Computers in a new steelworks

By R. G. Massey

The building of the new Spencer Steelworks presents a unique opportunity to plan the widespread use of computers for automating plant processes and administrative procedures, and for rapid information handling.

The overall plan which has been developed is described and the first stage of implementation, involving four interconnected systems, is considered in detail.

Introduction

Those who travelled by train from London to the Cardiff Conference may have seen on their left-hand side just before reaching Newport a series of red, white and blue, mainly blue, buildings stretching for about three miles. This they will have read was the Spencer Works of Richard Thomas and Baldwins, the most modern strip mill in the world. It is the steelworks referred to in my title.

A modern steelworks is, in fact, a string of several works each taking as its raw material the output of the previous process. Thus we have, in order, the *coke ovens* where coal is converted into coke and, very important, gas; a *sinter plant* where iron ore, limestone and small coke are made into sinter by fusing them together; an *iron making plant* which uses the sinter and large coke and lots of air as input to its blast furnaces and produces molten pig iron and slag; a *steel making plant* where molten pig iron, scrap steel and oxygen are used in L.D. converters to refine the iron into steel, and where ingots of the required sizes are produced; a *universal slabbing mill* where the ingots, after being brought to a uniform temperature, are rolled down to about 6 in. in thickness, up to 5 ft in width, and about 30 ft in length; a *hot strip mill* where the slabs are rolled hot from about 6 in. thick down to about $\frac{1}{10}$ in. thick, and where the resulting strip which is then about $\frac{1}{3}$ mile in length is coiled up; a *cold reduction mill* where, after cleaning in an acid bath, coils are rolled cold down to about $\frac{1}{50}$ in. in thickness, and *various finishing departments* where strip is annealed, tempered, cut up into sheets, flattened, oiled, resquared, inspected, packed and dispatched. In all there are some eight major processes.

In being able to handle the basic raw materials of iron ore, coal, limestone and, one must add, air through all the intermediate processes up to the production of steel sheets and coils for the customers (who are mainly car, domestic appliance and drum manufacturers), the works is known as an *integrated* one with much the same connotation of the word integrated as is used in the phrase "integrated data processing." The first turf (a somewhat euphemistic term for the vegetation growing on what was virtually a marsh) was turned for this works in August 1959, and the last major process came into operation for the first time on 4 September 1962. The works therefore qualifies for the title of "New" I think.

Survey of potential for computers

So much for a brief description of the steelworks itself. What of the computer systems? For this, I must go back about three years to a time before the construction of the plant had started. R.T.B. asked the British Iron and Steel Research Association's Operational Research Department to survey the potential for computers in a modern integrated steel works, and to make proposals for Spencer Works in particular. This B.I.S.R.A. did in March 1960 shortly after another important and relevant step had been taken by R.T.B. This was to engage a company of consultants—E.A. Automation Systems Ltd., to advise on and to introduce, throughout R.T.B., automation both of processes and of administrative procedures.

The B.I.S.R.A. remit was limited to administrative and data-handling procedures, and for those purposes they envisaged the works covered by two interconnected systems of computers, an off-line system of three medium-sized computers, and an on-line system of five "satellite" systems as they called them, each handling information to and from an area of the works. The two systems were to be inter-connected by random-access storage accessible to both. These proposals were studied by E.A. and, in October 1960, they issued a report which agreed very substantially with the B.I.S.R.A. proposals, but modified the "hierarchy" of computer levels somewhat by the introduction of a process-automation level, and the splitting of the upper B.I.S.R.A. level into two, one for planning and general off-line work, the other for production scheduling.

Fig. 1 illustrates the four levels of computer system which, in fact, form the basic concept of all the computer developments at Spencer Works.

As I mentioned, we have a level for such general tasks as planning, accounting, stores control and other off-line data processing, a level for scheduling, where customers' orders are turned into schedules for every shift on each process, and this level in turn is divided into a system covering the three departments of coke, iron and steel called the "heavy" end, and a system for the remainder of the works called the "finishing" end. The level below these comprises a production controller for each main area or areas. These are designed to display the detailed schedules to the operators item by item on visual displays or printers, and to collect data about the actual progress of production and performance of plant from keyboards and automatic instrumentation.

Fourthly there is the level of process control or automation of the machinery itself, and computers can be envisaged controlling sinter, iron and steel production, and all the rolling processes. In such cases level three of production control becomes more a link between the automation computer and the scheduling level than a link with the operators.

Implementation

These proposals were submitted to the R.T.B. Board of Directors and approved in piinciple. As a result of this the Department of Information Handling and Production Control was established at Spencer Works in February 1961, and we were told to implement the proposals, to the design and installation stage as far as possible by the start of the Works in conjunction with E.A., and to cover the rest of the works with as up-to-date a manual or punched-card system as possible, making it capable of easy conversion later to a computer system. As a department we were to concentrate on levels two and three, level one being left for the future and level four being more the concern of the departments operating the plant. The staff were gathered by secondment from the three existing service departments of the company, Organization and Methods, Operational Research and Productivity Engineering. During the past year and a half the professional systems staff has increased to about 30, about half of whom have been engaged on the computer side. In addition we have now got about ten programmers.

The first task was to decide which systems out of levels two and three to tackle as Stage one of the computer system, and which areas to cover manually. This turned out to be relatively easy to do. E.A. stated that, by the start of the works, they could provide one system at the scheduler level and one at the production-control level. There is no doubt that for scheduling orders through a steel plant one has to start at the Finishing End; a Heavy End Scheduler is almost meaningless without the Finishing End one already installed.

Interconnected systems

A parallel decision was taken by the production and engineering departments to automate the hot strip mill, i.e. to implement the hot strip mill level four computer system, and this meant that unless we introduced the ingot and slab production controller we were going to be faced with a number of awkward computer/manual system interfaces.

Thus we decided on the three interconnected systems shown surrounded by shading in Fig. 1:

The Finishing End Scheduler,
The Ingot and Slab Controller,
The Hot Mill Automation Computer.

The Hot Mill Automation Computer is an American

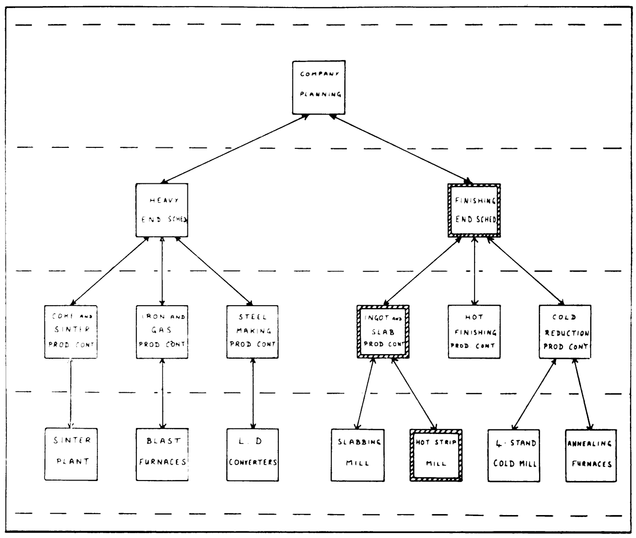

Fig. 1.—Four levels of computer system

G.E.412 computer with a 56,000-word drum as backing store. The Finishing End Scheduler and the Ingot and Slab Controller are both Panellit 609 systems using Elliott 803B computers and magnetic-film units.

To assist in the training of programmers and the development of programs, and also to provide standby coverage for the 803 computers which will both be on-line, a third 803 computer was purchased, and this was the first to be installed in December 1961. This will have as its bread and butter work the running of statistical routines on the inspection data collected each week by the Quality Control Department, and will also carry out some of the longer-term production planning calculations.

Constraints in scheduling procedure

I would like to consider first the Finishing End Scheduling Computer as this is the key computer as far as levels two and three are concerned.

The initial input to this machine consists of the customer's orders punched on paper tape. Prior to punching, the orders are scrutinized, and a quality control "routing" applied which specifies all the processing which is required by the material for the order from the steel plant to dispatch: for instance the type of steel required, the surface quality required on the slab, the temperatures required in the hot mill, etc. Among the data is, of course, the important item from a scheduling point of view—promised delivery date. It takes about four weeks for an order to pass through our Works.

Each process has many technical restrictions on its working and the sequence in which it can produce or process steel. The most complex process is the hot strip mill where, owing to wear on the rolls in contact with the strip, particularly at the edges, slabs must be rolled in decreasing width after each change of rolls, which takes place approximately every 12 hours. How-

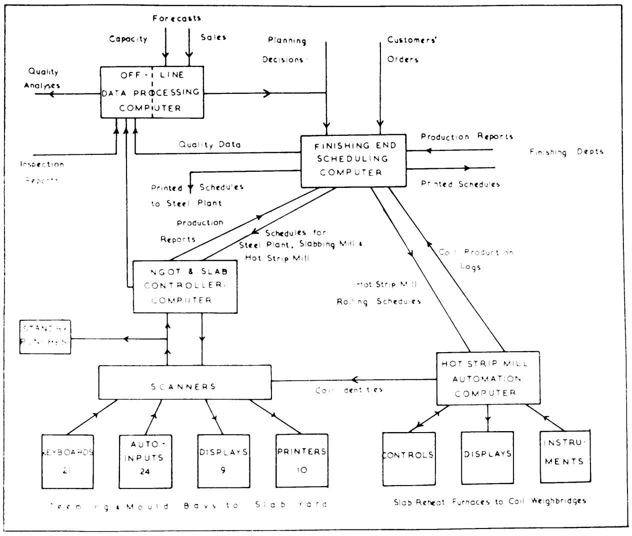

Fig. 2.—Interconnections of computer systems—Stage 1

ever, when rolls have just been changed, heat has to be put into them as quickly as possible to bring them to their correct rolling shape. This is done by rolling slabs into thick strip, and the widths of these slabs are made to get wider until the maximum is reached. Only then does the decreasing-width rule start. This gives rise to what is known as the *coffin* pattern of rolling. To complicate matters further the ıolls in contact with the strip, known as *work rolls*, are given their necessary stiffness by larger back-up rolls, and these in turn wear. They are, however, only changed once per week, and thus the maximum width on each coffin is also subject to its own coffin rul:, and the strip mill's maximum width is only normally achieved on about two schedules in the earlier part of the week.

There are several further restrictions such as those which forbid large changes in width or thickness between two successive slabs, and there are others, which in most works have grown up over the years, developed between the hot mill manager and the scheduling staff. These are the difficult ones to program!

As I said, the hot mill is the most complex process, but there are scheduling restrictions on all the processes and, except in a few cases, these prevent it being possible to have slabs and coils passing through successive processes in the same sequence. The inter-process stocking areas are vital as places where the sequences can be changed.

The interconnections of the computer systems are shown in Fig. 2. The scheduling computer system is responsible for taking customers' orders and, in the light of the delivery promise, routing, planning decisions and technical process restrictions, issuing schedules or working sequences for each major process—about ten in all.

This is done in stages. Taking the hot mill as the example again, a preliminary schedule is produced once per week covering a week, a work schedule based on

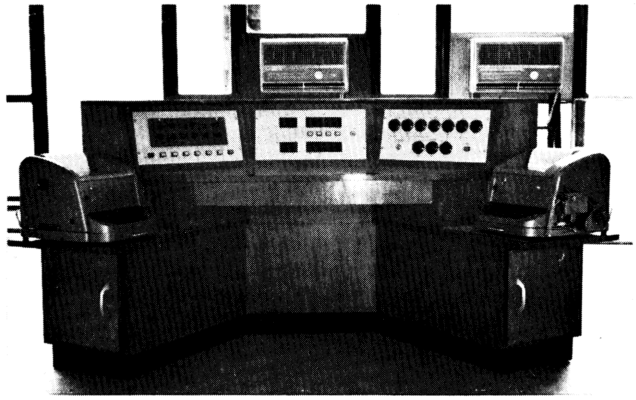

Fig. 3.—Console of Ingot and Slab Controller

actual slabs produced by the slabbing mill once every 12 hours to cover a roll change, and a hard schedule covering only the slabs on the work schedule which have been notified as ready to enter the reheating furnaces in front of the hot strip mill every four hours. This procedure is repeated, in essence, for the subsequent processes. A preliminary schedule is produced saying what we plan to do for a week ahead, and a work or hard schedule saying what we can do for about a shift ahead.

In most cases the schedules are punched out on paper tape, pı inted on off-set litho masters by Flexowriters and duplicated on a Multilith for distribution.

Information transmission

In the case of the hard schedules for the steel plant and the hot strip mill, they are transmitted by a direct link to the Ingot and Slab Controller Computer, where they are stored on magnetic film.

This computer is provided with a control console (Fig. 3) which has provision on the right-hand panel for inserting information to the system or asking for information to be printed out or actuating any function of the system. On the central panel the time is displayed digitally together with any other information which has been asked for and on the left-hand panel are alarm signals for various fault conditions. Two printers are provided on this console.

The computer is connected directly by cable to a scanning room situated in the basement of the slabbing mill some 600 yards away.

Here four "scanners" are provided, each connected by cable to a number of printers, visual displays, input consoles and instruments situated in key points and pulpits in the works. The cables all come to junction cabinets which occupy one wall of the scanner room. Most of the signals are digital, from rotary switches set up by operators, or from width or thickness readings. Some, such as the temperatures of furnaces, are analogue.

Fig. 4 shows the display which is presented to the slabbing mill operators. It gives the size of the incoming ingots, the steel grade (which governs rolling practice), the size of slab required, whether automatic scarfing

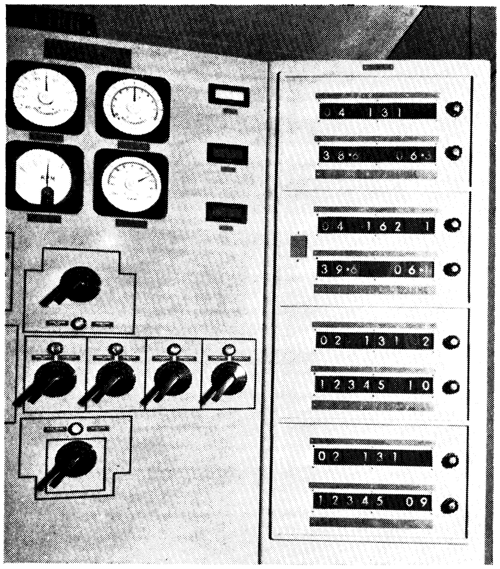

Fig. 4.—Display presented to slabbing mill operator

(passing an oxygen flame over the surface of the slab) is routed, and how many more ingots are to be treated identically. (This last display is automatically counted down.) It also gives this same information for the next batch of ingots.

Fig. 5 shows the view in the other direction in the slabbing mill pulpit over the slabbing mill operators. The input keyboard can be seen in the corner. This is used to record the rolling of each ingot, and to signal to the scarfer operators what scarfing is needed, if any. If an ingot is rejected or rolled to a different size, this is recorded here. The actual settings of the last pass for each ingot in the mill, i.e. the slab cross section are transmitted to the Ingot and Slab Controller automatically.

There are some 20 input consoles or keyboards attached via the scanners to the Ingot and Slab Controller. In case of mal-functioning of one input console, the Superintendent in charge of the system is provided with a general purpose keyboard in the computer building. This is similar in construction to the other keyboards but has an extra two switches on which the number of the keyboard being simulated can be set up.

A keyboard is operated by first setting a selector switch to indicate the type of information being keyed in. The decade switches on relevant modules on the keyboard are then set up as required, and the "data insert" button is pressed. A light which has been displaying "O.K." now changes to "Wait" until the computer has read the information and carried out tests for possible inaccuracies. If it can find none the light returns to "O.K."

If, however, for instance, a cast number has been keyed in which has not yet been made, the computer cannot accept the data, and instead of the "O.K." light, a "Query" light is lit. The operator now has a second chance, but whatever is keyed in the second time, the

Fig. 5.—View over slabbing mill operators

light will return to "O.K." If the computer is still unable to accept the information a print-out on the console occurs, and it is then up to the Superintendent to sort out the discrepancy. We expect a significant improvement in primary recording as compared with that achieved normally with this ability to pick up errors as they are made.

Summarized reports

At periodic intervals, the Ingot and Slab Controller updates the Finishing End Scheduler with summarized production reports about the steel plant, slabbing mill and slab yard performance.

Returning to Fig. 2 for a moment, at the same time as the hard schedule for the hot strip mill is transmitted to the Ingot and Slab Controller and printed for distribution, a punched tape is prepared containing the rolling data for every batch of identical slabs, i.e. a rolling item. This will be read into the G.E.412 computer after its installation, and this in turn will control all the operations of the mill automatically, the pusher displays, the scale breakers, the five stands of the roughing mill, the delay necessary after the roughing stands to achieve the correct temperature, the six stands of the finishing mill, the cooling water sprays and the coilers. At present all these are controlled by operators in a number of pulpits and some degree of the complexity of a pulpit can be seen in Fig. 6, which shows the pulpit for the finishing train. This will all be controlled from the information on the schedule tape, and the feed-back will be in the form of a punched-tape production log for each coil showing the amount on and off gauge, on and off width, the finishing and coiling temperatures, etc.

The Finishing End Scheduler (see Fig. 2) receives production reports from the Ingot and Slab Controller, from the Hot Mill Automation Computer and, until more systems are installed, from manually-punched reports from the Finishing Departments. These are used to update the inter-process stock files, before issuing further schedules, and to examine the progress of every order both as regards timing and as regards the amount of material being processed, taking into account expected yields. Any shortages are immediately reordered, and excesses are applied to other orders if possible.

Finally the scheduling computer prints out data required in the weekly quality control analyses. These are combined with other data punched directly from quality control reports which have been designed as punching documents and are processed in the off-line computer as shown.

Conclusion

I am afraid this paper is only a sketch of the system, which is not yet complete. The scheduler is installed, and programs up to hot mill preliminary schedules are written. The Ingot and Slab Controller was installed last week (end August 1962) and is undergoing tests this week. One of the four scanners is working, a second is delivered, the other two are manufactured and due for delivery any day. The G.E.412 computer has not yet been shipped from the United States; it is due in December. The off-line computer is already producing some of the Quality Control Analyses, but programming will need to continue on this for another two or three months.

Fig. 6.—Pulpit for finishing train

Our aim is to complete these four systems, as far as they can ever be said to be complete, by about a year from now. It will be a busy and, at times, a frustrating year, but it will certainly be an exciting one.

Summary of discussion

Mr. K. L. Smith (*IBM (U.K.) Ltd.*): The approach to plant planning, scheduling and control described by Mr. Massey is an advanced and exciting use of data processing in the steel industry and I look forward to seeing the system when it is eventually operational.

However, I should like to ask why it was decided to implement the scheme with a number of small computers of different types rather than one large computer since:

(*a*) it is a well-established tenet of computer folk-lore that the cost of processing a given problem is reduced as the power of the computer is increased—so a large machine would be cheaper than a number of smaller machines;

(*b*) an integrated system would simplify the intercommunication problem between the several stages of planning, scheduling and control;

(*c*) the traditional claim for hierarchical systems, that they facilitate growth of a central computer complex, would not seem to apply here since the complete systems planning has been undertaken at the outset;

(*d*) a large computer would enable more advanced scheduling programs to be executed.

Mr. R. G. Massey: The Scheduling Computer, the Ingot and Slab Controller, and the Hot Mill Automation Computer are all real-time machines. This means that we would have had to have installed a computer with extensive time sharing capabilities. We did not think that a suitable machine existed at the time of placing the order for our system.

We have not in fact carried out the complete systems planning for the entire hierarchy of computers, but only for the first four computers which I have described. We are free to design further stages in the system quite independently, and it is quite possible that a larger computer would be installed to take over the scheduling work, and for the 803 at present doing the scheduling to be used as the central computer in one of the lower level systems.

The problem of breakdowns and maintenance is also somewhat reduced by having a number of similar small systems, rather than one large one.