PRODUCTION CONTROL WITH THE ELECOM 125

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The revolution in the office which electronic digital computers eventually will bring about, will not be accomplished by a clash of thunder, charged with 100,000 volts, and accomplished with the speed of light. Instead, it looks to me as if the electronic computer will have to enter the office wearing a blue serge suit with pin stripes, topped off with a Homburg, and acting on the whole very much like timid little Mr. Casper Milquetoast.

By now you have heard many of the objections to electronic computers raised by our hopeful, but sceptical, friends in management engineering, accounting, comptrolling, banking, and associated fields. They hear that we can do 4,000 additions a second, or 40,000, or 40 million, and they ask embarrassing questions like, "How many copies does it give me for distribution to sales, accounting, manufacturing and the executive offices?" Or, "Are you always correct to the last penny?" Or, "How do you get the thing into my office without knocking down the walls?"

Bearing all the needs for, and objections to, office electronic computers in mind, the people of the Electronic Computer Division of the Underwood Corporation have taken the attitude that the business data-handling system must come into the office quietly and without fuss. It should look fairly familiar. The people needed to operate it should look more like office clerks, supervisors and potential vice-presidents, rather than the proverbial mad scientist.

With that attitude in mind, a group of Elecom people went up to the Underwood typewriter manufacturing plant in New England some months ago to look over the production control problem and to see what an electronic data-handling system had to offer. Before making the trip, we had been primed with a lot of facts about how expensive the operation was; how many errors were being made daily; how far behind reports and surveys were; and how, in general, the whole procedure was inefficient.

Nobody mentioned beforehand the obvious facts that Underwood had been manufacturing typewriters successfully for more than half a century; that somehow in the process, all the necessary parts got together, and that the Underwood type-writers worked satisfactorily when completed and delivered.

We learned a lot. The results of what we learned are now taking shape as we build the Elecom 125 Electronic Business System.

What did we learn?

First of all, we learned that a million dollars for an electronic system is a lot of money. This was not exactly new to us, since the whole effort in the Elecom line of computers has been to produce relatively low-cost machines.
A million dollars to most average-sized businesses is a lot of money, since, with the exception of very large centralized corporations, and the Federal government, the need for giant, lightning-speed computers usually cannot be justified by the present dimensions of the operation.

Take the Underwood production control operation. The exact number is a commercial secret, but Underwood produces 'hundreds of thousands' of typewriters a year. The number of different parts going into the various models, such as standards, portables, electrics, typewriters with special feed devices, etc., is about 12,000. Fifty different departments at the Underwood factories handle these parts. On the average, any particular part travels among four of the fifty departments. As examples, there are the plating department, the blanking department, the heat treating department, primary press department, secondary press, and some forty-odd others.

The dimensions of the production control paperwork operation were modest. Underwood had some fifty people doing the production control paperwork. The total payroll cost is of the order of $150,000 a year. The savings to be effected by any electronic equipment installed should be able to pay for the equipment in a couple of years, rather than ten or fifteen.

Also, Underwood already has a paperwork system. This system, with all its shortcomings and strong points, has been built up through experience over many years. It involves existing names of parts, part numbers, accounting numbers, department numbers and names. It involves procedures for ordering materials, the various stages of manufacturing the 12,000 parts, assembly, shipping finished typewriters, billing customers, paying Underwood's bills, and so on and so on.

To change the whole system overnight would not be practical. Too many people, too many processes with too many ramifications are involved. Not only in New England and New York, but all over the United States, in Canada, England and around the world. No Underwood vice-president in his right mind would allow everything to stop and be completely changed. The cost in changeover and lost motion would be excessive. And suppose the new system developed some bugs?

Since production control was not the only office problem in Underwood, the electronic data-handling system which we delivered for production control should be general purpose, not limited to the one special application.

Let me break down the lessons we learned, and the results, in terms of hardware.

**Input and Output**

Input and output units should be completely independent of the central data handler. This allows 'ganging up' on the computer on the 'in' side, and the multiplication of output units to keep ahead of the computer in producing the visual copy.

The input and output devices should be cheap. The work done on the
input unit should be capable of easy checking. The input to the computer should be in a form understandable to the office typist. Input to the computer itself should be rapid. The ten digits per second rate achieved by the Flexowriter and other punched hole tapes was not fast enough. Even the Ferranti reader appeared to be too slow.

The economic cost of using present devices to type and simultaneously punch holes in paper tape also appeared to be undesirable. So we designed a new input unit, called the Underwood Tapewriter. The Tapewriter is an Underwood Electric typewriter which produces two typed impressions simultaneously: first, the normal English letters and numbers of the data being inserted. This visual copy is then available for a check against the letters and numbers on the original document from which the data is transcribed.

At the same time, the Tapewriter produces the coded-dot binary pattern for the English letters and numbers which have been typed. Thus, when the typist strikes the keys for 'JOHN JONES', two things happen. The capital letters JOHN JONES are typed on a piece of paper, or any business form inserted into the Tapewriter. At the same time, the dot patterns for the letters JOHN JONES are printed on a strip of half inch wide paper tape. If the girl strikes the correct keys, the correct coded dot pattern is produced automatically, since both letter and coded dot pattern are printed by the same operation.

We expect to produce and sell the Tapewriter at an approximate price of $1,000 each. Thus, multiplication of input units becomes economically feasible. Since a typist can type, handle documents, etc., at an average rate of three digits per second, and since the input from the printed dot paper tape to the computer is at the rate of 600 digits per second, the Elecom 125 data handler can keep up with some 100 to 200 typists.

Once the paper tape is produced and removed from the Tapewriter, it is then inserted into a photoelectric reader attached to the central computer. The reader and computer convert the printed dots into pulse patterns on magnetic tape. Once the information has been transcribed to magnetic tape, the computing system is ready to go to work.

Let me mention one important feature of the input unit. The Tapewriter produces hard copy - the normal number of carbons can be prepared - so that the sceptical businessman has data, in visual form, in English letters and numbers, on paper. Carbons can be routed around the office and factory for various purposes. Other copies can be filed where desired. Thus, if the office manager desires to reconstruct an account, audit a set of transactions, or look over his records, he can do so without going to the magnetic tape and calling for a print out. Thus the businessman does not have to depend upon magnetic tape alone.

Checking input data can be done by several methods. Two typists can prepare the same data independently, with the tapes then being compared by the computer. Or, visual checking of the original document against the hard
copy can be done. Errors then are corrected by the preparation of a trailer 'correction' tape fed into the computer. Errors which the typist catches as she types can be corrected by backspacing and the use of an 'error' key, which blanks out the data in error.

At the output end, the requirements were much the same. Output should be independent of the computer, cheap, flexible, and of a nature enabling output to keep up with the computer. Like many other computer manufacturers, we are hoping that a cheap, reliable line printer will be available soon, but we are not waiting for the miracle to happen in the next couple of months.

The present Elecom 125 output unit is an Underwood electric typewriter, with a photoelectric reader attached. The photoelectric reader reads the printed dots on the paper tape which has been produced by the computer as the final output. The reels of printed dot paper tape are mounted on the output typewriter, read photoelectrically, and the output typewriter types out hard copy at the rate of ten digits per second. Since the computer can produce printed dot paper tape at a rate of 600 digits per second, theoretically it would take 60 output units to keep abreast of it. In practice, the number is less since the electronic data handler takes time to process tape, convert from magnetic to paper tape, etcetera.

At the proposed price of $2,500 per output typewriter, multiplication of the digit-per-second output rate is feasible and economic in terms of the cost of the entire system. For $25,000, the customer can buy 100 digits per second. Considering present printer costs, the economics are not out of line. The price of the output unit should decline as the quantity produced reduces the unit cost, and we are prepared to go to a line printer as soon as one comes along which fits the bill.

The Elecom 125 Computer

An electronic computer for a modern office must be simple to operate, reliable in operation, easy to maintain, and fast enough for the job. The Elecom 125 computer has grown naturally from its little brothers, the Elecom 100 and the Elecom 120 computers, along those lines.

First, we use what we consider to be the simplest and most reliable type of memory, the magnetic drum. The Elecom 125 has a magnetic drum memory of 1,000 eight-digit words, each plus sign. For more rapid access, we use a ten word recirculating channel.

How reliable is a drum? Nobody really knows. However, we have an Elecom computer which has been operating without any drum trouble for more than two years. The part most likely to wear, the bearings, are estimated by our mechanical engineers to have a normal life of at least 100,000 operating hours. On the basis of a 20-hour computer day, that is something like 20 years. If the computer is used only one shift or less, the life expectancy of the bearings in the drum unit should be of the order of 100 years.

The Elecom computers operate at a fairly sedate pace. Since the pulse rate of the Elecom 125 is 107 KC, compared with over two megacycles in some
of the million dollar computers, we have more tolerance in our circuitry, so that the chances for error and failure are reduced sharply.

The primary weak points, to date, of electronic computers seem to be vacuum tube failure and imperfect magnetic tape.

The vacuum tube problem we attack by not using so many. The Elecom 125 computer contains about 350 vacuum tubes. Ninety percent are of two standard types, 6CL6s and 12AT7s, which can be purchased in the local radio shop in case of emergency. The entire Elecom 125 system, including both the computer and the sorter, contains less than 600 vacuum tubes. Statistically, the fewer the tubes, the fewer the chances for tube failure.

As to magnetic tape, Elecom computers utilize a system of presprocketing, developed by our engineers, which eliminates errors caused by faulty magnetic tape. The raw tape received from the manufacturer is run through an electronic sprocketer. The sprocketer examines all areas of the tape, and puts a magnetic pulse in one channel where the tape is discovered to be good. On the areas (one or two percent) of the magnetic tape where faults in the coating are discovered, no sprocket pulse is laid down. Thus, in operation the computing system merely skips these marginal areas of the magnetic tape. The sprocket pulses are permanent, and are never erased or changed during any operation of the data-handling system.

We have included many self-checks in the Elecom 125 system. In addition to pre-sprocketed tape, we have a built-in odd-even check; we check forbidden combinations in the computer; we have a special check for recording and reading on the memory drum; and program checks can be included to the specifications of the most scrupulous auditor. We can, we believe, safely guarantee accuracy to the exact, not the nearest, penny.

Electronic Sorting

I now come to a term which is generally avoided by computer people - sorting. As we all know, data processing is a cinch. The trouble is, the daily inputs of data, the outputs in the form of listings, reports, etc., are all out of sorts.

The production control people at Underwood first wanted the data on type-writer parts in part number order; then they wanted the parts listed by departments. Other reports required certain data on a limited number of critical parts listed in priority order. The input information comes into the production control office in the form of white, blue, pink and yellow slips, letters, phone calls, and reports from the New York Office a hundred miles away. The master library reels are all nicely sorted out when the operation is started. In order to process the master tape reels and come up with new information, the daily inputs have to be sorted into part number order. Then, when the output data is produced, it has to be resorted into the order required by the particular report being prepared.

The requirements for electronic sorting are much the same as for the rest of the system. It must be simple, automatic, reliable and economic. Furthermore,
since almost exactly half of the time involved in the production control job turned out to be sorting and resorting, the sorting process should not tie up the central computer.

The electronic sorting unit of the Elecom 125 system is completely independent of the data-handling process. We do not use the central computer for a programmed sort. We have an independent sorter which does all the sorting and collating.

To keep the cost low, we utilized the fact that our memory drum was built for a maximum capacity of 2,000 eight-digit words. Since we found that 1,000 words of memory was more than adequate for programming the simple operations involved in a business paperwork problem, we therefore used the other half of the same drum for sorting.

The cost of manufacturing the drum, turning it, timing, gating and so on had already been incurred in putting the memory drum into the computer. We added magnetic heads and the associated electronic equipment, but we didn't have to build a sorter from scratch. Thereby, we cut the cost of the sorting system considerably.

I will not go into the details of the sorting process. However, the sort is completely automatic. There is no reel handling except at the start and finish of the operation. The sorter is 'programmed' for the particular operation about to be done in a few moments. A switch is set to indicate the length of the items being sorted, data is fed into indicate which digits of the item are being sorted on, and that is all. When the sorter has sorted the data into the desired arrangement, it halts automatically. Collating sorted data, pulling out desired data from a large, sorted file, and similar processes all are done on the sorter, not the computer.

Thus, the Elecom 125 can sort and process data at the same time. Or it can sort alone, or process data alone. Of course, it cannot sort and process the same data simultaneously. Just as you cannot sort and list data contained on punch cards without duplicating the decks.

To sum up the hardware in the Elecom 125 system, we have:

Input Tapewriters, producing hard copy and reels of paper tape on which the coded information is contained in the form of printed dots.

The central computer, a 1,000 word magnetic drum electronic computer of moderate speed, with associated magnetic tape drives, and facilities to handle paper tape input photoelectrically, with a printer at the output end which produces reels of paper tape containing printed dots.

The electronic sorting unit, independent of the electronic computer, with four associated magnetic tape drives.

The output units - Underwood electric typewriters with photoelectric readers attached. The photoelectric readers read the printed dots and activate the typewriter to produce hard copy at the rate of ten digits per second.
The cost of the system, depending upon the number of input and output units, is of the order of $175,000 to $200,000.

The Production Control Operation

At Underwood, we did not attempt to devise an ideal production control process, thereby completely revising the present system. We attempted to handle the data, and produce the reports, listings and documents, at present used in Underwood. This meant dealing with purely alphabetic, purely numeric and alpha-numeric data. This problem of mixed alpha and numeric information is common to most office operations. Therefore the Elecom 125 sorter was designed to sort numbers, letters, or any combination of the two.

We did not attempt to do away with Underwood's existing files. Instead, we built upon the foundation of the existing files, so that the people charged with the responsibility for controlling the production of typewriters would have means for instant access, if emergencies arise, to data covering any part merely by going to the files and looking at the pieces of paper.

We did not attempt any revolutionary method of input. We do not sense spots, read original typed numbers and characters, or try to decipher the handwriting of the New York Office manager by electronics. Our input operation depends upon a human being, sitting at a machine, typing data in the appropriate form for the electronic system.

Although the application did not require it, our system of independent input and output allows for physical removal of input or output operations from the central computer and sorter. The problem of converting paper tape dots to teletype signals, and reproducing the printed dot paper tape at the other end is a simple one, and can be applied where the operation demands it.

We did not, in the main, ask the computer to make judgments or to come up with theoretical optimums. As in most paperwork operations, we found that the problem at Underwood was to get correct information, in time, to the people who have to exercise judgment. At present, with a hand system which is slow and inaccurate, judgments as to which typewriter parts to manufacture, which materials to buy, which departments to speed up and which to slow down, are often made solely on the basis of long experience, or rule of thumb. With the Elecom 125 system, the people who must exercise control will have complete, up-to-date information at eight o'clock every morning as to how everything stood the previous afternoon at quitting time.

As one man, employed by Underwood in the Production Control operation for many years, said; even this relatively modest achievement seemed to him like 'A trip to the moon.'

To accomplish this result, we found the breakdown of operations would be as follows:

Input typing and checking; from sixteen to thirty hours per day, depending upon the type of checking operation.
Electronic sorter time: about two hours per day.

Electronic computer time: about four hours per day.

Output typing time: about twenty-two machine hours.

We had an additional load of detailed reports, in several different forms, to be prepared once every two weeks. We found that such reports would require about twelve hours of computer time, and forty hours on the electronic sorter. By using the Elecom 125 system, as designed, over the weekend, we have ample time to get the necessary reports ready by eight o’clock on Monday morning, current as of 5 p.m. the previous Friday. At the present time, without using electronics, these reports are rushed out in a day or two by assigning twenty or twenty-five typists on a priority basis to do the job.

We analyzed the personnel requirements of the operation and discovered:

We did not reduce the number of higher-trained persons, each exercising some form of judgment, very drastically. We merely gave them the information to do their jobs more intelligently and on an up-to-date basis.

We did reduce sharply the need for clerks, typists and form-handlers.

Thus, the electronic revolution seems to add up to the need for as many or more trained people, and less untrained or lower trained office personnel, at present doing the routine, dull jobs.

The economics worked out to be a maximum saving of about $100,000 per year in personnel costs. This for an investment of $200,000 in electronic equipment, so that the system, used for production control only, should pay for itself in about two years.

However, the total load – four hours per day – on the central computer and sorter are of a magnitude to allow for other work to be converted to the Elecom 125. We believe our equipment should be used twenty hours per day, with four hours for down time and preventive maintenance. That means that the load on the 125 could be multiplied by four or five before the limit is reached. If the factor holds up, and the computing system is utilized fully, the Elecom 125 should be able to take over paperwork operations now involving some two hundred or two hundred and fifty one-shift people, and pay for its costs in something like six months.

For larger jobs, we recommend the use of a number of Elecom 125 systems. There are many advantages to decentralized computers. They can be placed in different locations. If one computer completely breaks down, the others can share the additional load, and so on.

For the million dollar cost of a large computer, we can offer five relatively moderate speed data handlers, five electronic sorters, and some twenty-five input and ten or fifteen output units. Our tape moving speeds, computing speeds, sorting speeds, and in and out volumes become more than comparable and respectable on a dollar for dollar of cost basis.
The computer and sorter work decimally; no conversion to and from binary is required. Programming is done by us, the manufacturer, and included in the system cost. We train both operators and programmers, if desired, and estimate that it takes a couple of weeks to train an intelligent office girl to operate the computer, and three weeks or so to instruct a college mathematician to program the system.

Maintenance will be done by us, or we will train maintenance personnel for the customer. We believe that per shift, one maintenance man, of the order of skill of a radio or television repairman, can successfully keep the Elecom 125 operating. He requires three or four weeks training by us. This is the plan we have followed with Elecom computers now in the field.

Only the future will tell whether or not the trend is to larger, faster, more complex computers, or with the slower, cheaper and more modest data handlers. The answer is that there is probably room for both.

We at the Electronic Computer Division of the Underwood Corporation are confining ourselves to the medium sized and small computing and data handling systems. We are trying to walk before we run, and we hope not to stumble in the process.