AN APPROACH TO MANUFACTURING CONTROL USING INEXPENSIVE SOURCE TO COMPUTER COMMUNICATION

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SUMMARY

More efficient use of computers to reduce costs as a result of improved scheduling and control of manufacturing operations is made possible through the availability of timely, accurate and complete information.

This requires more effective data gathering from the lowest and most dispersed level of operations. Such extensive coverage is made economically feasible through the application of a concept of tailor made systems which provides versatility through the use of a variety of modular subassemblies. Low cost is possible through extensive use of components and devices mass produced for other purposes. Some aspects of two systems which employ these concepts are described.

BACKGROUND

An understanding of the reasons which underlie the development program described in the pages that follow forms an important background to the design philosophy being pursued.

The principal business of Western Electric Company is manufacturing telephone apparatus, cable, switchboards, etc., chiefly for the A.T.&T. Company and its telephone subsidiaries, procuring and selling to such companies materials and supplies not of its own manufacture, and installing central office equipment for such companies.

Company operations are spread across the country in 12 factories and 35 Distributing Houses which in total employ approximately 100,000 people. In general, goods of a particular type are produced at only one location. There is, however, extensive flow of material between factories in the course of building up product from basic raw materials to its final form.

From the diversity of products being made and the number of making shops that depend for their input on the output of others, it becomes evident that the Company is at grips with a very substantial control problem. This problem has its roots on the manufacturing shop floor.

The traditional way to avoid missing ship schedules is to provide adequate in-process stocks of materials to keep the pipeline full. In this manner, it is hoped that disturbances due to unpredictable factors will be smoothed out. Low annual demand for a proportion of the product line makes such a strategy costly.

The degree of effectiveness in controlling (sic: provide guidance and instructions) the organization of the Company from the lowest working to the highest policy making level depends on the ability to deliver accurate and
timely information that is sufficient and only sufficient to the people and only those people that need it. Potential reductions in the cost of producing goods is the basic incentive underlying the search for improved effectiveness in manufacturing control.

INTRODUCTION

The variable characteristics of the data which have a bearing on the effectiveness of a control system are:

1. Timeliness.
2. Accuracy.

The system parameters which have a bearing on the above characteristics are:

A. Closeness of originator of data to point of data entry.
B. Sophistication of communication system.
C. Degree of computer involvement.

Timeliness

Timeliness of the data is beyond the ability of the originator or his supervisor to adjudge. In general, data must be timely enough to be of value and only in retrospect can the need for prompt transmittal of one item of data be evaluated. The timeliness factor is enhanced by bringing the point of data entry as close to the originator of the data as possible. Timeliness is also enhanced by providing increased sophistication in the data communication system. Finally, the timeliness characteristic is most appropriately judged within the computer in competition with all other items of entered data that form the overall problem parameters.

Accuracy

Accuracy is largely controlled by the elimination of manual data handling between the originator and the data processor. Hence, it would seem that the accuracy might be achieved by requiring the originator to introduce his data himself.

Accuracy is enhanced by an increase in data communication sophistication coupled with judicious use of controlled formats, timing devices and prompt error control feedback.

Greater accuracy is yet possible with the application of computers to cross check separate reports which can be cross correlated and errors can thus in fact be corrected before damage to the control model can occur.

Sufficiency

Sufficiency applies both to the amount of data entered and the amount of control (guidance or instructions) disseminated.

The amount of data to be introduced by a person decreases as the point of entry gets closer to the source. The use of pseudo-codes and automatic data generation contributes to the reduction of the amount of data to be actually entered. (By-product effect is to increase accuracy and reduce delay).

Sufficiency is primarily enhanced by application of computer technology. Highly coded and abbreviated input data can be readily transformed into full blown expanded form by computers in the course of analysis and processing. Computers can then, on the basis of fundamental information, produce the whole range of reports and directives tailored in each and every case to the specific needs and requirements of the recipient.

Sophistication of the communication system in this case permits the dissemination at more frequent intervals of more abbreviated documents. This has the effect of relieving the recipients of a great deal of analytical effort and handling of superfluous material.

THE CHALLENGE

Current commercially offered designs, in general, contain capabilities far in excess of those required for the systems, comprised of large numbers of data entry devices, deemed desirable for reasons discussed.

The cost of purchasing equipment to satisfy each of four different applications with the equipment offered for sale by six different manufacturers are shown in Figure (1). We find that we can produce systems capable of fulfilling our needs at costs substantially lower than those shown in Figure (1).

This cost reduction is made possible, in part, through extensive use of mass produced ele-
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<table>
<thead>
<tr>
<th>Features Provided</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
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<td>Number of Stations</td>
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<td>49</td>
<td>15</td>
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<td>Variable</td>
<td>Fixed</td>
<td>Controlled</td>
<td>Controlled</td>
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<td>Recirculating</td>
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<td>No</td>
<td>3 minute</td>
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<td>Preset</td>
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<td></td>
<td>6 - Lamps</td>
<td>Switches</td>
<td>No</td>
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<td>Bell</td>
<td>Lamp</td>
<td>Lamp</td>
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<td>3</td>
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<td>No</td>
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<td>Use Numeric Display</td>
<td>No</td>
<td>Timeout</td>
<td>Timeout</td>
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<tr>
<td></td>
<td></td>
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<td>Output Paper Tape</td>
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<td>60 ch/sec</td>
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<td>20 ch/sec</td>
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<td>Off line</td>
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<td>Model 29</td>
<td>Model 33</td>
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<td>1620 (IBM)</td>
<td>Monroe XI</td>
<td>1410 (IBM)</td>
<td>1410 (IBM)</td>
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<td>16</td>
<td>71</td>
<td>25</td>
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<td>Manufacturer A</td>
<td>B</td>
<td>C</td>
<td>D</td>
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</table>

Figure 1. Comparative Costs of Implementing Certain Systems.

ments made usually for the communications industry. We, of course, because of familiarity and ready availability, prefer to employ Western Electric products. Similar elements to the ones we use are available from a number of other sources thus permitting our concepts to be implemented by others.

THE DEVELOPMENT

Station Requirements

We have imposed on ourselves these requirements:

1. Originator must have immediate access to a station without having to travel (if a bench hand, device must be at arm's reach)—This does not necessarily imply immediate access to the system for purposes of entering data; in fact, this arrangement makes possible the use of slower access and transmission rates.

2. Station must be the smallest possible capable of providing necessary features for its location and application (bench space at premium).

3. Station must be that which is least expensive yet capable of providing necessary features for the required location and application.

4. Volume of variable data ot be entered by an individual must be kept to a minimum.

FEATURES

System Features

Maximum Use of Pseudo-codes

The ability of computers to accomplish such
functions as table look-up allows the use of pseudo-codes. Fewer digits may be used for complete identifications of jobs, materials, machines or people.

**Maximum Use of Automatic Information Generation**

Identity of originating station carries with it information to aid in interpreting data such as identity of originator and location; hence nature of reportable jobs or work.

**Provisions to Enhance Accuracy and Reliability of Information Entry and Flow**

Controlled format, feedback to data originators, use of card readers to maximum extent possible for fixed types of data and simple procedures to be followed.

**Station Modules, One or More of Which Are Required for Entry of Data**

*Variable Information Input Module*
1. Rotary dial
2. Ten Key push button dial
3. Multiposition switch units

*Fixed Information Input Module*
1. Card reader to handle special design cards
2. Card reader for handling conventional tabulating cards
3. Memory devices (automatic dialers)

**Means to Assist or Direct Users**
1. In requesting service.
2. That service is available.
3. In using set correctly and entering data accurately.
4. Through an information delivery module of minimum capability to serve their needs.

**The Simplest Data Collection Station:**

*Entry*—A rotary telephone dial provides limited but effective means to:
1. Request service
2. Enter transaction codes
3. Enter fixed data
4. Enter variable data

Advantages are:
1. Minimum operator training
2. Proven reliability
3. Low cost

Disadvantages are:
1. Slow in operation
2. Digit by digit operation
3. Range limited to about ten miles unless audio modulation is employed

**Visual Signalling**—A signal lamp provides indication to user of:
1. Service availability
2. Proper functioning of system
3. Correction of operating procedures

Advantages are:
1. Low cost
2. Creates no disturbance to others

Disadvantages are:
1. Only limited meaning can be applied

**Packaging**

Assembling a rotary dial and a signal lamp in the least expensive housing available provides a complete data collection station that can be petite, graceful, familiar to factory workers at the lowest level of production—and it lights up.

**Comments**

It is evident that this type of station lacks all sophistication within itself.

Features to provide error control are incorporated in the control center as required and described further. Effective interpretation to permit use of the data introduced requires the backup of a digital computer.

**Add-on Modules**

A broader range of station features is possible through the use of larger housings and

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*Figure 2. The Simplest Data Collection Station.*
the incorporation in the station circuitry of several additional modules.

*A multiple key assembly* can be plugged in the station set. Each of the keys can be set for locking or momentary contact mode of operation. The purpose or function of each key is marked on the adjacent designation strip. Suitable wiring at the control center fulfills the control or data reporting functions called for by each particular key as a function of the specific station identity.

Auxiliary lamps under each designation strip position are available for supervisory signalling to the station user.

Figure 3. Some Add-on Modules.

*A card reader* compatible with the rotary dial can be installed in the station set. This particular reader, intended for automatic telephone number dialing, accepts a plastic card which has a capacity of fourteen decimal numbers.

The practice of recirculating cards through the system made possible by pseudo-code assignment enhances the economy of the hardware. Security and reliability is provided as required through use of self-check number arrangements.

*Numeric Display*—In certain cases the use of a digit-at-a-time display is indicated. This display provides the station user with some check of the accuracy of data entry. In addition, this numeric display can be used for centrally originated dissemination of control information to the station user. Work assignment is an important potential use of this single digit display.

*Message Display*—More sophisticated displays such as a twelve-message unit are used in stations where data entry sequence is more complex or in special stations used during training periods.

*Voice Feedback*—The least expensive technique of feedback to data originator is through the use of voice to an earphone or loudspeaker at the station. Voice feedback of-entered data on a digit or field at a time basis from the control center is in many cases quite appropriate. With commercially available digital-to-spoken converters this feature is provided economically.

**Audio Frequency Signalling Modules**

*Ten Key Dial With 2/8 Oscillator*

The use of audio frequency signalling provides a number of additional features. The operation of one key on a Ten Key dial and oscillator module delivers an audio output consisting of two tones out of eight.

The advantages of this unit are:
1. Faster operation possible
2. Unlimited range of transmission over conventional voice grade circuits
3. Provides potential for increased station versatility

Disadvantages are:
1. Some practice required to use efficiently
2. Cost higher than rotary dial
3. Control center requires additional electronic equipment to receive and decode signals generated at station

*Multiple Key Assembly*

The 2/8 code provides for sixteen discrete combinations. Some of these may be generated by suitable connection of the multiple Key Assembly to the oscillator subassembly of the dial module. In this manner, special controls and supervisory functions can be added to the system with no change to the cabling.

*Card Readers*

A card reader similar to that used in DC pulsing systems can be added. This card
reader connects to the oscillator subassembly and causes the generation of 2/8 coded output. It should be noted that the coding and the card used in both types of card readers is identical, hence mixed systems using the same cards are quite feasible.

A more sophisticated card reader capable of handling tabulating cards can also be readily connected to the oscillator subassembly.

**Special Stations**

**Clock**

The entry of time in the flow stream of input data adds a frequently needed parameter. A clock-controlled digital code generator is connected to the system on the same basis as any data input station. The clock station circuit is set to request service at predetermined absolute times. Access to the system is granted in queue with regular stations and true time (the actual time of access) is logged. The difference between logged time and predetermined "service request time" provides a measure of service delay. This allows the actual time of service requests by station users to be determined statistically. Special circuitry prevents successive clock entries if no operator entries have been made in the interim period.

**WIRED APPARATUS SHOP**

**Shop Character**

The "Wired Apparatus Shop" is typical of many production organizations both in Western Electric as well as in other companies. This particular shop was chosen to test hardware concepts and techniques for effective utilization of management information.

The physical arrangement which is shown as Figure (5) employs 49 people in each of two full shifts of operation. The group consists of three sections. One of these is concerned with the production of one class of telephone switching frames. The second section is responsible for the production of another class of similar frames. The third section is responsible for inspecting and testing the output of the first two sections. The organization chart, of this shop and of its management superstructure, is shown in Figure (6).
The production process consists of:

(A) Assembling subassemblies to frames.

(W) Wiring between these subassemblies and cable terminals as prescribed for each type of unit.

(I) Inspecting visually for a variety of defects.

(T) Electrically testing the entire wired assembly.

(P) Packing for shipment.

Other shops outside the group in question provide the variety of materials required to produce the frames. The materials required include wired subassemblies, factory made cables, power units, framework parts, fastening devices, precut and skinned wired and miscellaneous supplies. In all, there are some 1000 different items required. Requirements for each item vary with the mix of types of frames the group is ordered to produce. Fortunately, the maximum variation is generally felt on low cost items.

The value of the product shipped annually is approximately $20 million. Each shift contributes approximately $1 million of direct effort including its portion of overhead costs. The cost of carrying in-process inventories or safety stocks to forestall unpredictable occurrences can be quite high. Slight decreases in efficiency tend to increase this inventory or cause delays in shipping. These delays are costly both to the group in terms of increased inventory and to the customer who frequently has established an installation schedule with committed materials from other shops, and may have manpower waiting on site.

The famed maxim “For the want of a nail the campaign was lost”, provides an insight to the reasons that lead to a desire for complete and timely knowledge of elemental facts. Many of the reasons for decreases in efficiency and delayed shipments are found to have assignable causes. These causes can be corrected in most cases with early knowledge of negative and disturbing occurrences. The absence of the only worker skilled in wiring a particular frame is a disturbing but obvious occurrence which can be adjusted by rescheduling.

More elusive, however, is a general but slight decrease of efficiency among many workers.
Frequently, this is detected weeks after the goods were shipped, probably on schedule, but at the cost of bad temper and ulcer producing pressures applied at short notice. Detection of a negative efficiency trend on an operator to operator and frame to frame basis with source data collection on the same basis, alerts the supervisor to seek the trouble. Recognition of the problems followed by prompt corrective action can lead to quicker control of inventory investment and schedules.

A common reason for decreased efficiency results from defects found by the inspectors and testers. Analysis of these on an operator, defect, and type of frame basis provides the supervisor with a daily guide as to where he should expend true supervisory effort in the sense of assistance and training of his group.

Work assignment by type of frame to individual operators can be performed to meet the objectives of the group. At periods of heavy order, load frames are assigned to operators to take advantage of their experience and state of training. During intervals of light load or when ahead of the game, deliberate assignment can be made for training purposes thereby upgrading the potential effectiveness of the group. This requires detailed timely knowledge of operator activity only practical with point of source data collection.

There are numerous other areas which can be developed to improve overall shop effectiveness and minimize the effect of disturbing events through the availability of basic and timely information as to:

- WHO is the operator
- WHAT happened (start of work, found defects)
- WHERE is the report made from
- WHEN was work on the unit started

*Hardware Organization*

*Data Originating Station*

The entry device to the system consists of a simple housing to mount a rotary dial, DC pulsing card reader, six button key assembly, bell, and a miniature "Nixie" numerical display tube for visual display of data being entered.

![Data Originating Station](image)

The row of push keys for this set are labeled in this application from top to bottom: "release digit", "cancel entry", "Spare", "right operator", "left operator", and "end entry".

The user can introduce information in the system by inserting a plastic perforated card in the reader slot. As the card rises, its coded content is read into the system. This can be such data as job number, part number, special instructions or user identification.

Next, if required, the user can dial quantity or other appropriate modifiers. Each dialed digit appears on the visual display tube to provide assurance that the entry has been recorded at the control center. The push keys are used for special functions such as terminating the transmission, canceling a dialed digit or a whole message, and special meanings assigned to each station. Predetermined codes are logged whenever one of these keys are operated.

Access to the system assures the users that they will be given access in the order of request. In this system, we have true point-of-source data collection eliminating the need for an operator to leave the work position to enter data.

*Time Generating Station*

Connected to the control center on the same basis as any operator station is a digital time generator of the type described earlier.
Selective Feedback of Quality Information to Bench Workers

Engineers functional for the operation of the shop added to the basic data collection system an interesting feature which does not interfere with normal data collection operations. Transmissions made by inspectors are monitored by a pulsing relay inserted in series with the input to the control center counter module. This relay operates switching equipment to recognize the entry of four of some twenty types of inspection items. This equipment then directs signals to the bench position of the operator responsible for these four types of defects where for each a daily cumulative count of occurrences is displayed.

Information Flow and Usage

The layout of the shop shows a total of 28 data collection stations located in such a manner that it is not necessary to leave the work position to enter a report.

Although all the stations are substantially identical in appearance and mode of operation they provide a wide range of reporting functions. The identification of each station is automatically entered at the end of each transaction. Operator assignment to particular positions are reported only whenever a change is made. In this manner, the WHO and WHERE and some indication of WHAT is provided with no user effort.

<table>
<thead>
<tr>
<th>Type of Station</th>
<th>Number of Positions</th>
<th>Total Number of Messages</th>
<th>Number of Characters per Message (Auto Card)</th>
<th>Total Number of Characters per Message Per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>7</td>
<td>3080</td>
<td>3</td>
<td>11 3080</td>
</tr>
<tr>
<td>Mix</td>
<td>26</td>
<td>280</td>
<td>3</td>
<td>11 280</td>
</tr>
<tr>
<td>Inspector</td>
<td>2</td>
<td>148</td>
<td>3</td>
<td>8 148</td>
</tr>
<tr>
<td>Test</td>
<td>2</td>
<td>130</td>
<td>3</td>
<td>8 130</td>
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<td>Experiment</td>
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<td>74</td>
<td>3</td>
<td>6 74</td>
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<tr>
<td>Total per Day</td>
<td></td>
<td>1630</td>
<td></td>
<td>15650</td>
</tr>
</tbody>
</table>

Figure 10. Daily Expected Information Flow Per Shift.

<table>
<thead>
<tr>
<th>Number of Characters Entered (Per Day)</th>
<th>Rate of Entry (Ch/sec)</th>
<th>Time Required (Seconds)</th>
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<tbody>
<tr>
<td>Automatically</td>
<td>4990</td>
<td>28</td>
</tr>
<tr>
<td>Through Card Reader</td>
<td>7150</td>
<td>10</td>
</tr>
<tr>
<td>Manual</td>
<td>3510</td>
<td>2</td>
</tr>
<tr>
<td>Total Daily</td>
<td>16660</td>
<td></td>
</tr>
</tbody>
</table>

Figure 11. Expected Per Shift Busy Time.

WHEN is provided automatically, as described earlier, by the Digital Time Generator.

The WHAT for each station is then the only information required to be entered by the using operator. The bulk of the WHAT messages become an error free semi-automatic operation through the use of a coded prepunched card.

The assembly operator originates one of the more important transactions: He enters a pre-coded card which will be associated with a frame until it is packed. He must also dial a code which identifies the type of frame he hangs the card on. Subsequent entry of the card by a wiring operator associates that particular unit with that operator. Entry at the time of starting work on the unit, by inference, signals termination of work on the unit previously reported.

Inspectors and Testers have more complex entries to make in addition to the card; they must dial in defect codes and quantities of each type found.

The computer can readily assimilate the above facts to produce a very broad spectrum of control information. This spectrum is limited only by the amount and accuracy of background information also available to the computer for reference. Figure (12) shows the
type of control information developed as a function of facts collected and background information available. Figures (13) – (15) are indicative of the types of reports which it is technically feasible to provide, either automatically or on demand, to the various levels of management through low cost page printers located near the recipients.
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THE PIECE PARTS SHOP

Another embodiment of the concepts put forth so far is a newly installed Data Collection System in a metal piece parts shop. This is a shop where about 125 people on each of two shifts produce small metal parts using a variety of manual, semiautomatic, or automatic machine tools such as punching and stamping machines, shears and power brakes, screw machines, lathes and milling machines. The work travels in lots of from less than ten units to tens of millions of units per lot. The number of operations to be performed on a lot varies from one to more than twenty with an average of about five. A computer provides the shop with schedules for control of production. By having access to current "setup" and "make times" rather than theoretical values, changes in efficiency or capacity can be taken into account by the computer to yield more realistic schedules.

Standard production messages which are transmitted to the computer from the shop indicate the start and finish of each operation on each lot together with the identity of the machine on which it is being performed and the time of the day at which each occurrence takes place. In addition, there must be inspection reports and a number of other "special situation" reports to handle the variety of occurrences in the shop. A total of 18 different types of transmissions are used to cover the variety of situations (Figure 17).

A given message may be formed by appropriate combination of the following components:

1. Transaction Code: One or two digits which define the nature of the message.
2. The identification of the particular job or lot travelling through the shop.
3. An operation number to identify the one of several operations.
4. Machine group to identify the particular machine used for running this job.

Various combinations of the four items account for the bulk of normal production messages. In addition to these there are several special message types such as lot splits, quantity changes, inspection results, error corrections, etc., which may also involve quantity.

<table>
<thead>
<tr>
<th>TAPE FORMATS</th>
<th>INPUT MESSAGE FORMATS</th>
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<tr>
<td>Format: 5 6 7 8 10 11 12 12A 15 Format: 5 6 7 8 10 11 12 12A 15</td>
<td>Format Code</td>
</tr>
<tr>
<td>Digit #:</td>
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<tr>
<td>1</td>
<td>ST ST ST ST ST ST ST ST ST 1</td>
</tr>
<tr>
<td>2</td>
<td>ST ST ST ST ST ST ST ST ST 2</td>
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<td>3</td>
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<td>ST ST ST ST ST ST ST ST ST 8</td>
</tr>
<tr>
<td>9</td>
<td>ST ST ST ST ST ST ST ST ST 9</td>
</tr>
<tr>
<td>10</td>
<td>P P P P P P P P P P P</td>
</tr>
<tr>
<td>11</td>
<td>P P P P P P Q Q Q Q Q</td>
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<td>12</td>
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<td>13</td>
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<td>19</td>
<td>P P P P P P Q Q Q Q Q</td>
</tr>
</tbody>
</table>

Figure 17. Tape and Message Formats.
Such special messages, however, are restricted and are permitted only from a limited number of special stations set aside for that purpose.

The GATES II Data Collection System

The basic station is very simple in nature, consisting of a rotary telephone dial for variable information entered by the human operator, an automatic card dialer for entry of fixed information and a signal lamp for control purposes.

A limited number of special stations also are provided. These stations are logically similar to the basic station described above with the addition of four Burroughs sphericular displays. Their purpose is to allow verification of such information as quantity which is entered only from these stations. The right-most display unit is used to guide user by identifying the fields within a message. Such expressions as: CODE, CARD, OP #, and QUANT are displayed. Preservation of the fixed length of individual fields is desirable for purpose of error detection. In the case of quantities, which normally require one to eight digits, it was decided to represent all quantities with four digits; the first three significant digits (including leading zeros when necessary) plus a magnitude indicator. Reported quantities will be in error by no more than 1% which is satisfactory for this application. The magnitude indicator is equal to the number of digits in the original number. Thus: 12,425 would be entered as 1245 and displayed as 12400; 231,604 entered as 2316 and displayed as 231,000, etc. The fourth display device is arranged to present the proper number of low-order zeros to give a rounded number in proper form.

A digital clock is provided for logging of time. Every two minutes the clock enters the time of day if there has been activity since the last two minutes interval.

Basic Station Operation

Let us consider a situation where a worker wishes to make a standard production report indicating, for example, that work has been finished on the run of a particular job. This person takes a card on which is coded the job or lot identification number and also a card which identifies the machine which was used for this operation, to a basic station. The lot identification card is inserted into the slot of the card reader. Now the user requests service from the system by simply dialing a “one”. The central control equipment recognizes this operation of the dial, remembers the request for service, and when available, connection is made to the station and the readiness to receive data is indicated to the user by the lighting of its signal lamp—this lamp is referred to as the service light. The user has ten seconds to notice that the service light is lit and begin entering the first item of information which is a transaction code. The system is set up to allow transaction...
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codes to be either one or two digits in length thereby allowing subclassifications of major transaction codes. Entry of the first digit of the transaction code immediately determines the length of the message, its format, and field delineation. The first item after the transaction code in a job completed message is the job-identifying card. To cause this card to be read, the user merely depresses the start bar. As the card is read, the service light flashes. When the card stops moving and the service light ceases to flash, the user realizes that the reading of the card is complete and enters the next item of information which is a two-digit operation number taken from a layout or instruction sheet traveling with the job. Three digits from the machine card are read and, in the case of a complete message, the transmission is terminated. The control equipment having received the proper number of digits previously determined by the transaction code, disconnects the station and extinguishes the service light.

**Human Engineering Features**

Several aspects of this operation are interesting from the human point of view. The first is the use of a timer to measure the elapsed time between successive digits. Three different timing intervals are provided. Ten seconds are provided from the moment the service light is first lit until data begins and also at those times when a user may be removing or inserting a card from the card reader. Five seconds are permitted between successive digits within a field of variable information being entered from the dial and approximately half a second is permitted between successive card-reader-originated digits for the purpose of catching attempts to dial fixed information from the rotary dial. The result of any of these timing intervals being exceeded is the termination of service for that particular input device and the extinguishing of the service light. The control equipment, realizing that a message has been terminated prematurely, discards all data entered so far and considers the message aborted. When the message is entered properly the service light will go out immediately after the entry of the last digit of the message, no sooner, no later. The user is instructed that in the event the light should go out before the message has been completed, or in the event that it remains lit after the message is completed, then an error condition is indicated and this particular message will be discarded. The operator must reinsert the message from the very beginning. If the operator senses that he has made an error in mid-stream, he simply stops what he is doing, allowing the current time interval to be exceeded and causing the message to be aborted automatically. The ability to deliberately abort a message in process gives the user a degree of freedom in catching his own mistakes.

A second aspect from the human standpoint is the organization of the data sequence for entry. First, two fields of variable data are separated by a field of fixed data from a card. This separation is amplified in the mind of the user and confusion between adjacent fields is reduced. Secondly, the last field of information is fixed. This means that the user has the option to abort even the last digit of variable information and should not enter the last card unless he is reasonably sure that all data to that point has been entered correctly. If the last field of data were variable then the control equipment would receive the last dial digit and take away service assuming that it had a correct message. The user then would not have an opportunity to abort the message if he suddenly sensed that the last entered digit was an error. In the one instance where the data could not be organized to assure that a card would be last, a special pseudo field is required consisting of the single digit “one”. This is the last digit entered and serves as an indication of acceptance of the message.

**System Organization**

A block diagram of the control system of GATES II is shown in Figure (20). Each station is connected with its own three-wire cable to the central control unit where an appearance is connected to several station scanners, each consisting of a rotary stepping selector which is capable of connection to any of the stations. Each station scanner is the input to one of three service channels. Their outputs converge in the punch and printer control which controls the outputs to a printer located in the shop and a paper tape punch located remotely in the computer room. The printer provides a listing of certain selected types of messages as explained...
further. Any failure of a unit within a service channel or the disconnection for maintenance or repair of any unit causes the associated service channel to be made automatically busy and traffic is routed around to other available channels.

When a station requests service, a line relay associated with it operates and locks to remember the request. The first available service channel is then connected, the light in the station is turned on, and the first timing interval is begun. The first digit received which is a transaction code is stored in the first digit position of the buffer memory and interpreted to determine the number of digits which should be received in this particular message and the interdigital timing between each successive digit. In addition, the combination of the transaction code and the identity of the calling station is used to determine whether or not this particular message should also be printed. In the event that it is a printing message, the separation of fields on the printer by spaces is also determined at this time. As each successive digit is entered, a digit counter advances and stores each received digit in the appropriate position of a 15-digit buffer memory. When the proper number of digits are received, or in the event of timeout, the service light is extinguished. The scanner directs the punch and printer control to connect to the punch or the punch and printer and proceeds to output characters previously stored. Characters are outputted at approximately nine characters per second when punching and printing or at 18 characters per second when punching only. The tape receives information in BCD “Flexowriter” code while the printer receives ASA X3.4 code. The first information to come from the scanner control is the identification of the calling station and the identification of the particular service channel which is being used. Immediately upon emission of the station number, the station scanner is freed and made available to hunt and connect to any other station requesting service. The illumination of the service light, however, is delayed until the scanner control has completed outputting the previous message and has prop-
erly reinitialized itself. When the last digit is cleared from the buffer memory and a blank character is attempted on the next cycle, the punch and printer control disconnects the scanner and executes the termination sequence which consists of a carriage return signal to the punch and a carriage return line feed signal to the printer. The scanner control then clears its memory and resets to its proper initialized condition.

CLOSING COMMENTS

We have a general approach to the handling of special purpose information flow systems allowing us to provide at short notice economical source data collection.

This is done through a versatility of technique rather than through an all purpose station. The concerted effort to use mass produced low cost elements is an important factor in keeping equipment costs down.

By providing, as described, inexpensive and easy to use data collection systems, we are able to justify the use of computers in our manufacturing planning, control and supervisory functions. Many of these functions could not have otherwise been performed short of being part of much more complex projects, which, because of their complexity, may never have been tackled.

The authors wish to express appreciation to their colleagues who helped make these systems possible—in particular, to Jim Gorman in the areas of circuit design and Miss Bonnie Small who was responsible for the design of the “management information as required” concepts.

REFERENCES


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