DEVELOPMENT OF COMPUTER CONTROL AT FAIRYMEAD MILL

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ABSTRACT

The development of computer control at Fairymead Mill is described. Three applications comprising acquisition of cane receivals data, sampling control, and direct digital control of evaporators are operating successfully. With the confidence and expertise gained from the 3 areas now under computer control, work is progressing in other areas, one of which is supervisory control of the entire factory.

Progress in developing computer control applications has been assisted by the adoption of a project approach. Distinct applications are identified and given definite completion dates. Production people are involved in project management and development and have responsibility for computer operations on shift. The computer has now become an integral part of the processing equipment at Fairymead.

INTRODUCTION

Computer control has been a late starter in cane sugar milling. Contributing factors are the small size of sugar factories (compared to petrochemical complexes) and the variable and complex nature of cane. Chemical and physical processes in a sugar mill are not all that well understood. Under these conditions, advanced control systems require considerable development work.

But computer technology has progressed to the extent that small, powerful computers can be used as alternatives to multiple analogue controllers when loop numbers are greater than about 50. Economic justification becomes even more favourable if added benefits can be shown for special control functions like supervisory, optimal, or adaptive control. Such control actions can be incorporated into a digital computer control scheme, at little extra cost. Our problems in measuring and understanding what is really going on in a sugar mill mean that the added advantages of advanced control will be harder to achieve. On the other hand, the potential returns are undoubtedly high.

The potential of computer control and 2 very promising areas of application in the mill led to the installation of an IBM System 7 computer at Fairymead in 1972 on a project basis. Developments have followed in an orderly and manageable way and the computer is now an integral part of the processing equipment. The initial progress has justified the decision to develop computer control and an accelerating rate of application in other areas of mill operations is anticipated.

PROJECT APPROACH

Project management and organisation are of some significance. The research and development nature of the work has been recognised by the com-
pany and by the Commonwealth Industrial Research and Development Grants Board. A project team has been formed which consists of the project manager who is also responsible for production, a programmer/systems engineer, and a specialist consultant. Assistance has been provided by IBM and the team is joined during the slack season by chemists who are also responsible for computer operations on shift.

The initial applications of cane receivals data acquisition, sampling control, and efft control were chosen for their relevance in reducing the cost of manufacture. They were also straightforward enough to develop staff confidence and expertise. This type of application puts a good deal of pressure on the project team to produce a successful result as failure is obvious and expensive. The same policy of organizing work into projects is being continued. We find that the most rapid progress to a final, documented, operating system is made when the job has clearly defined goals and specifications.

Fairymead have tried to reduce the mystery and concomitant suspicion of computer control by formal courses and by placing the computer in the mill. A combined laboratory and control complex has been built in the mill in which the computer is located. The computer is unattended but is adjacent to the control room which will become the control operations area for shift supervisors who have an intimate knowledge of computer operations by virtue of their slack season programming experience. Close proximity of the computer to the weighbridge/tippler, to number 1 mill, and to the evaporators has been of great advantage in development work. Fig. 1 illustrates the location of carriers, tip, and the laboratory and control building.

**APPLICATIONS**

*Cane Receivals*

Two-hundred-and-four farmers and the company's own plantations supply cane to Fairymead in small rail trucks holding a nominal 3 tons of cane.

![Legend and Figure 1](image-url)
Each rail truck is weighed, its number recorded and for each consignment from each farmer, crop, harvesting and transport statistics are recorded. Cane is paid for on the basis of weight and quality. Sampling is regulated by the Cane Prices Board who limit the maximum number of trucks which can be included in the one sample. For convenience in cane payment purposes, the cane receipts data is organised into files for each consignment of cane which include a heading containing the consignment note information and records of truck numbers, truck weights, sample numbers, extraneous matter weights and ccs.

**TABLE 1.** File organisation for cane receipts data.

<table>
<thead>
<tr>
<th>Item</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consigned note</td>
<td></td>
</tr>
<tr>
<td>Time weighed</td>
<td>month day year modulus 11, 4</td>
</tr>
<tr>
<td>Growers key number</td>
<td>digit number</td>
</tr>
<tr>
<td>Variety code</td>
<td>burnt or green, ratoon year, variety</td>
</tr>
<tr>
<td>Time burnt</td>
<td>day hour</td>
</tr>
<tr>
<td>Time on siding</td>
<td>day hour</td>
</tr>
<tr>
<td>Repeated truck record</td>
<td></td>
</tr>
<tr>
<td>% extraneous matter</td>
<td>XX, XX</td>
</tr>
<tr>
<td>Sample number</td>
<td>XXXX</td>
</tr>
<tr>
<td>Truck number</td>
<td>XXXX</td>
</tr>
<tr>
<td>Net weight</td>
<td>X.XXT^2</td>
</tr>
<tr>
<td>Harvester code</td>
<td>XX</td>
</tr>
</tbody>
</table>

*Notes: 1 Generated by the computer.
2 T is a tare-indicator digit
3 Only for plantation cane*

A new, combined tippler and weighbridge was installed at Fairymead for the 1973 season. Cane is tipped into a side feed carrier immediately after weighing. Crushing rates of more than 300 tch have been achieved with a cycle time which can be as low as 28 seconds. The arrangement has many advantages from an operating point of view. Labour has been reduced to a minimum, but the necessity to tip a truck every 30 seconds puts a strain on conventional data recording facilities. A time sequence is illustrated in Fig. 2. The operator must be able to enter the consignment note in the 18-20 seconds after the weight of the last truck of the previous rake has been recorded and before the number of the first truck of the new rake is entered. The numbers should be verified and corrected if in error. Precautions should be taken to ensure that numbers are not left out or lost.

The computerised system meets all the specifications on integrity and timing and extends the degree of control which can be exercised over tipping control and information processing. The operations performed by the computer are as follows:

* Cane quality is measured in units of ccs (commercial cane sugar content) according to the formula:
  \[ ccs = \frac{3}{2} P (1 - F + 5) - 1/2 B (1 - F + 3) \]
  \[ \frac{100}{100} \]
  where P = Pol % first expressed juice
  B = Brix % first expressed juice
  F = Fibre % cane
Record consignment note data and check for errors.
Request repeat when errors are detected.
Allow the operator to cancel entries.
Record truck number.
Record truck weight via a connection wired to the scale head.
Record tare weight or weigh the empty truck.
Lock the spotter which pushes trucks on to the tip until a truck has been tipped or the operator has cancelled the truck record.
Lock the tip until the truck number and weight have been recorded.
Control the tip so that the carrier is loaded evenly.
Determine if the truck is to be greased and control the greasing device (more than one-half the trucks at Fairymead have journal bearings. These are identified by numbers less than 1 008).

One operator only is required at the tip. He has the following duties:
Initiate a cycle by spotting a truck on to the tip.
Enter truck number.
Enter consignment note data when the last truck of the previous rake of trucks has been weighed.
He is supported by 2 people, one coupling and the other uncoupling trucks.
A third operator performs general duties and is available to take over from the others during meal breaks.
The cane receivals data are recorded on a magnetic disk which is removed every 24 hours for processing on an IBM System 3 computer installed in the company's offices. This computer handles all the commercial work of the company including the processing of cane payment and harvesting reports and statistics from the information recorded by the process control computer.

**Sampling Control**

The control of first expressed juice sampling for cane payment purposes is initiated by the entry of data at the weighbridge. Objectives of the control program are to collect an aliquot of juice from each truck except the first and the last in each sample rake and to make the quantity of each portion proportionally less as the number of trucks in the rake increases. The program restricts
the maximum size of any sample to 25 trucks and avoids sampling juice for rakes of less than 3 trucks. These restrictions were applied to comply with the general regulations prescribed by the Cane Prices Board for juice sampling. Provision is made for the control of manual sampling for the analysis of extraneous matter, fibre, and special juices.

The following are sampling control functions:

- Increment sample number when a "new rake" transaction is initiated at the weighbridge.
- Increment the sample number when the number of trucks is greater than 23.
- If there are only 24 or 25 trucks in the rake, the extra trucks are combined with the preceding sample.
- Track each truck on the side feed carrier, the main carrier, and the elevator by measuring carrier movement.
- When the mid point of the truck to be sampled reaches the end of the elevator, set a delay equal to the time taken for passage through to the first mill and the sample lines.
- If the truck is not the first or last of the rake, take a sample of juice by diverting the sample juice to a receiver for a time which is inversely proportional to the number of trucks in a rake.
- If the length of the rake is not known, take a sample for a minimum time (about 1 second).
- If the truck is the last of the rake, move the table holding the sample containers to position the next sample container under the receiver. Subsample the collected juice into the container.
- Mark a truck if a special juice or fibre sample has been requested at the weighbridge. Turn on the appropriate light during the passage of the truck past each of the sample points.
- Similarly, initiate extraneous matter sampling for the nominated truck in each sample. (The nominated truck can be the first, second or any truck in a rake and may be selected and varied by the chief chemist to preserve unbiased sampling.)
- Record the truck number if an extraneous matter sample is taken and, when the component weights are entered, calculate the percentage extraneous matter and store in the cane receipts file.
- Record the weight of each truck as far as the first mill.
- Log mill stops as being equivalent to the time the main carrier stops.
- Display the last digit of the last sample number for checking against sample container number and counters which are pulsed on sample initiation at the weighbridge and the sample point.
- Notice that an empty container will result from a 1 or 2 truck rake preserving the sample number sequence in the sequence of sample containers.

**Evaporator Control**

The computer is in direct control of evaporators. The system has been described fully by Mooney et al. To summarise, sensors to measure liquid level in vessels and supply tank, pressure, and brix are connected to the computer which also opens and shuts control valves for juices and syrup and steam flow. The control scheme is novel in its use of low cost float switches for liquid level measurement. Not only is the cost of the sensor less than one-fifth the
cost of an analogue differential pressure transducer, but the sensor has digital output in the form of contacts. The cost of connecting digital sensors was about 2% of the cost of connecting analogue differential pressure cells.

Despite the low resolution of liquid level from only 3 switches on each vessel, control of level was adequate. Control could be improved by adding a fourth switch and by combining action on the inlet and outlet valves of the last vessel. Table 2 illustrates the quality of control measured over a 24 hour period.

### TABLE 2. Performance of evaporation control system.

<table>
<thead>
<tr>
<th></th>
<th>Within set point range</th>
<th>Within expanded range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of range mm °Bx</td>
<td>% of total time</td>
</tr>
<tr>
<td></td>
<td>% of range mm °Bx</td>
<td>% of total time</td>
</tr>
<tr>
<td>Level no. 1</td>
<td>70</td>
<td>52</td>
</tr>
<tr>
<td>Level no. 2</td>
<td>65</td>
<td>51</td>
</tr>
<tr>
<td>Level no. 3</td>
<td>65</td>
<td>59</td>
</tr>
<tr>
<td>Level no. 4</td>
<td>53</td>
<td>73</td>
</tr>
<tr>
<td>Level no. 5</td>
<td>25</td>
<td>89</td>
</tr>
<tr>
<td>Brix</td>
<td>1.5</td>
<td>64</td>
</tr>
</tbody>
</table>

Control action is the digital equivalent to proportional plus integral analogue control. Gain and integral action constants are adjustable to allow tuning of control loops as in analogue control. The same program can be shared by other control loops by defining the measured signal, the outputs, and the control constants.

Towards Supervisory Control

Small computers have limitations in performing the enormous computational load of classical optimisation calculations. Yet some form of on-line supervisory program seems essential if the factory is to be operated at maximum rate and efficiency. Performance improvement is usually regarded as the most promising area for computer control but all too often the complexities and difficulties of developing a workable system reduce the benefits that could be obtained.

The second stage of work at Fairymead involves a heavy commitment to developing a practical and flexible supervisory control function. The emphasis is on flexibility. Indeed, Fairymead have sacrificed early progress on crushing rate control to develop a set of programs which will allow production staff at Fairymead to expand the supervisory control function. Changes in processing, changes in plant configuration, improvements in instrumentation, and increased knowledge of chemical and physical processes will be easily accommodated by the program.

The structure of the programs is shown in Fig. 3. The data logging and direct digital control modules have predecessors in many other control installations.

The process calculation module is not normally available. The sugar industry seems to have an almost unique need to calculate quantities which
cannot be measured, or are difficult or expensive to measure. Typical quantities are pol extraction, mud solids, mud moistures, bagasse moistures, reabsorption factors, and heat transfer coefficients. Some of these are physical quantities; other are performance indices. All have relevance in control.

The program uses measured and averaged data for the calculations which are based on heat and material balances, performance formulae, rate equations, etc. A structure has been evolved which allows changes to be made in the plant structure, the equations, the measured variables and the quantities to be calculated.

The process calculation phase provides data for the supervisory control calculations which are scheduled for development in 1974. The results of the supervisory control calculations will be values of set points for control loops on number one mill speed, imbibition water flow, exhaust steam pressure, filter wash water, syrup brix, etc.

CONCLUSIONS

Experience with operating a factory with 3 areas under computer control has led to the following conclusions:

The most satisfactory results come when work is organised into projects which have precise specifications and goals and a real test of success.

The computer should be regarded as part of the processing equipment and preferably located in the mill. Production staff should have responsibility for its operation.

Initial hopes for returns from computer control have invariably been reinforced by our experience to date.

Manual back-up as the only alternative to computer control has worked successfully in periods of computer failure.

Truck coupling and data entry are now the only manual operations involved in the processing of cane after selection of a line of full rail trucks through to the crystallisation process.
REFERENCE


APPENDIX I

Data Acquisition and Control Computer

Type: IBM System 7, Model C03
Core: 12K, of 16 Bit Words
Cycle time: 400 ns
Input/Output: One module with 4 groups (16 inputs per group) of digital input, 2 of which are process interrupt and 4 groups of digital output. Eight analogue input points.
Disk storage: One fixed and one removable disk with total capacity of 2.4 million words.
Teletype: Model 5028 with paper tape punch and read facility.
Auto restart: This feature automatically restarts the system after power failure.
Data entry: One IBM Model 2791 Area Station with numerical entry keyboard, guidance display panel and Model 1053 printer located in the weighbridge.
One IBM Model 2796 Data Entry Unit located in cane sample room for entry of physical cane quality analysis.

Commercial Computer

Type: IBM System 3, Model 10
Core: 16k bytes
Disk Storage: One fixed and one removable disk compatible with System 7.
Printer: Model 5203, 200 lines minute
Card Reader: Model 5424
Card Punch: Three Model 5496

DESARROLLO DEL CONTROL CON UN COMPUTADOR EN EL INGENIO FAIRYMEAD

G. Mitchell, D. B. Batstone y R. Deicke

RESUMEN

Se describe el desarrollo del control con un computador en el Ingenio Fairy Meadow. Hay tres aplicaciones que funcionan ya exitosamente. Estos son los cálculos relativos al pago de la caña, el control de muestreo y el control digital directo de los evaporadores. Con la confianza y la experiencia adquiridas en estas tres áreas ya controladas por el computador, la aplicación a otras áreas va progresando. Una de estas es el control de la supervisión de toda la factoría.

El progreso en el desarrollo de aplicaciones del computador se ha logrado adoptando el sistema de proyectos. Se identifican posibles aplicaciones y se fijan fechas de ejecución. El personal de producción participa en la administración y desarrollo de los proyectos y luego se encarga de la operación del computador trabajando por turnos. El computador se ha convertido en parte integral de los equipos de proceso en el Ingenio Fairy Meadow.