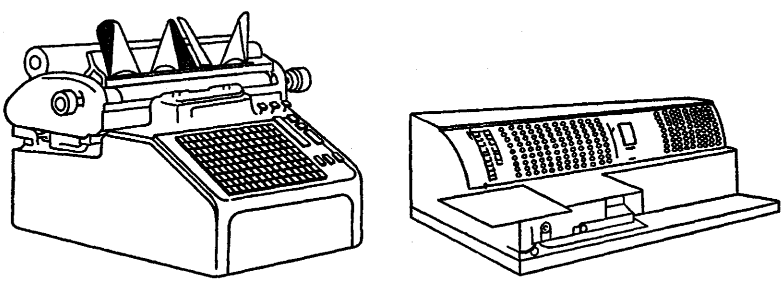
A sizable class of multi-function devices is the group generally known as accounting machines. While the line of distinction is not always completely clear, accounting machines tend to fall into one of two categories: those designed for general purposes and those used in specialized applications.

General-purpose accounting machines are essentially multiple adding machines coupled with printing devices and with bed or carriage mechanisms which move the record forms to appropriate positions.

A typical application of such a machine is found in revenue accounting for hotels. Data from the source documents showing details of charges to guests are inserted in the machine by depressing keys for codes and amounts. The machine simultaneously produces two copies of the customer's account card and a summary of revenue, classified according to room rentals, food, beverages, valet services, garage rentals, and so on.

Thus the machine sorts, calculates, and summarizes, as well as records. Moreover, it performs two of the three sub-functions of recording: transcription and reproduction. The required mental and manual work consists only of inserting the appropriate forms and depressing the correct keys; all other operations are automatic.

Other common illustrations of the use of general-purpose accounting machines are accounts payable applications in which voucher registers and distribution schedules are produced simultaneously and usage in connection with payrolls, in which payroll registers and earnings records of employees are produced at the same time.

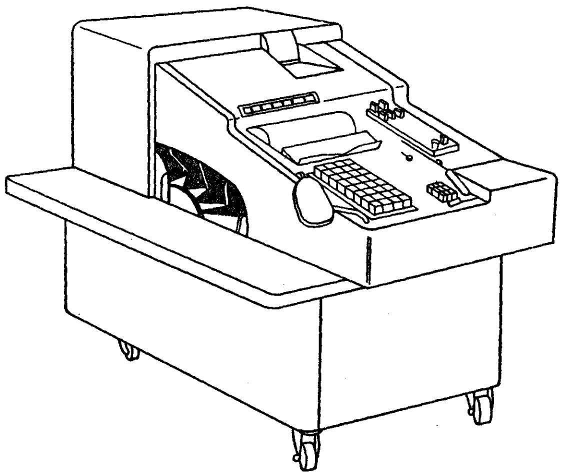


GENERAL PURPOSE ACCOUNTING MACHINES

Special-Purpose Machines

A highly specialized form of accounting machine is the bank proof machine. This device is used primarily to sort checks according to banks or branches for which they were paid. The machine has a series of adding machines, or accumulators, which list and summarize the amounts of the checks, by banks, upon depression of code and amount keys by the operator. The special feature of the machine consists of a series of metal pockets which, in one type of machine, are mounted upon a revolving drum. The positions of the drum are synchronized with the accumulators.

Thus, as the operator, in depressing the keys, signals the code of the bank, the amount of the check is entered in the accumulator for that bank and simultaneously, the revolving drum moves into a corresponding position, causing the check to drop into a pocket which contains all the checks paid for that particular bank. In another type of machine, the checks are dropped into the pockets through slots which are opened upon depression of the keys. The bank proof machine performs the operations of sorting, calculating, summarizing, and recording.



BANK PROOF MACHINE

In terms of basic operations, the billing machine is unique among accounting machines in that it performs all the calculating operations. It also summarizes and records. The billing machine is basically a calculator, coupled with printing devices and carriage mechanisms. However, billing machines have only limited ability to perform sorting operations, such as segregating the billed items into categories.

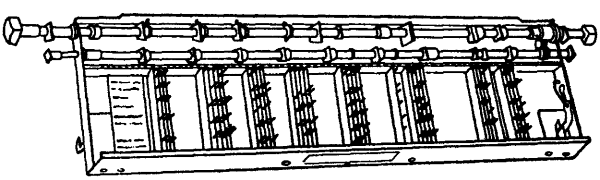
Addressing machines can be adapted to operations other than their basic recording sub-function of transcribing. Some models have a limited ability to sort, using signal devices which cause the acceptance or rejection of plates, according to plan. A few models have a limited ability to summarize information from the metal plates.

Devices to Broaden Flexibility

Multi-purpose machines — those performing more than one basic processing operation — handle a substantial part of the task of data processing. Over the years, there has been a continuing effort to broaden the flexibility of these machines and thus to expand the range of their abilities to perform processing operations.

Flexibility may be improved by increasing the number of adding machines (accumulators) in the device. Or, the mechanisms in carriages or beds may be enlarged, thus increasing the ability to manipulate forms. Keyboards may be expanded and internal mechanisms correspondingly changed, thus making provision for the use, in processing, of alphabetic characters and special symbols, as well as numbers; this may, or may not, entail the installation of additional accumulators. Flexibility also may be improved by increasing the abilities for physical handling in processing, such as the incorporation of receptacles for holding money or documents.

The use of control bars may substantially increase the flexibility of processing. A control bar is a detachable device which functions somewhat like the bar by which the spacing is fixed in typewriting. The control bars in accounting machines have numerous stops, which may be arranged in various patterns, depending upon the requirements of the job to be processed. The stops are arranged in positions in relation to the mechanism so as to control the operations. By employing a series of control bars, each with the stops arranged in a pattern for a particular machine routine, the appropriate control bars may be attached to the machine as operations are changed. In this way, resetting of the mechanism in the various operating patterns, a time-consuming task, is avoided.



A TYPE OF CONTROL BAR

The recent development of electronic data-processing machines already has contributed, indirectly, to improvements in the flexibility, speed, and accuracy of accounting machines. For example, in some types of machines, small electronic calculators have replaced mechanical calculating mechanisms. Similarly, the principle of magnetic media, primarily developed for the electronic system, is being used in some accounting machines. With the aid of special attachments, information on magnetic media is read and fed into the machine, thus providing improved speed and accuracy in processing. The adaptation of various devices in the electronic system to the operation of accounting machines is continuing and promises to broaden still further the uses of these machines.

In partial contrast to the trend toward increasing flexibility, the development of machines for use in certain industries represents a trend to specialized usage of multi-purpose machines. The window-posting machine, used in savings banks, is an illustration of this type of application. The basic characteristics and abilities of these machines do not differ from those of other multi-purpose machines. Special-purpose machines are an adaptation, or tailoring, of machine abilities for a particular use.

Communicating

In a broad sense, the function of communication spans the area of external contacts with groups such as customers, stockholders, and the general public, as well as the transfer of data internally. The present discussion is limited to the latter phase of communication as related to data processing.

Internal communication of data comprises the assembly and transmission of data into the processing routine and distribution of the results of processing to the user of the data. Essentially, communication is a transportation function.

Data may be transmitted either orally or in written form. Oral transmission is used mainly in the interest of immediate speed or convenience, at the risk, however, of error unless the data are subsequently checked against written confirmation.

Written communication involves two aspects: the medium upon which the data are expressed and the method of transportation. The medium may be a sheet or piece of paper, a paper tape or card, or magnetic tape.

Modes of Transportation

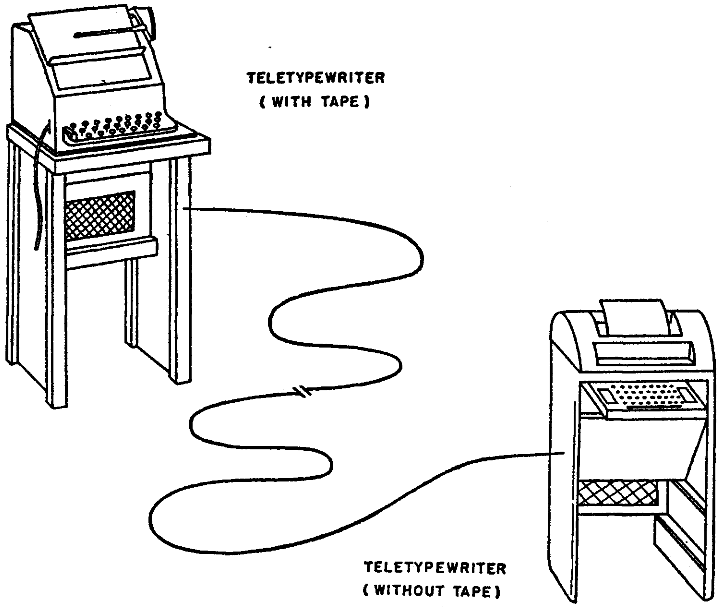
The method of transportation may be manual, mechanical, electrical, or combinations of two or more such methods. The purely manual method, through the use of messengers and so on, is wholly familiar. Among the mechanical methods are devices and arrangements such as special belts, tubes, and other conveying mechanisms, as well as the use of common carriers – rail, truck, and air – and the mails.

Electrical transmission in written form is accomplished by the passage of data through electrical circuits. Mechanical devices usually are employed in sending and receiving the data. Transmission is effected by the use of either telegraph or telephone wires. The data may be turned over to the communications company for transmission or, in establishing a communications network, the sender may lease or purchase the equipment required. The wire itself is leased in nearly all cases.

Transmission by either facility – telegraph or telephone wire – is accomplished by the same basic methods. Two principal types of equipment are employed: Teletype and Transceiver. A third type of equipment, Teledata, recently has been announced. All these types of equipment operate according to the same general principles. Electronic scanning equipment, previously described herein in connection with recording operations, also is used in communication where data are reproduced at locations other than the point of origin.

Teletype Equipment

Teletype equipment consists of typewriters and electrical conversion devices. In the sending operation, the data are manually typed and the machine produces conventional typewriter copy. Simultaneously, by the action of the keystrokes upon the conversion device, the data are transmitted over the wire or, alternatively, a paper tape is produced for use in wire transmission subsequently.



One purpose in producing the paper tape, rather than immediately transmitting the data directly over the wire, is to permit checking the data before transmission. Another is to utilize more efficiently the capacity of the wire. The attainable manual speed of typing is slower than the potential speed of wire transmission. Hence, in order to handle the transmission within the time allotted, it is sometimes necessary to accumulate the output of the operators, on tape, so as to utilize the wire capacity to the extent required. This is known as "off line" operation, since the accumulated output of the operators is typed on dead machines. In contrast, typing on live machines for direct transmission over the wire is known as "on line" operation.

A third purpose for producing paper tape at the sending point is to permit the accumulation of data there in situations where the receiving end is busy. In a communications network, two or more locations may have data ready for transmission to a common receiving point at the same time. If the facilities at the common destination cannot accommodate these data simultaneously, data at some of the sending locations may be stored temporarily on paper tape and later transmitted to the receiving point. Switching centers sometimes are used for the accumulation and transmission of data at convenient intermediate points.

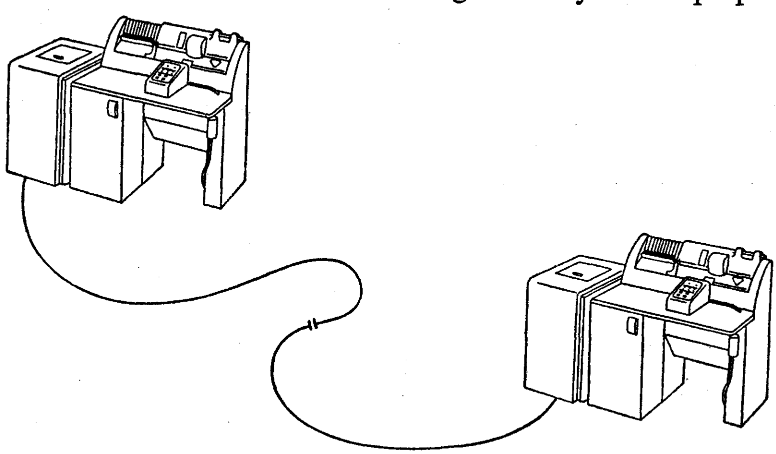
Alternatively, in the sending operation, data upon punched cards may be transcribed, by the use of an electrical conversion device, upon paper tape for transmission by wire. In comparison with the methods previously described, the feeding of punched cards into the conversion device takes the place of transcription by typewriter.

The procedure in the receiving operation is merely the reverse of that in sending except that the receiving operation is always wholly automatic. Data at the point of reception pass into an electrical conversion device which causes either the production of a paper tape or drives a typewriter to produce conventional copy. The purpose in producing paper tape, rather than copy, is to provide a medium for handling the data upon mechanical or electronic equipment.

It is evident from the foregoing that the use of paper tape theoretically is not essential to transmission or reception by wire, i.e., a message may be sent and received by wire merely by the use of a typewriter and a conversion device at each end of the wire. Nevertheless, for the reasons given above, paper tape often is employed.

Transceiver

The Transceiver is a device designed solely for the purpose



of transmitting data from punched card to punched card. Neither a typewriter nor a paper tape is used. The Transceiver is essentially a conversion device. In the operation of the equipment, a Transceiver at the sending end reads the card and transmits the data over the wire. A Transceiver at the receiving end punches the data into a card.

Teledata

Teledata is a device designed solely for the purpose of transmitting data from punched tape to punched tape. No typewriter is used. Teledata also is essentially a conversion device. In the operation of the equipment, a Teledata transmitter-receiver reads punched paper tape and transmits the data over the wire. A transmitter-receiver at the receiving end punches the data into a paper tape.

Codes

To accomplish automatic transmission by wire, it is necessary that numeric and alphabetic characters and other symbols be represented by combinations of pulses, or the absence of pulses, in the electrical circuit. These combinations are arranged in a code form known as channel code.

The data presented for transmission may be expressed either in plain language or in one of the code schemes used in the classification of data. Both these forms of expression may be characterized, for purposes of data processing, as "classification code". The classification code, in either form, of the data to be transmitted will consist of numeric or alphabetic characters or other symbols. For purposes of wire transmission, the classification code must be converted into the channel code used in the electrical circuits.

In the alternative, when punched cards are used, plain language or classification code will be expressed, in patterns of holes upon the cards, in a special code scheme which may be described as "card code". In such case, the card code, for purposes of wire transmission, must likewise be converted into channel code.

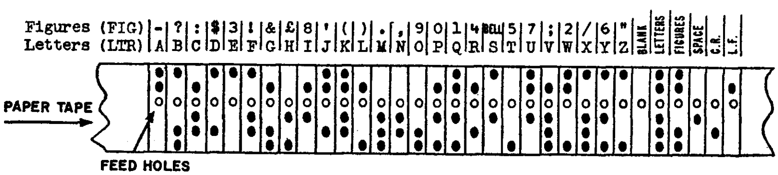
Conversion is accomplished by automatic devices which translate classification or card code into channel code.

Channel codes are not used solely in transmission by wire. They are also used where paper or magnetic tape serves as the medium in interconnecting units of processing equipment operated at the same location, as well as in electronic computers.

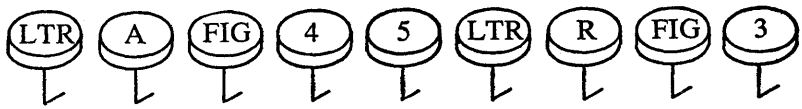
Teletype Code

In transmission by Teletype, the equipment employed is set up to handle a maximum of 32 combinations of pulses and no pulses in the circuitry. When expressed upon paper tape — as is often the case — data appear as combinations of holes and no holes in that medium and these, in turn, become the equivalent of pulses and no pulses in the circuitry. The code employed is arranged in 5 channels, hence the maximum number of attainable code combinations of pulses and no pulses is 2^5, or 32.

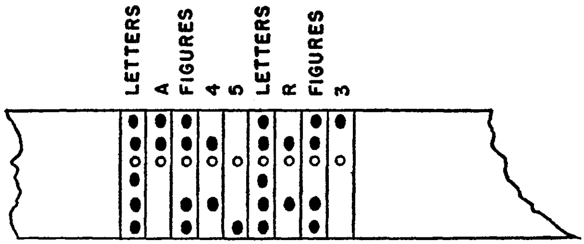
In assigning the 32 combinations available in 5-channel code, 6 are set aside as signals to the equipment to execute basic machine functions. One of these signals is an instruction to print letters and another is an instruction to print figures and symbols. These instructions cause the typewriter type faces to move up or down, thus providing access to a second bank of characters. In this way, the remaining 26 code combinations, coupled with the code instruction signals, can be arranged to represent the 26 alphabetic characters, the ten decimal digits, 15 symbols, and one additional signal, or 52 positions in all. Thus, the assignment of these various positions in 5-channel code may be illustrated as follows:



As an illustration of the translation into 5-channel code, assume that the classification code "A45R3", appearing on a source document, is to be translated into channel code. The classification code would be typed on the Teletypewriter by striking the following keys in sequence:



and the tape would appear as follows:



Where the typewriter is not used, the conversions being from punched cards to paper tape, and conversely, the process is similar. Electrical conversion devices make translations between card codes on the punched cards and the 5-channel code in both the sending and receiving operations. In addition, mechanical devices set the position of the punched card in such a way that the card codes will appear on the card, at the receiving end, in the correct fields on the card.

Possible Disadvantages

The 5-channel code used in Teletype transmission was first developed many years ago for the purpose of transmitting commercial telegrams. It has proved to be highly satisfactory for that purpose and has long been established in the design of communication equipment. However, for purposes of transmitting data, 5-channel code has two disadvantages, which may, or may not, have practical significance, depending upon the purpose of the transmission. Both these possible disadvantages stem from the limited number of channels. The first is the restricted number of symbols available in the code combinations. A disadvantage which may be more serious is the limited ability to detect inaccuracies. Electrical pulses transmitted over a wire are subject to electrical interferences which may cause occasional distortion. Thus, even though the data be checked for correctness at the sending end, interference may produce inaccuracy at the point of reception. If the data are in plain language, the inaccuracy may be obvious, which should lead to correction; on the other hand, the inaccuracy may not be apparent. If the data are expressed in classification or card code, rather than plain language, errors usually will not be evident.

This disadvantage of possible undetected errors tends to restrict the use of the 5-channel code for the purpose of transmitting data by Teletype in data processing. To overcome this disadvantage, there are two alternatives. Checking procedures, such as the transmission of intermediate totals or even the duplicate transmission of data, may be introduced into the processing routine; or other equipment, utilizing more than 5 channels, may be employed.

Not to be overlooked, however, is the factor of speed of transmission. If additional channels are used, the time required for transmission is increased roughly in proportion to the number of added channels.

Transceiver Code

The Transceiver employs an 8-channel code. In the code scheme, each character — number, letter, or symbol — is represented by four pulses in the circuitry, the only variation between the characters being their placement in the channels. The mechanism not only registers the position of the pulses but counts them as well, to ascertain that four pulses — no more and no less — are transmitted for each character. This feature of the code structure provides a basis for checking accuracy in transmission.

The use of 8 channels makes available a greater number of code combinations than in the case of 5-channel communication employed in teletype equipment. Under the code structure used in 5-channel transmission, the number of available code combinations, as heretofore stated, is 32. As also previously explained, through the design of teletype equipment, it becomes possible to increase the code combinations to 58, 6 for machine functions and 52 for numbers, letters, symbols, etc.

The number of possible code combinations available in 8-channel communication by Transceiver is 70. All of these 70 combinations, however, are assignable to letters, numbers, and symbols, as compared with 52 in 5-channel communication. None is required for machine functions since the machine operation is from one conversion device (Transceiver) to another, without intermediate operations by the use of typewriter or paper tape.

To the present time, the 8-channel code used in the Transceiver has been employed only in that equipment. However, other 8-channel codes, differing in structure from Transceiver code, are used in other types of data-processing equipment for the purpose of transmitting data.

Codes Used in Teledata Equipment

Teledata equipment employs codes of 5, 6, 7, or 8 channels. These codes are also used in other types of equipment. Teledata equipment is used exclusively in wire transmission. Paper tape is used as the medium in all communication by Teledata.

In general, 6-channel code provides both upper and lower case letters in addition to the other characters available in 5-channel code. This code is also used in other types of equipment, such as the input to addressing machines, where wire transmission is not involved.

The 7-channel code is used mainly in electronic computer systems. This code provides, in 6 of the channels, 64 code combinations for letters, figures, and symbols. The 7th channel is used to provide a check upon accuracy in recording and manipulating the data.

The 8-channel codes were originally used in the operation of electric typewriters, not involving transmission by wire. These codes are now also used in wire transmission. The 8-channel codes provide, in general, the code combinations available in 7-channel code as well as, by means of the 8th channel, additional code combinations for machine functions.

Accuracy checks are provided in the code structures of all 7- and 8-channel codes. Teledata equipment has certain features by which the accuracy of transmission by 5- and 6-channel codes is automatically checked.

PUNCHED-CARD METHODS

	Page
The Punched Card	62
The 80-Column Card	62
The 90-Column Card	64
Reading the Card	65
Control Wiring	65
Basic Punched-Card Equipment	67
Key Punch	68
Interpreter – Verifier – Need for Verification	
Sorter	70
Collator	72
Merging – Matching – Sequence Checking	
Reproducer	74
Gang Punching – Mark Sensing	
Calculator	78
Punched-Card Accounting Machine (Tabulator) . .	78
Summary Punching	
Limitations	81
Cyclical Operations	81
Control over Cards	83

PUNCHED-CARD METHODS

With the development of punched-card equipment there became available, for the first time, a method for the mechanization of data processing on a broad scale. The earlier punched-card equipment made its appearance about 1890. Following a period in which improvements were introduced and usage gradually widened, the transition to extensive usage of punched-card equipment began in this country about twenty-five to thirty years ago. Today, punched-card equipment is employed in a multiplicity of applications, both in business and government.

Punched-card equipment performs four of the six basic operations in data processing: sorting, calculating, summarizing, and recording. The operation of classification precedes the entry of data into the punched-card system. Punched-card equipment does not, in itself, communicate data; the data must be brought to and taken from the equipment by other means.

Fundamentally, the principal characteristics and advantages of the punched-card method are:

The foundation of the method lies in the representation of data by holes in a card. The holes serve as signals to activate mechanical and electrical equipment.

The card provides a constant medium as a basis for containing and processing data. The card is compact, uniform in size, easily stored or moved from place to place, and easily duplicated.

The equipment is highly automatic in operation. Preparation of the card itself is accomplished by keystroke. Under certain conditions, the keystroke itself may be performed automatically. Having performed this initial operation, together with setting up the required circuitry in the equipment, all successive operations of the equipment are performed automatically, save for transporting the cards from one machine or location to another. No further manual operations are necessary.

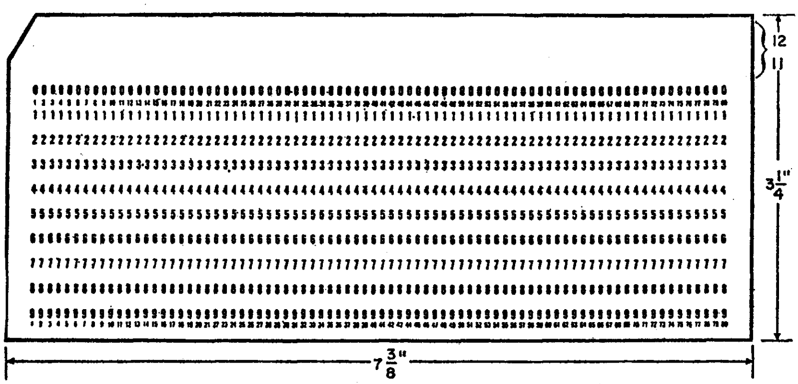
Thus the punched-card method eliminates much of the human effort required in the processing of data under manual or other mechanical methods. Generally, the method is best suited to situations that are characterized by large volumes of data-processing operations and where the processing routine can be so organized as to involve few exceptions to a common pattern, thus minimizing the need for human intervention and decision.

The Punched Card

For the purpose of machine processing, the sole function of the card is that of a medium for expressing the code classifications of data. The card used in data processing is a thin, high-quality paperboard. The card must be cut to precise dimension in order to assure uniform placement of the holes used as the basis of processing.

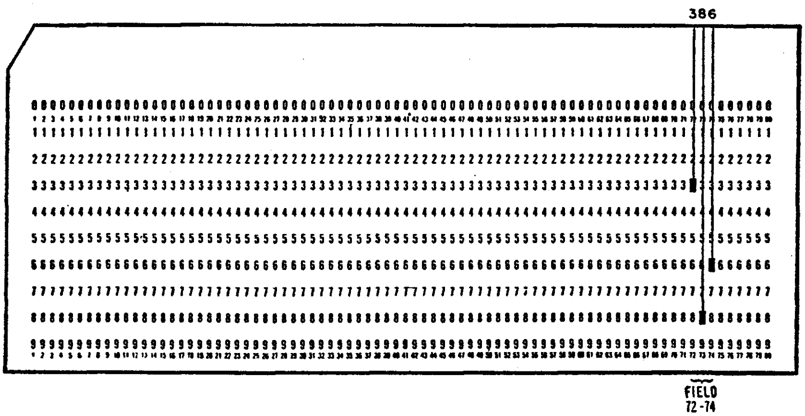
The 80-Column Card

A standard card used by one manufacturer contains eighty vertical columns and twelve horizontal rows, as follows:



The horizontal rows 11 and 12, although understood to be applicable to the positions indicated in the illustration, appear as blank areas upon the card.

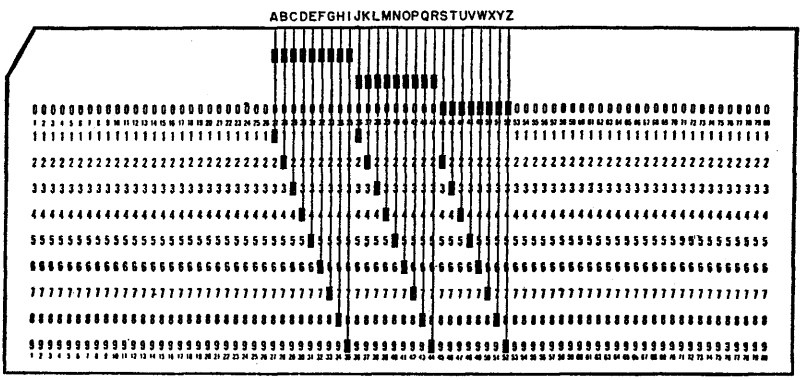
In planning the use of the card, the eighty columns are divided into fields. For example, if one of the classifications to be expressed on the card were the salesmen's route numbers and the classification code for route numbers contained a maximum number of three digits, then a field of three vertical columns would be set aside for that classification. Assuming field 72 to 74 to have been reserved for route numbers, the route number 386, when punched into the card, would appear on the card as follows:



The horizontal rows 1 to 9 are known as digit punches and the rows 11, 12, and 0 as zone punches.

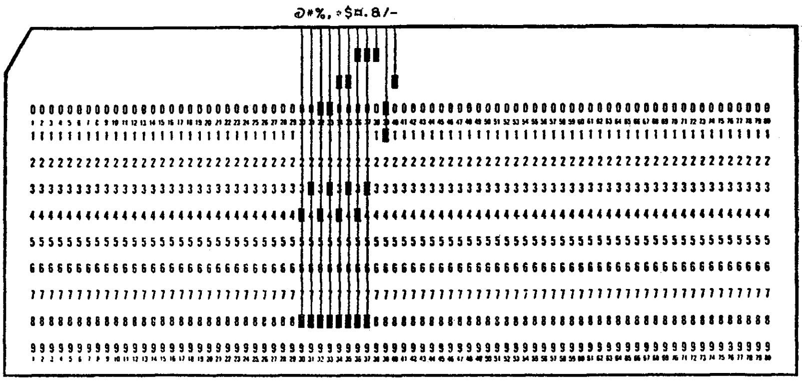
Classification code numbers — such as the route number 386 shown in the foregoing illustration — are shown by using the digit punches and the 0 zone punch. Classification code letters and symbols are shown by using the digit and zone punches in special arrangements or combinations.

The combinations for indicating letters and symbols are standard. The punching scheme to indicate letters is shown in the following illustration:



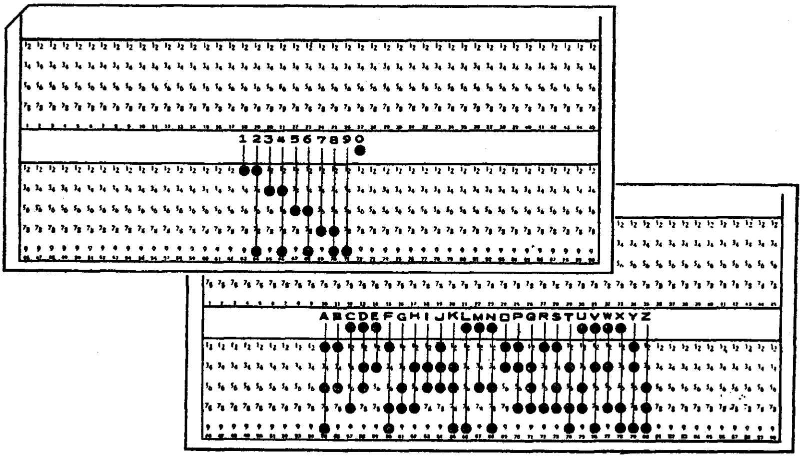
It will be observed that each letter is represented by combinations of one zone and one digit punch in the same vertical columns. Both holes are punched simultaneously, by single keystroke.

Symbols are represented by the following combinations of punches, also in the same vertical column: 1 zone and 1 digit, 1 zone and 2 digits, 2 digits, and 1 zone. The following illustration shows the punching scheme used to denote symbols:



The 90-Column Card

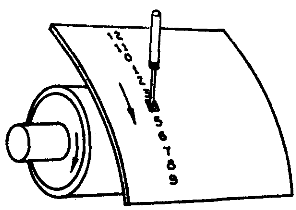
Other manufacturers use cards with varying numbers of vertical columns and horizontal rows. For example, one other manufacturer uses a card arranged in two banks, each consisting of forty-five vertical columns and six horizontal rows. Data may be entered in either bank, thus providing ninety columns for the entry of information. In the punching scheme, numbers are represented as holes in one position or in combinations of two positions and alphabetic characters are represented by holes in combinations of two or three positions. The following illustrations indicate the punching scheme for the 90-column card:



Reading the Card

The holes in the card must be interpreted, or sensed, by the equipment so as to activate the machines for the purpose of processing. Sensing is accomplished mechanically, electrically, or electronically.

In the electrical sensing process, the card is fed into a device which passes the card over a metal drum and under a series of metal reading brushes. As a metal brush passes over a hole, contact is made with the metal drum which sends an electrical impulse into and through the brush. The impulse is identified in the equipment, first, by association with the location of the specific brush picking up the current, which corresponds to the location of the vertical column on the card, and second, by the timing of the impulse, which corresponds to the position of the horizontal row on the card. This process is roughly illustrated as follows:



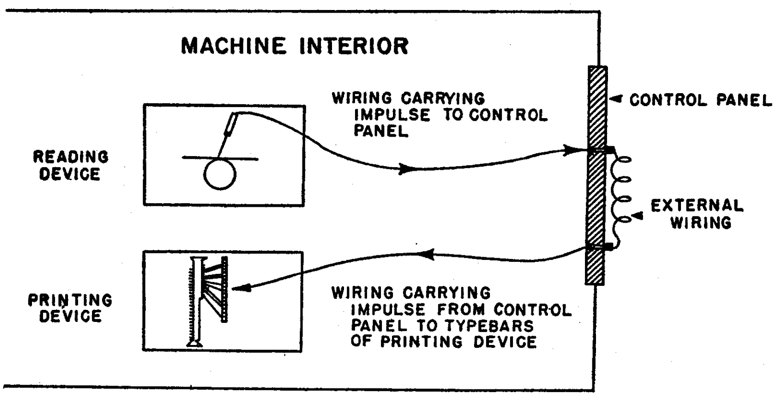
In sensing cards mechanically, the equipment is activated by metal pins which pass through the holes in the card.

Some newer equipment senses holes in punched cards electronically.

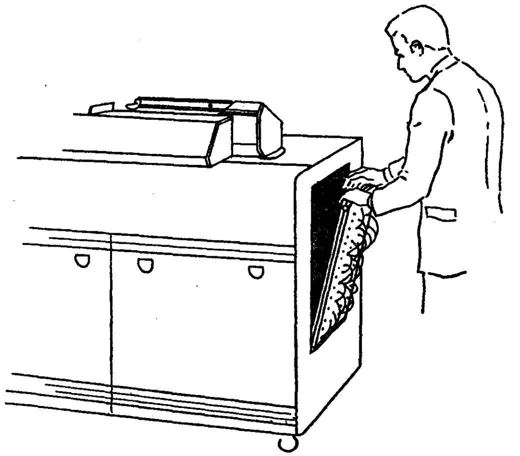
Control Wiring

Having sensed the holes in the card, there remains the step of directing the electrical or mechanical energy generated in the sensing mechanism in such a way as to produce the required operations by the equipment. One way in which the energy may be so directed is by means of a control panel, sometimes referred to as a plug-board. The control panel provides flexibility by permitting interconnections in a broad variety of patterns.

The control panel operates in a manner similar to that of a switchboard. The purpose, in the operation, is to direct the impulses generated in the sensing mechanism of one part of the equipment into circuits leading to other parts of the equipment. The brushes in the sensing mechanism are connected internally to the control panel. Wires leading to other parts of the equipment also are connected internally to the control panel. The circuits are linked together through the use of plugs which are themselves interconnected by wires. The plugs are inserted externally, in appropriate holes in the face of the control panel, causing contact to be made with the internal connections to the equipment. The wires running between the plugs provide a path for linking together the circuits within the equipment. To illustrate, if it be desired to print the information in certain fields of a series of cards, the impulses from the sensing circuits would be directed to printing devices by linking together, through the control panel, the circuits to these two parts of the equipment.



The control panel may be likened to a nerve center. The wiring of control panels and the interconnection of circuits in large-scale processing operations involve complex techniques requiring specialized skill. The external frame of the control panel, consisting of the face and the plug-connected wires, is detachable. Accordingly, external frames as wired for the respective routines in punched-card processing are maintained on file, for attachment to the equipment as required.



INSERTING A CONTROL PANEL

Another way of directing energy from the sensing mechanism is by means of wiring units. In this method, wires serve as the carriers of mechanical energy from the sensing mechanism, causing activation of the equipment. Wiring units also are detachable and may be interchanged as required.

Basic Punched-Card Equipment

The card provides the medium for containing the data, the sensing mechanism interprets the card, and either fixed wiring, the control panel, or wiring units provide the means for directing the course of the processing operations. The sensing mechanism, control panel, and wiring unit, however, are not self-contained and separate devices. Rather, they are integral parts of certain punched-card machines.

The primary punched-card machines (always operating upon the card) required to perform the four basic data-processing operations of the punched-card system are the key punch, the sorter, the reproducer, the punched-card accounting machine (usually referred to as the tabulator), and the calculator. In practice — and for reasons which will appear later — the calculator frequently is not required; also, an additional machine, the collator, is extensively used in many processing routines.

The principal items of auxiliary equipment, sometimes used in combination with the primary machines, are the verifier and the interpreter.

Key Punch

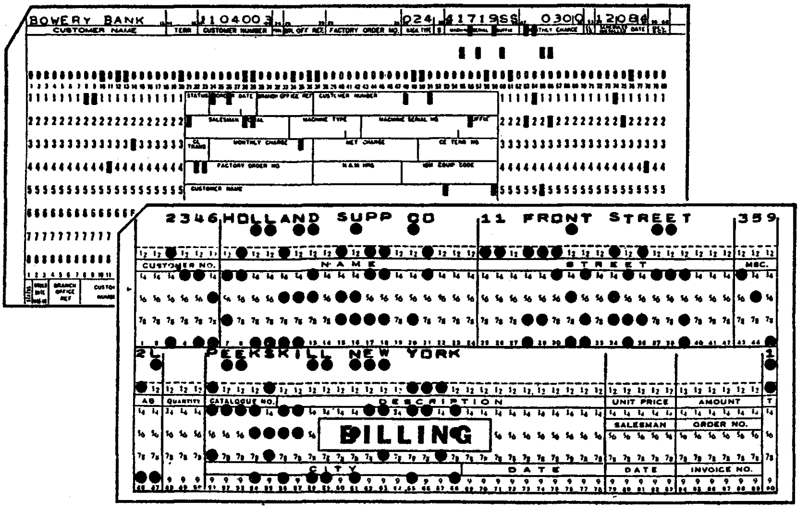
The key punch is a recording device. It serves to record data by entering them upon cards in the form of representative punched holes. It may be described as a key-driven punch die.

The key punch is operated manually by depressing keys set upon a keyboard. The card is mounted upon a mechanism, a part of the key-punch machine, which correctly aligns the card to permit punching in the designated fields of the card. In one type of key punch, the card moves laterally and punching proceeds from column to column. In another type of key punch, the card remains in a stationary position, and following depression of the keys, the mechanism is tripped, causing all information to be punched into the card simultaneously.

In laying out the fields on the card, it is important to conform the order of the fields, to the extent practicable, to the order in which the classification codes appear upon the source document. This speeds up the key-punching process, since the operator, working from the source document, may punch the codes in straight order.

Interpreter

Visual interpretation of the holes in a punched card is difficult. In some situations – usually for purposes of reference – it is convenient to have a means of ascertaining, at a glance, the code contents of all or part of a card. The interpreter meets this need. The interpreter consists of a sensing device and a printing mechanism, linked together by a control panel or fixed wiring. The machine reads data recorded in the form of holes in the card and prints the data on the card. Following are illustrations of interpreted cards:



One type of machine, the printing card punch, combines the operations of the key punch and the interpreter by printing the classification codes upon the top horizontal edge of the card simultaneously with the key-punching operation.

Verifier

Obviously, the accuracy of all subsequent card processing depends upon the accuracy of the original punching of the card. The verifier affords a means of checking the correctness of the original punching.

The mechanism of the verifier is the same as that of the key punch, with certain additional features. The verifier of one manufacturer performs the checking operation in the following manner:

Cards, as previously punched, are placed in the feeding hopper. Working from the source document, the operator depresses the keys on the verifier. If the keystrokes, denoting the codes, fall into the same positions as did those in the original punching, the verifier causes a small nick to be cut along a vertical edge of the card. If the positions of the holes indicated by the two operations do not coincide, the verifier locks temporarily and causes a small nick to be cut along a horizontal edge of the card. Subsequent visual inspection reveals the incorrect cards.

A similar machine of another manufacturer, upon depression of the keys, slightly elongates all correct holes. The incorrect cards — those having one or more round holes — are signalled by a reading device which, upon encountering a card with a round hole, causes a card of a different color (a "signal" card) to be inserted immediately on top of the incorrect card.

Need for Verification

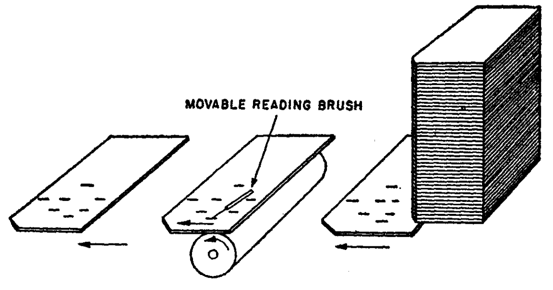
In many situations, it is unnecessary to verify the original punching of the card by the use of these special verification devices, or indeed to verify it at all. Numeric information as punched in the card may be corroborated by accumulating totals of the data as punched and comparing them with totals independently accumulated at another stage in the processing routine. Alphabetic information may not require checking in cases where the errors would be obvious and would not cause harm or inconvenience. If the card has been interpreted, perhaps verification may be made more readily by visual inspection than by machine process. If a group of cards contains data having one or more common classifications, the classifications may be verified by visual inspection.

Sorter

The sorter consists of a reading device, a rack of pockets, and a mechanism to shunt the cards into their appropriate pockets. The machine operates by using the reverse-digit method of sorting.

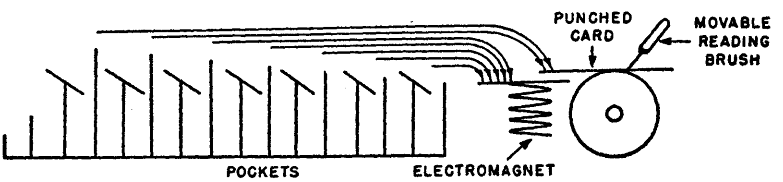
While the following description covers generally the operation of the mechanical sorter of one manufacturer, all sorters, whether mechanical or electrical, operate according to the same general principles.

There is one brush in the reading device. The card moves past the reading device, from right to left, as illustrated in the following drawing:



The brush is first set to sense the hole in the furthest position at the right in the fields to be sorted. All the cards to be sorted are moved past the brush in this position, whereupon the position of the brush is reset to sense the hole in the position to the left of the first position sorted, and so on until the fields have been completely sorted.

Following contact with the brush, the card moves past a layer of blades of varying lengths, the ends being arranged in staggered order, thus:



When the brush senses a hole in the position sorted, an electrical impulse is passed to an electromagnet underneath the series of blades. The magnet causes the appropriate number of blades to be depressed, thus opening a passage between the blades. The card moves through this passage, which forms a chute to the corresponding pocket where all cards having holes in the same position become stacked.

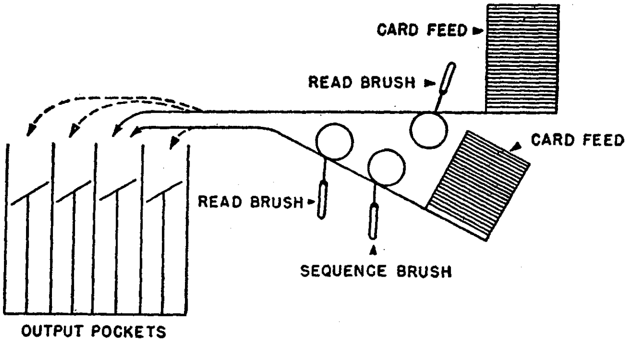
The sorting rack contains thirteen pockets — nine for digits (1 to 9), three for zones (0, 11, and 12, singly or in combination with one or more digits), and one for rejects. Cards having zone positions used in representing alphabetic characters must be sorted twice: first by digits and second by zones. The reject pocket receives those cards not applicable to the planned sorting selection.

In the more recent models of sorters, the cards are sensed by photoelectric means, thus increasing the sorting speed. Speeds of sorting range from 450 cards a minute by mechanical devices to 1,000 cards a minute by electronic machines. The significant speed in the individual case, however, is the effective sorting speed for the particular routine. To determine this, the rated card speed must be divided by the number of positions to be sorted; also, allowance must be made for card-handling time, a factor which may be of material significance.

Collator

A very important auxiliary device widely employed in sorting by machine is the collator. This device is used in merging and matching. All sorters have the ability to perform the operation of merging but the collator performs this operation at greatly superior speeds. The ability of sorters to perform the operation of matching is limited.

The collator consists of two reading devices, a comparing mechanism, a rack of output pockets, and a control panel. In contrast to the sorter, which controls only one column at a time, the collator handles several columns simultaneously. The comparing mechanism of the collator has the ability to compare code magnitudes as sensed by the reading brushes and to cause the activation of the equipment in accordance with the result of the comparison. The collator may be illustrated, in diagram form, as follows:



Merging

Merging consists of the rearrangement of two files into one, in sequence. Before the merging operation begins, the two separate files are arranged in the same basic sequence. For example, if the purpose of the merging operation were to compile a consolidated list of parts at all locations, the separate groups of cards covering the parts for each location would first be arranged in sequence, say, by part numbers.

In the merging operation, the two stacks of cards, each arranged in the same basic code sequence, are placed in the collator adjacent to the reading devices. The basic code sequence may be either from low to high, or conversely. In the following discussion, it will be assumed that the cards are arranged low to high, with the highest number on top and the lowest number on the bottom in each stack.

As the cards are sensed by the two readers, simultaneously from the bottom of each stack, the comparing mechanism compares the code magnitudes. The card having the lower magnitude passes to the output pocket; the remaining card, from the other stack being merged, is held at the reading station. A second card from the stack which produced the card of lower magnitude in the first comparison is then sensed, the comparison operation is repeated, the lower-numbered card is ejected to the output pocket, and so on, successively, until the two stacks of cards finally are arranged in the output pocket in sequence. In the event that the code magnitudes of two cards being compared are equal, the card from the stack mounted in the lower position on the machine is passed to the output pocket first.

Matching

The matching operation is similar to that of merging in that two groups of cards are sensed simultaneously. In matching, however, the objective is to identify and segregate codes that are equal whereas in merging the purpose is to select successively the codes of higher (or lower) magnitude. As an example of the matching operation, a stack of cards, containing various items of information as to vendors' invoices that are awaiting payment, might be matched against a second stack of cards representing a master file of vendors for the purpose of obtaining, from the second stack, the addresses of those vendors included in the first stack.

Before matching, the two stacks must be arranged in sequence according to vendors' numbers. In the matching operation, the reading devices sense and the comparison mechanism compares the vendors' code numbers, causing those cards having the same numbers to be ejected together. Unmatched cards are diverted to separate output pockets.

Sequence Checking

Because cards are occasionally misfiled—and thus cards which supposedly are in sequence in fact are not—it is customary, before initiating a merging or matching routine, to check the basic code sequence of the cards.

Sequence checking is performed by passing the cards through the reading device of the collator. The device compares the code on each card with that of the immediately preceding card. If the code on the second card is in basic code sequence with the preceding card, the order of the two cards is correct and the checking continues. If the code on the second card is not in basic code sequence with the preceding card, the machine issues a signal to indicate incorrect sequence, whereupon the card is removed from the stack and inserted manually in its proper place.

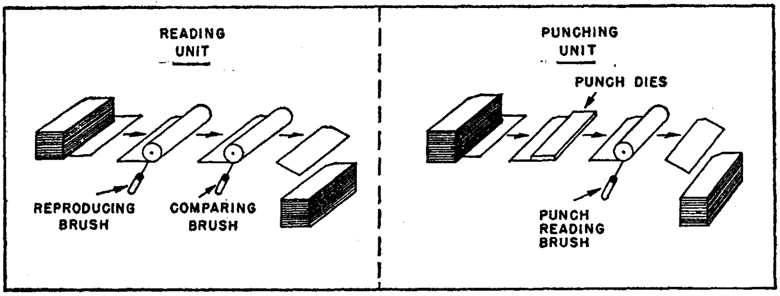
In practice, all or part of the sequence checking operation is performed simultaneously with the operations of matching or merging.

Reproducer

The reproducer is a recording mechanism. It is used to duplicate, on a new card, in the same or different positions, all or part of the data contained on an existing card, or to place constant data upon either a new or an old card.

Duplication of information is frequently required, particularly in the case of routines which are repeated at regular intervals. For example, payroll data for a current period consist of information relating solely to activity for that period, such as hours worked and rate of pay, together with additional information, recorded in the preceding period as well as in the current period, such as employee number and department. The latter type of information thus is a duplication of data previously recorded.

The reproducer of one manufacturer consists of a reading unit, a punching unit, and a control panel. The operation of the machine may be roughly illustrated as follows:



In the duplication operation, the old cards are placed in the reading unit and the new cards in the punching unit. The columns of the old card to be duplicated are sensed by the reproducing brushes in the reading unit. These brushes are connected, through the control panel, to the punch dies in the punching unit. Accordingly, upon sensing, the punch dies are actuated and punch the new card.

After sensing, the old card moves to the comparing mechanism in the reading unit and the new card, after being punched, moves to the reading brushes in the punching unit. These two sets of brushes are interconnected, through the control panel, for the purpose of checking the duplication operation. The brushes sense the holes and the comparison mechanism checks the holes in the old card against those in the new card as a verification of the accuracy of the punching operation. If the comparison reveals no difference, both the old and new cards are released and the operation proceeds to the next cards; if a difference occurs, a signal issues from the equipment.

In the line of equipment of another manufacturer, the operation of reproduction of cards may be performed by either of two types of machines. The first type is a machine which performs the operation of reproduction only and the second group of machines perform certain operations associated with collating, as well as the operation of reproduction.

Gang Punching

The re-use of constant information is often necessary in data processing. A common example is the re-use of dates in various documents. Constant information is inserted into cards by a method known as gang punching.

In the gang-punching operation, the only equipment required is a punching unit, such as that described in the preceding illustration. A master card — blank except for the holes to indicate the constant data — is first inserted in the punching unit. The master card is sensed by the reading brush, which is connected to the punch dies. The electrical impulses from the reading brushes activate the punch dies, causing the dies to duplicate, in the first card in the stack to be processed, the holes sensed from the master card. The first card in the stack then moves to the punch reading brush where it, in turn, is sensed, causing the punch dies to duplicate the constant data in the second card of the stack to be processed, and so on, until the entire operation has been completed.

While the operations of duplication and gang punching are similar, there is one essential difference between the two. In duplication, a series of cards, each one of which may differ in content from the other, are reproduced; in gang punching, the data to be inserted in each card are identical.

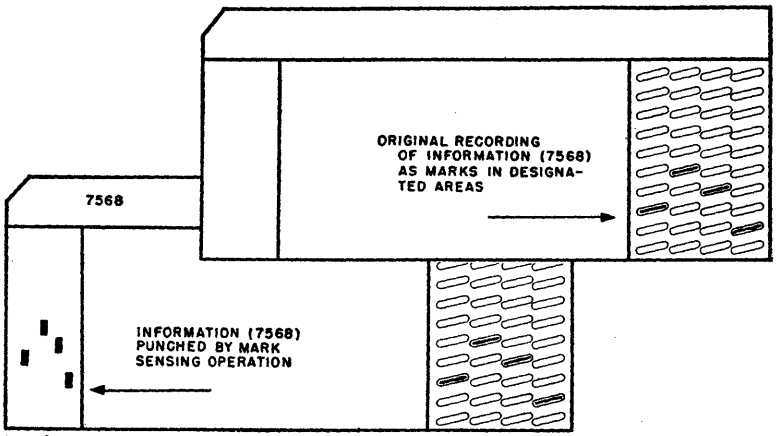
The reproducer may be set up to perform both duplicating and gang punching in one continuous operation. In this way, information in cards may be duplicated by producing new cards and, at the same time, constant information may be inserted into the new cards.

Gang punching is extensively used as a means of calculating. In this process, a series of master cards are used to insert precalculated data as constant information into each card to be processed. Preceding the gang-punching operation, the cards are sorted into all the combinations to which calculation is to be applied. For example, in the case of an hourly payroll, the cards would be sorted according to both rates and hours worked so that all cards showing, say, a rate of $2 an hour and 35 hours worked, $2 and 38 hours, $2.25 an hour and 36 hours, $2.25 and 40 hours, and so on, would be arranged in separate groups. Master cards are then inserted immediately ahead of each group – master cards showing $70, $76, $81, and $90, for example, as applied to the groups illustrated in the preceding sentence – whereupon, by gang punching, the required results of calculation, as shown on the master cards, are inserted into the individual cards to be processed. In this operation, the reproducer is set up, through the control panel, in a manner that permits continuous processing of the cards without interruption as successive master cards are reached.

Mark Sensing

Another important use of the reproducer is the reading of data originally recorded as marks upon a card and the translation of the data into holes in the card – a process known as mark sensing. Although not all models of reproducers have this ability, the reproducer is the only device presently available that will transfer mark-sensed data to cards.

Mark sensing may be illustrated as follows:



In the mark-sensing operation, the data are first recorded manually, with the use of a special type of pencil, as marks upon a card. The marks are sensed electrically in the reproducer, causing activation of the punch dies and thus the recording of the data in the form of holes in the card. Mark sensing is frequently used in operations such as timekeeping and meter reading. To work smoothly, the marking itself must be carefully done: the marks must be placed accurately upon the original card and the card should be kept clean and not bent or folded.

Calculator

The calculator used in the punched-card system has the ability to perform the basic arithmetic operations of addition, subtraction, multiplication, and division. In terms of general principles, the operations of the calculator are relatively simple in concept. The machine consists of reading brushes, a punching device, a series of registers and accumulators, and a control panel. The reading device senses the data to be operated upon and actuates the computing devices. The latter make the computations and actuate the punching device to record the result as holes in the columns provided on the cards.

However, the internal design of the calculator, with the various computing mechanisms and the intricate circuitry required, is complex. In the older types of calculators, the computing units are rotary-type mechanical devices, actuated and operated electrically.

Recent models of calculators employ electronic devices in the computing operations. The speed of computation is multiplied many times as compared to that attainable in mechanical computing devices. Also, electronic calculators have the ability to perform complex mathematical computations.

Punched-Card Accounting Machine (Tabulator)

The tabulator, above all others, is truly the basic device in the punched-card system. The end results of operations on other mechanisms in the system – useful as they are – are still expressed only as holes in cards. The tabulator summarizes and prints. It takes the data shown as holes in the cards upon the completion of operations by other mechanisms, converts them to plain language, and prints them upon a report or other document.

The principal elements of the tabulator are a reading unit, a printing device, a series of accumulators, and a control panel or wiring unit. The reading unit performs the usual function, in the system, of sensing the holes in the cards. The principal parts of the printing device are type bars or wheels, hammers, and automatic carriages.

The type bars are, in effect, columns of type faces. The bars are arranged vertically and each bar contains the type faces of all the numbers and other characters provided in the system. The hammers are arranged in fixed positions, one hammer for each type bar. Upon activation, the type bar is raised vertically until it reaches the point where the number or character called for is opposite the hammer, whereupon the hammer strikes the bar, causing the character to be printed.

Printing speed is increased by the use of type wheels, incorporated in the more advanced models of tabulators. In this printing method, hammers are not required. Printing is accomplished by moving the print wheel forward at the time the required character has been rotated to the appropriate position opposite the document to be printed.

The automatic carriages are adjustable, thus making possible a wide range of variations in the format of reports and other documents printed by the tabulator.

The accumulators are of the conventional rotary type. The tabulator will add and subtract but is not designed to multiply or divide.

The three components – reading unit, printer, and accumulators – are interconnected through the control panel or wiring unit. The outstanding feature of the tabulator is its flexibility. This is provided largely by the multiplicity of wiring arrangements that may be made, through the control panel or wiring unit, in interconnecting the components of the equipment.

The tabulator will print all or part of the data from all or part of the individual cards, and will accumulate, summarize, and print all or part of the data from all or a part of a group of cards as well as provide intermediate sub-totals. It will produce documents involving external end-use, such as invoices and payroll checks, records for internal use such as changes in ledger accounts, and a broad variety of reports. It has a limited ability to sort, as, for example, by causing receipts and disbursements, or the agings of accounts receivable, to be printed in separate columns of a document or report, and the related totals to be accumulated separately.

Summary Punching

In many situations, it is necessary to prepare a punched card to contain data representing all or part of the end result of a tabulator routine. For example, after processing the activity in a customer's account for a current period by tabulator operation, the printed tabulation will show the balance in the customer's account at the end of the period. This balance, of course, also is the opening balance applicable to the succeeding period. To enable the tabulator later to process the activity in the account for the succeeding period, a card must be prepared showing the balance in the account at the beginning of that period as well as, for identification purposes, the account number of the customer. The card is prepared by an operation known as summary punching.

The distinguishing feature of the operation of summary punching is the insertion, in a new card, of information not shown on any existing card. In the illustration given, the balance to be brought forward is contained in the equipment and upon the printed summary produced by the tabulator. The balance is not shown, however, on any card theretofore used in the processing. This circumstance distinguishes summary punching from reproduction, which is limited to the insertion, in new cards, of information contained in existing cards.

Summary punching is performed by interconnecting the tabulating equipment to a punching unit in such a way as to cause the punching unit to punch the holes in a new card corresponding to the information required. In some models of tabulators, a punching unit is included as an integral part of the tabulating equipment. In the case of other models, in which a punching unit is not included, summary punching is performed through interconnecting the tabulator, by cable, with the punching unit in the reproducer.

Limitations

By performing most of the basic data-processing operations by mechanical means, the punched-card system makes possible great reductions in the human effort required in the data-processing function. The punched-card method has been available for many years, yet there are still many opportunities for successful extension of this method, in business concerns and elsewhere.

On the other hand, there are limits to the effectiveness of the punched-card method in the processing of data. One limitation relates to the handling of exceptions to normal machine routines. The isolated case, or a few exceptions to the pattern of a large mass of data, usually cannot economically be adapted to processing in the system. This limitation is inherent in all mechanical systems. A common illustration of this is occasional payroll terminations. The preferable method of handling such items usually is to process the individual terminations manually, followed by punching a separate card containing the applicable data, rather than running one termination item through the entire payroll routine.

Another limitation is the restricted extent to which the system may be set up to take alternative courses of action in the processing operations, commonly referred to as decision-making ability. The processing of individual items, from their origin to the final result, frequently requires a series of decisions. Certain devices in the system have the ability to make one or two decisions but none has the capacity to make an extensive series of choices. The practical effect is that operations in the punched-card system are conducted in pieces, not as one continuous process. On the other hand, the decision-making abilities of the punched-card system exceed those of other mechanical systems.

Cyclical Operations

Inherent in the operation of the punched-card system is the practice of performing the various repetitive processing routines in cycles. The records produced from processing on this basis cover only the period of time spanned by the current cycle. Thus, in the normal course of operations, the system does not provide a continuous chronological record. In some situations, this may entail inconvenience in obtaining information from the system.

For example, the record of activity in a customer's account for the period of a year comprises a series of separate records of activity, each record covering whatever interval – a day, a week, or a month – has been established as the cycle for the purpose of processing. Furthermore, as a matter of practical arrangement, the tabulator run will be a vertical listing covering the activity in the accounts of all customers for the period of the cycle. The run will show, however, separately as to each customer, the balance in the account at the beginning of the period, the individual charges and credits, and the balance at the end of the period. It is not practicable, in the punched-card system, to interrupt the tabulator run to insert, individually as to each customer, the record for the preceding period, run the record of current activity, and thus to produce a cumulative individual customer's record. Therefore, in order to obtain the complete history of a customer's account for the period of a year, it would be necessary to refer to a series of tabulator runs.

A collateral inconvenience stemming from the lack of a continuous record form and the practical necessity of processing in cycles, is that special procedures must be adopted in order to ascertain the status of an individual account at any intermediate time within the period of the processing cycle. For example, if the customers' accounts are processed once a week, to determine the balance of a customer's account in the middle of a week – at that time – it would be necessary to refer to the last preceding run, to obtain the cards showing activity since the close of the period covered by the preceding run, and from these, to compute – in many cases, manually – the new balance.

A chronological historical record may be provided in the punched-card system. To do so, however, necessitates further operations beyond those required in the cyclical routines. A separate record must be constructed, to which the transactions of the various cycles are successively carried.

One method of doing this is known as facsimile posting. This is essentially a manual operation. A copy of the tabulator run is prepared as a hectograph master. The hectograph master copy is then placed over the separate record and the applicable data, line by line, are impressed on the record by the spirit method.

In two other available methods, postings are made automatically from punched cards to the separate chronological record.

Control Over Cards

The punched card is the equivalent of source or intermediate documents in manual, and other mechanical, systems. By reason of their compactness and uniform size, punched cards are less likely to become lost than comparable media in other such systems. However, in the event that loss or misfiling of a card occurs, the procedure to locate the missing card is no different in principle from that applicable in other systems. First of all, there must be a means of ascertaining that a card in fact is missing. This feature is covered procedurally by establishing predetermined totals as a check upon each processing operation. Second, there must be a means of identifying the lost card. Procedurally, this is accomplished by comparing the details comprising the predetermined total with the related details developed in the current processing operation.

ELECTRONIC DATA PROCESSING

	Page
Code Forms	86
Code Forms in the Punched-Card System	86
Code Forms in the Electronic System	88
Basic Abilities	89
Principal Components	90
Auxiliary Equipment	91
Programming	92
Reading In	93
Manipulation	94
Writing Out	94

ELECTRONIC DATA PROCESSING

The processing of data electronically is accomplished by manipulating them in electrical circuits. The operation of the electronic system may be broadly explained by comparison with the operation of the punched-card system.

In substance, the operation of the punched-card system consists of the representation of the data in the form of holes in a card, the common medium used in processing through the system; the sensing of the data in the card; and the manipulation of the sensed data by means of fixed wiring, control panels, or wiring units to convey "instructions" to the equipment, causing it to become activated in the manner required.

In the electronic system, the data are represented in the form of magnetic spots upon magnetic tape, inked dots or punched holes in paper tape, or holes in cards. The data are sensed, or "read", and communicated (by conversion from the spots, dots, or holes in which expressed in the medium) to the equipment in the form of pulses and no pulses in the circuitry. A series of instructions for manipulation of the data are prepared and read into the equipment in the same manner. Manipulation of the data then proceeds by the movement of the electrical pulses and no pulses in the system, in conformity with the instructions.

The first broad distinction between the punched-card and electronic systems lies in the method of handling the media, the vehicles used to contain the data, through the system. Processing in the punched-card system is accomplished by mechanical handling of the card media through mechanical devices. The speed of processing is limited by the ability to handle the media. Processing in the electronic system is accomplished by the movement of the media – electrical pulses – through electrical circuits. The speeds of manipulation are far greater than those attainable in mechanical systems.

The second broad distinction between the punched-card and electronic systems is the method of communication between the units of equipment in the system. One of the outstanding features of the electronic system is the emphasis upon interconnection of the equipment, with the objective of making possible a continuous chain of processing from the point where data and instructions are read into the system to the final step of printing out the results. In the punched-card system, communication between units of the equipment is comparatively laborious and much slower. The subject of communication in turn leads to the consideration of code forms.

Code Forms

The complete cycle of processing, under all systems, starts from the point of data, in plain language, upon a source document and ends with a report, or other final document, also in plain language. Thus the complete cycle, in terms of the form in which the data are expressed, is from plain language at the beginning to plain language at the end.

In the course of processing under any system employing mechanical or electrical devices, the data must be expressed at all times in form acceptable to the equipment. The various forms, or systems, used in the expression of data for processing purposes are known as codes. To clarify the distinction as to communication between units of equipment in the punched-card and electronic systems requires an explanation, in some detail, concerning the use of code forms in the two systems.

Code Forms in the Punched-Card System

In the punched-card system, the code forms used in the processing cycle are as follows:

1. The plain language upon the source document is converted to a classification code — an alphabetic, numeric, or alpha-numeric scheme of equivalents.
2. The classification code upon the source document is converted to a card code — the code used in expressing data, in the form of holes, upon the punched card.

From this point onward — the data now being expressed upon cards in a code acceptable for processing — the use of code forms depends upon the course the processing stream must take to accomplish the desired objective of the routine.

3. One stream leads directly to conversion of the card code to plain language. This occurs where all subsequent processing is performed in card code and any required communication between the equipment in the system is accomplished by physically carrying the cards from one machine to another.

4. The other stream leads to conversion of the card code to channel code — a system of representation of data by placement of spots, dots, or holes in various positions in horizontal channels. This occurs where communication between the punched-card machines is accomplished over telegraph or telephone lines, involving the use of transmission equipment. In the transmission of channel code over the wires, the code designations become converted into pulses in electrical circuits. Conversion of card code to channel code also occurs where communication between machines at one location is accomplished by paper tape, rather than physical transference of the cards.

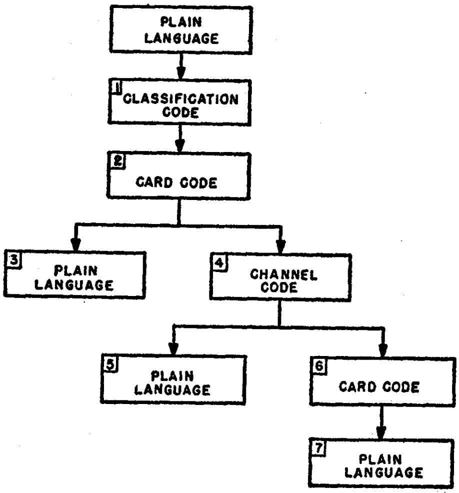
   Again, from this point onward — the data now being expressed in channel code form — the use of code forms depends upon the course the processing stream must take in order to accomplish the desired objective of the routine.

5. One stream leads directly to the conversion of channel code to plain language. This occurs when no further processing — other than a printing operation — is required.

6. The other stream leads to the conversion of channel code to card code. This occurs where additional processing by the punched-card machines is required in the routine.

7. The final step, in this second stream of processing, is the conversion of card code to plain language in the final report or other document.

To summarize, the use of code forms in the punched-card system may be expressed diagrammatically as follows:



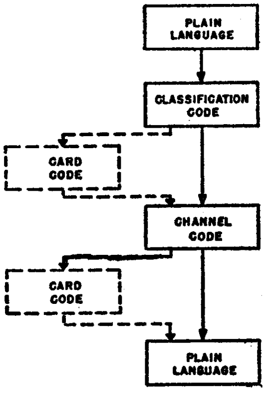
Thus, it will be seen that communication between units of equipment in the punched-card system involves either the physical transference of the card media from one machine to another, or the use of tape or wire media, which necessitates conversion to a different code form.

Code Forms in the Electronic System

In the electronic system, interconnection between those units of the equipment used in the manipulative phases of processing is complete. Only one code form – channel code – is used, although card code is sometimes used in connection with reading data into and out of the system.

As in other data-processing systems, data in plain language upon source documents are first converted to classification code. Data expressed in classification code, and the required series of instructions, are then converted to channel code, or, intermediately to card code and thence to channel code. In the course of processing, the channel code designations become converted into two electrical states in the equipment. Data and instructions, as read into the system, are first conveyed, in the form of electrical pulses, to storage devices where they either remain as electrical pulses, circulating within the medium, or are converted into static charges. From storage, the data and instructions are called forth and moved through the system, in the form of electrical pulses, in accordance with the plan (the instructions) of manipulation. Finally, the data, in the form of pulses, are converted to plain language and printed upon the final report or other document; or, the data are converted intermediately to card code and from that code to plain language upon the report or other document.

The use of code forms in electronic processing may be illustrated diagrammatically as follows:



Thus, in the electronic system, communication between units of the equipment is automatic and the code form remains constant throughout the processing cycle, except to the extent that card code may be used in the input and output stages.

Basic Abilities

Basically, the operation of the electronic system consists of the retention and movement of electrical charges and pulses in the equipment, in a common code form. Coupled with this fundamental concept are certain basic abilities of the equipment. Among these are:

Storage: the system provides space for holding large masses of data.

Access: data can be instantly found and transferred to other locations in the system.

Computation: the system performs all types of mathematical operations.

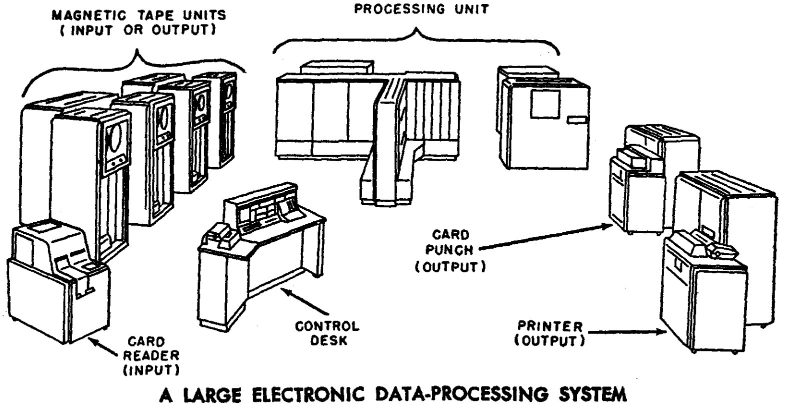
Decision-making: the system has almost unlimited ability to make simple decisions as required in the course of the processing operations and to take alternative predetermined courses of action based upon such decisions.

Speed: in all phases of operation.

By the application of these fundamental concepts and basic abilities, the electronic system is enabled to perform five of the basic operations in data processing: sorting, calculating, recording, summarizing, and communicating. Classification, the initial coding of data, which cannot be organized in a predetermined plan of operation, necessarily must precede the entry of data into the system.

Principal Components*

The heart of the electronic data-processing system is the central processing unit, often called the computer. The processing unit receives instructions and data, stores them in and calls them out of its "memory" as needed in the processing routine, performs arithmetic operations upon them, and has the further ability to make comparisons between numbers or other characters and to take the action called for by the result. It also directs the processing operations within itself and controls the flow of inbound and outbound information.



A LARGE ELECTRONIC DATA-PROCESSING SYSTEM

The processing unit consists of a control unit, a storage device, and an arithmetic unit. The control unit interprets the instructions and directs the various data-processing operations. The storage device, or "memory", receives the instructions and data from the input device, stores intermediate results, and releases information, all as directed by the control unit. The arithmetic unit performs the arithmetic and comparison operations upon data and instructions routed from the storage device, again as directed by the control unit.

Directly linked electrically to the processing unit are devices which "read" information into it and "write" information out of it. These devices are collectively characterized as input equipment and output equipment. The function of the input devices is to read, from the input medium (a tape or card), the data of the problem and the instructions necessary to its solution and to move them into the processing unit. The function of the output devices is to receive the information emitted from the processing unit and to dispose of it as directed by the control unit.

Auxiliary Equipment*

Inbound information fed into the "reading" device must be expressed in, or converted into, the code scheme of the processing unit and conversely, outbound information, emitted from the processing unit through the "writing" device, in the same code scheme must be converted to plain language and transcribed upon the end-use document. To do these things necessitates the use of input preparation equipment and output printing equipment.

Input preparation equipment is technically not considered to be a part of the electronic system. The electronic system begins, or takes over in the data-processing routine as a whole, at the point where the information is "read" into the central processing unit.

Some of the input preparation equipment may be electronic in principle but at least a part of it always is not; the combination of equipment used for this purpose depends upon many factors not of uniform importance in all cases. The significance of excluding all this equipment from the concept of the system may not be, as yet, commonly understood. There is a tendency to visualize the electronic system as one that handles all steps in the data-processing routine. This is a misconception – one with practical implications.

These become apparent by considering the operations performed by the input preparation equipment. A data-processing routine, as a whole, begins at the source documents which constitute the record of the transactions. In the chain of processing between the source documents and the operation of "reading" information into the processing unit, input preparation equipment handles a broad range of operations. The purpose of these steps is to transcribe information from the source documents onto a medium acceptable to the processing unit. The practical significance of this is two-fold: first, to perform these input preparation operations may require the services of many people, operating a large battery of the same types of equipment, such as card and tape punches, as are used in mechanical systems; and second, the speed of performing the operations is still bound by human and mechanical limitations.

Thus data processing, in its entirety, cannot be wholly performed by electronic means at the present time. Nevertheless, the electronic phases of processing encompass a vast area. Moreover, the challenge to overcome the limitations of input preparation equipment has met a strong response, and encouraging progress is being made.

Programming*

Programming consists essentially of analyzing the source data and determining what is to be done with them to produce the required end result. Electronic systems do not think for themselves; they can do only what they are instructed to do. Human beings not only must give the system its instructions; more importantly still as a practical matter, they must do a prodigious amount of work to know what the instructions should be. Programming, in the electronic system, is analogous to the planning of processing in the mechanical system, where the basic data-processing operations are precisely planned in terms of the data to be operated upon, their source, the nature of the operations to be performed by the equipment of the system, and the disposition of the results.

For example, if the routine to be programmed is the processing of sales transactions, the source material may be sales orders and shipping records and the end-use documents may be sales invoices and sales distribution reports. Among other items of information, the sales order and shipping record may show the customer's name and address, the terms of sale, date and route of shipment, description, number, and price per unit of items sold, and transportation or other additional charges. The sales distribution report may show sales by departments, by individual products or lines of products, by salesmen or sales territories, or by geographical units such as states, counties, or cities.

The first step in processing would be the transcription of data from the sales orders and shipping records upon a medium (a tape or card) acceptable to the system. In this connection, it would be necessary to consider the capacities and order of use of input preparation equipment. Also, as a part of the over-all plan of manipulation, the arrangement and sequence of the data upon the medium would be precisely determined.

Reading in

The next step would be to read the raw data into the central processing unit of the system. Beginning at this point and continuing to the end of the routine, each step must be translated into instructions to the system. In connection with the reading-in operation, the instructions must specify the order in which the data are to be read. For example, the sales order data may have been transcribed upon one tape and data from the shipping record upon another. For the purpose of preparing the invoice, these data must be brought together. The instructions therefore must direct the equipment to read segments of each tape in a manner that will cause all data pertaining to the individual order or customer to fall into correct sequence.

Also, in connection with the reading-in operation, it is necessary to decide where the information is to go and to direct the equipment to send it there. All information read into the system is first routed to the storage unit. Obviously, in the plan of manipulation it is necessary to know at all times where to find information as needed in the successive stages of processing. Accordingly, the instructions must assign each item of information to a specific location in the storage unit and must direct the equipment to read the item into that location. This involves not only the allocation of space in a logical manner but also the consideration of available storage space.

Manipulation

Having read the data into the system in required sequence and having filed them in known locations in the storage unit, the next stage in processing is manipulation. In this connection, the instructions must direct the equipment to perform the basic operations of sorting, calculating, and summarizing required to accomplish the end results. In framing these instructions, as well as all others, provision must be made for all possible exceptions to the normal pattern of the routine.

Manipulation having been completed, once again it is necessary to determine where the information, now representing the results of manipulation, is to go and to direct the equipment to send it there. Results of processing are returned to the storage unit. The instructions must specify the spaces in the storage unit where the results are to be filed and must direct the equipment to route them to the assigned locations. Here again, this involves the consideration of storage space as well as the allocation of space in a logical manner. Space is needed simultaneously for data undergoing manipulation, for data representing the results of manipulation, and for the instructions themselves.

Writing Out

The final stage in processing is writing out the results. Output devices write out the results from the storage unit and convert them to end-use form. The instructions must tell the equipment where to get the results, where to write them, and how to write them.

The place where the results are to be found is determined by reference to the storage spaces previously assigned at the conclusion of manipulation. The questions as to where and how to write the results involve the purpose of the end use. Sometimes the results of processing are used as input information in subsequent processing, in which event these intermediate results will be written in coded form upon a tape or other medium for later use. Where the end use is a report document, the results will be written, in report format, upon the document.

To compose the results in report format involves the phase of programming known as editing. Information as emitted from the central processing unit is like very crude copy. It emerges as a stream of numbers and other characters, without placement of decimal points, designation of capitals, punctuation, and the insertion of dollar signs or other symbols. The equipment must be instructed to make the required changes and insertions.

Programming is a lengthy process, involving long study and the preparation of instructions, in minute detail, to direct the equipment.

• Excerpted from "Data Processing by Electronics" (1955) – Haskins & Sells.

INTEGRATED DATA PROCESSING

	Page
Elementary Example of Integration	97
Integration for Efficiency	98
Unification of the System	98
Interconnecting Equipment	99
Media and Codes	100
Wire Communication	100
Problems of Integration	101

INTEGRATED DATA PROCESSING

To integrate means – to quote a dictionary definition – "to unite parts or elements so as to form a whole". The need to do this in data processing has long been recognized. The concept of integration in data processing therefore is not new. However, there has been a new emphasis upon this concept in recent years, stimulated by the advent of new devices – principally tape-operated equipment – which promises to bring the concept nearer to fulfillment.

The objective in integrating, or uniting, operations in data processing is the familiar one of elimination of effort or duplication of effort. The need for integration arises in part from the multiplicity of needs of the users of data. Obviously, if the needs of all users can be met by means of a combined and unified operation, rather than a series of separate operations, there will be resulting economies.

Elementary Example of Integration

As an elementary example of handling the separate needs of several users by applying the concept of integration, consider the situation in a very small office where all work in the processing of sales orders is performed manually by an order clerk, a bookkeeper, and a shipping clerk. All orders are received by mail. Each of the office employees requires some information from each of the orders. One way in which the routine might be accomplished would be for the order clerk to make three copies of each incoming order. Two of the copies would be handed to the other employees and they, in turn, would extract and write out the information they required from their copies.

To integrate these operations, assume that the order document is redesigned as a four-part carbon interleaved form. The first part of the form is a statement for the customer. The second part, different from the first in appearance but having blank spaces for customer's name, address, quantity ordered, and so on, directly aligned under the corresponding blanks on the first part, is a shipping label. The third part is a duplicate of the shipping label with an additional check line for indicating that shipment was made. The last part of the form is a ledger sheet. Thus the routine has been reduced to "one writing", a basic principle in the integration of data processing.

In this simple example, by the redesign of an order form, the processing operation has become integrated and the operations previously performed by the shipping clerk and the bookkeeper have been eliminated. The incoming information has been captured at the source in a form that will allow it to flow through the office without ever being recopied.

Integration for Efficiency

Assuming, however, that the needs of users have been met in a unified plan of operation, there may be, nevertheless, a second need for integration: the need to integrate in order to raise the level of the efficiency in processing. The principal obstacle to the attainment of maximum efficiency heretofore has been the inability, or limited ability, to interconnect units of equipment within the processing system. To the extent that interconnection may be made, the flow of processing between the units of the system becomes a straight-line continuous operation, accomplished with a minimum of human intervention and effort.

Unification of the System

Interconnecting of the equipment, however, is only the final step in the application of integration. To pave the way, the system of processing must be unified.

In unifying the system, there are three principal objectives. These are, first, to bring into the source documents as much data as practicable so that they may serve as the basis of processing for as many needs as possible; second, to achieve, again as nearly as practicable, uniformity in design of forms and reports applicable to common activities; and third, to employ media for containing the data that will be acceptable to all machines in the chain of processing.

Unification of the system leads into the consideration of needs and preferences within the various departments of the organization. Assume, for example, that the data-processing operations of Divisions A and B, whose business activities are similar, are to be incorporated in an integrated system. The output from the processing of one Division must be upon media acceptable to the equipment of the other. Also, agreement must be reached on forms, procedures, and reports. Integration can always be achieved by resolving these arbitrarily, but frequently considerable effort is necessary to arrive at acceptable compromises. Unification of the system usually is a large-scale job, extending into analysis and coordination of all forms, procedures, and reports affected by the processing plan.

Because it is impossible to reduce all types of data-processing routines to a single pattern, integration must be approached in segments, by dealing separately with the complete processing routines involved in the respective activities of the business, such as sales, production, and purchasing.

Interconnecting Equipment

Various types of equipment may be used in the integrated system – typewriters, calculators, accounting machines, punched-card equipment, and electronic devices and systems. Interconnection requires media acceptable to the machines in the system. Since the only media presently available for purposes of automatic operation are paper or magnetic tape and punched cards, the media must be one or more of these. Each machine in the system must be capable of producing, or of being activated by, a tape or card. The medium need not be the same throughout the processing routine as a whole, since devices are available to convert tape to cards, and conversely. Conversion, however, involves additional time and cost.

Integration may be partial, as well as complete, within a given routine. For example, if it is impracticable to produce a tape or card at a very early stage in the routine, integration may be effected only from the next point in the chain of processing. A large part of the difficulty in the field of integration, in fact, lies in the application of integration techniques in these earlier stages, particularly as related to source documents. The ultimate objective always is, however, to push the applications, if not all the way, at least as far back toward the sources of data as practicable.

Media and Codes

The problem of interconnection is basically a problem of media. This, in turn, involves the matter of codes. The forms in which codes are represented upon the various types of media are as follows:

Medium	*Form in which code is represented in the medium*
Cards	Patterns of holes in various positions (card code)
Paper tape	Patterns of holes in various channels (channel code)
Magnetic tape and discs	Patterns of magnetic spots in various channels (channel code)
Electric wire	Patterns of pulses in the circuit (corresponding to channel code)

The various media may not be used interchangeably upon all types of processing equipment. For various reasons, equipment which will operate only upon one type of medium may be best suited to one part of a processing routine while equipment requiring a different medium may be the most efficient in other parts of the processing operations. Thus, the media used in the respective areas of processing may vary; or, the code forms upon the same medium may be different. Whenever the media or the code forms within the system vary, a problem of conversion arises. While conversion always can be effected, it should be minimized, since it increases the time and cost of operation.

Wire Communication

If all of the integrated processing operations are carried out at one location, and if different types of media or codes are used in the application, a problem of conversion will arise. There will be no further problem, however, attributable to the fact that the media or code schemes are different.

If the integrated operations are conducted at more than one location, a second problem may be involved. In the course of processing, it will be necessary to communicate between the locations. If the use of physical means of communication – the mails, and so on – is impracticable, communication must be effected by wire transmission. It is this circumstance that creates the second problem.

Communication by Teletype, the equipment used by or leased from the communications companies, is by 5-channel code. This code is sometimes characterized as the "common language medium." Because of the limited number of channels, 5-channel Teletype code cannot be relied upon to detect occasional errors in transmission. Various means may be employed to meet this problem.

Checking procedures, such as transmitting intermediate totals or even duplicate transmission of the data, may be introduced into the processing routine; however, such procedures may be impracticable or not wholly effective. Teledata equipment provides a self-checking feature in 5-channel communication.

Another alternative is to employ a different code structure. While other devices are now under development, the only equipment presently available for wire transmission and reception in code channels in excess of 5 are the Transceiver and Teledata. The Transceiver, however, can be employed only to transmit data in punched cards at the sending point for transcription into punched cards at the point of destination. Thus, if the Transceiver is used, additional conversions – from tape to cards at the sending point and from cards to tape at the receiving end – may be required in the integrated operation.

Problems of Integration

To integrate the processing of data may be a simple matter or, at the other extreme, a highly complex task. The magnitude of the attendant problems depends upon the size of the enterprise, the nature of its operation, and the type of its organization. In most of the complicated situations, the major problem is likely to be the manifold considerations – sometimes reaching into virtually all areas of the enterprise – to be resolved in the unification of the system of processing. In so far as equipment is concerned, the principal problem is wire communication.

Attempts at integration serve to challenge existing routines, resulting in worthwhile economies and improvements in efficiency, even though the extent of integration be less than complete.

ORGANIZATION AND CONTROL OF DATA-PROCESSING ACTIVITIES

	Page
Organization	103
Techniques and Procedures	104
Procedure Manuals	104
Flow Charts	105
Forms Design and Control	105
Job Analysis	106
Machine Work-Load Charts	106
Control Over Costs	107

ORGANIZATION AND CONTROL OF DATA-PROCESSING ACTIVITIES

The emphasis, in this study, has been directed at the basic data-processing operations of classifying, sorting, calculating, summarizing, recording, and communicating – their nature and the manner in which they are performed, both manually and with the aid of various devices and systems. A basic knowledge of these operations is a prerequisite to a thorough grasp of the problems in data processing.

However, the foundation for getting the processing job done – and done efficiently, quickly, and at the lowest practicable cost – involves more than a knowledge of basic operations and methods. There must also be an understanding of the organization for data processing and of the techniques and procedures which serve as guides in determining the manner of performing the work.

The organization and control of data-processing activities is a broad subject, extending into various detailed procedures and practices. The discussion here is confined to condensed comments upon the main areas of interest in this field.

Organization

In common with good principles of organization applicable everywhere, the responsibilities and authorities of the various people engaged in the data-processing activity should be clearly defined. Effective supervision is important in raising the level of efficiency in the various data-processing operations. Ideally, in the plan of organization, it is desirable to separate the execution of the work from the purely planning function.

In the planning area, methods and procedures groups have done important work. These specialists, assigned to the task of keeping abreast of technical developments, serving in an advisory capacity, and divorced from the work of day-to-day operation of the system, have contributed significantly to improving the efficiency and increasing the usefulness of data processing. Consultants from outside the organization also have made valuable contributions in this area.

Techniques and Procedures

There are various techniques and procedures that have proved to be effective in planning and organizing the data-processing job. Among these are the preparation of procedure manuals and flow charts, the study of forms design and forms control, the planning of human and machine work loads based upon job analyses, and cost determinations.

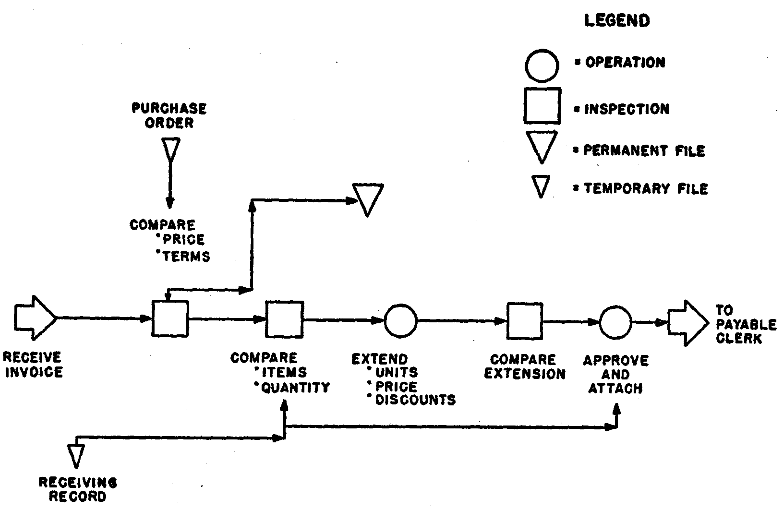
There are three key factors involved in making a choice of data-processing methods. These are: speed, accuracy, and economy. The relative importance of these factors is not always the same, however, and compromises therefore must or may sometimes be made. For example, payroll checks must be issued accurately and on time; therefore economy must be sacrificed, if necessary, in the prime interests of speed and accuracy. On the other hand, strict accuracy in some types of reports may not be essential, speed and economy being the more important considerations. Similarly, in other types of reports, accuracy and economy may be important but there may be considerable flexibility as to the times of issuance. The relative importance of the three factors affects the planning of the data-processing operations.

Procedure Manuals

Procedure manuals serve two purposes. First, the very act of preparing them tends to promote better organization and efficiency in data-processing operations since, in order to prepare a manual, the various routines must be analyzed and appraised. Second, the contents of the manual provide a valuable guide and source of reference in the performance of the work. In practice, the contents of procedure manuals vary, depending upon needs or preferences. Usually incorporated in the manuals are a detailed series of specifications as to each processing routine, showing the sources from which the data will be received, the time of receipt, forms and machines to be used in the routine, the nature of and manner of performing the various operations, the scheduled time for completion of the routine, and the distribution of the reports or other documents constituting the results of the processing.

Flow Charts

The procedure flow chart, widely used as an industrial engineering technique in the study of plant operations, also is adaptable as an effective tool in the planning of data-processing operations. In the chart, a scheme of symbols is used to designate basic functions – an operation, an inspection, a move, a filing, or a delay. The symbols are connected in sequence with notations to indicate type of operation, forms used, distribution of copies, or any other data deemed pertinent to the presentation of the routine. The procedural flow is indicated by lines on the chart, starting with the introduction of each source document into the data-processing stream and ending with the production of the final report or document. Flow charts frequently reveal unnecessary procedures or reports. Also, they are highly useful in developing written procedures. Following is an example of one type of simple flow chart, illustrating a small portion of the audit steps in a vouchers payable operation:



Forms Design and Control

Forms design, and the related subject of forms control, cover a wide range of detail. The objective in forms design is so to arrange the data upon media (forms) as to best facilitate the performance of the data-processing operations. Forms design is a specialized skill, requiring knowledge not only of techniques of arrangement but also of machine characteristics and capabilities.

Forms control is the application of standardization, in so far as practicable, to forms requirements. It includes such matters as color, size, and grades of paper to be used, minimization in number and variety of forms and stock quantities, and ordering procedures. Forms design and control are important in controlling the cost of data processing.

Job Analysis

The purpose of job analysis is to provide a guide for the planning of processing operations. Each processing operation is analyzed into its component parts, to determine the detailed steps within each operation and the time required to perform each step. Preparation of the analysis may, in itself, suggest better procedures. As a basis for laying out processing schedules in day-to-day planning, the detailed steps and time requirements shown on the master analyses are related to the volume of data to be processed. Subsequent comparison of the scheduled times with actual operating times serves as a check upon efficiency.

Job analysis also serves to bring into focus and to suggest solutions to the grading problem, that is, whether the abilities called for in the various operational steps are higher or lower than the abilities of the employees assigned to their performance.

Machine Work-Load Charts

The machine work-load chart is used in much the same way as job analysis schedules. Machine work-load charts are prepared by plotting available machine time against the time requirements for each piece or group of equipment under the processing schedule. In this way, peak requirements and unscheduled time are determined. Also, the charts may reveal a need for rearrangement of schedules or perhaps even for acquisition or disposal of equipment. When processing schedules are already tight, actions such as changing the date for completion of a few reports may require drastic rearrangements.

When used in conjunction with job analysis, the machine work-load chart serves to determine standard time requirements and as a basis for comparing the standards against actual performance. Sub-standard performance, if the standards are reliable, may indicate a need for closer supervision.

Control Over Costs

There is a growing awareness of the need for better control over the costs of data processing. Effective control is based upon knowledge and discipline. There must be intimate knowledge of costs under present and alternative methods of operation. There must be discipline by enforcing adherence to cost standards.

Techniques and procedures such as those previously described — job analysis, forms design and control, etc. — founded, in turn, upon knowledge of basic procedures and devices, provide the means for ascertaining present and alternative costs. Money costs, as the criteria in cost control, must be reduced to an acceptable basis of measurement such as cost by centers of operation, by individual operation or groups of operations, per document or report, per hour of operation, and so on, as may be appropriate. Preparation and analysis of processing cost budgets, determination of cost standards, and assessment of processing costs against the sub-divisions of the business benefited by the processing activities, all contribute to the enforcement of cost disciplines.

Paradoxically, the further the advances into mechanization — and thus, seemingly, the more complicated the data-processing function becomes — the lesser the difficulties in cost determination appear to be. Highly methodized routines are characterized by straight-line, continuous operations upon large masses of data. Under such conditions, the cost structure tends to become more simplified and thus the costs per unit of output are more easily measured than in situations where the operations are subdivided into many parts.