AUTOMATIC PROCESS CONTROL IN SUGAR & FACTORIES

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ABSTRACT

World-wide trends in the development of automatic control of sugar processes in recent decades were reviewed in this paper.

After a backgrounder, the development of automatic control process, in terms of cost effectiveness and benefits were discussed. Then its influence on process technology, together with questions of work organization and levels of automation, and finally, the social effects of automation were enumerated.

In the course of the review, the details of control installations worked upon personally by the authors at various times and locations were given, with the most detailed case being automatic pan boiling, and the most recent control installation being in 1979 at Batangas. Comparison is made of control practices in both beet and cane factory processes.

INTRODUCTION

The present day position of automatic control in sugar factories is constrained hardly at all by limitations of control technology. Almost all of the constraints are imposed by economic and social factors. When reviewing world trends in beet and cane factories from the standpoint of automation, attention must therefore, be paid to social and economic factors.

The extraction of sugar from cane in factories was one of the earliest factory processes to benefit from the industrial revolution, particularly in respect of the large refineries in the industrial countries which received sugar as raw material from the so-called raw factories located by the cane plantations.

In the raw factories, labor was cheap and heat comes free from bagasse. In the refineries on the other hand, fuel and labor were sources of major costs. It was only to be expected to find that while the raw factories remained small and labor intensive, the refineries expanded rapidly in all directions so as to obtain the maximum benefits of capital, labor and fuel economies. Automatic process control using the techniques of the petro-chemical industries spread rapidly after World War II, and by 1960, off-line control of refinery operations by digital computer was being undertaken (Brookes).
After World War II, a number of economic, technological and social factors began to affect the European beet industry particularly. The increasing costs of fuel and long distance transport made the separated cane raw sugar factory and refinery processes relatively, less cost effective than the once-through and integrated beet factory. The successful agricultural development program and the improvements in factory processes in Europe made the industry and attractive one for capital investment.

This investment obtained its return from improvements in factory extraction performance, lower fuel and labor costs. Fig. 1 illustrates the changing pattern over the fifties and sixties from results of the British Sugar Corporation.

**FIGURE 1. Changes in factory performance 1950-1965.**

**DISCUSSION**

**Cost Effectiveness**

Automatic control schemes were introduced so as to:

- give direct savings in labor costs
- give direct savings in material
- eliminate dirty and socially unacceptable manual tasks
- provide security to the increasing scale of plant and operations so as to
- minimize risks from mal-operation.

An interesting example of illustrating all these is the automated lime kiln now common in all the European factories. What in the British Sugar Corporation was once an arduous and dirty job for seven or eight men per shift, is now clean and easy work for one dayworker. The accurate control (Withers):system makes substantial fuel saving possible and this showed an even greater return than the labor savings.
On/off schemes

Automatic control is usually thought of in the context of continuous measurement and control of such parameters as pressure, flow and level. There is another type of automatic control system which can present considerable advantages when correctly applied. This type of scheme involves on/off repetitive operations on process plant such as filter systems, where regular cleaning is essential. Other on/off schemes have been developed for the control of cane yards in Australia (Diplock and Marshall). These systems are relatively expensive in first cost, but can be quite spectacular in terms of low operating cost and in the reduction of the labor force. In many European countries, it is becoming increasingly difficult to obtain people who are prepared to do the more dirty and arduous jobs which exist where routine cleaning is called for. In such cases, automation may be a prudent course of action.

A large number of these systems were developed in the European beet industry in the sixties and the majority of these automatic schemes are still operating on minimal maintenance. In some cases, the application of automation has gone hand in hand with a basic change in the process plant. For example, the filtration of second carbonation juice in the British beet industry is now done by a bank of fully automatic bag filters using the part-time supervision of one man per shift compared with previous installations of plate and frame presses using eight men per shift. The installations also occupies a smaller space and runs considerably cleaner, there being no significant steam or mud around the operating station. Processing results compare favorably with plate and frame press operation.

Automation of rotary vacuum filters requires no significant change to the filter itself with the exception of fitting remotely operated on/off valves and an automatic cleaning brush. For most of the time, the operator is working at a higher level on quality control, rather than doing manual cleaning.

![Block diagram of control system for 5 filter station.](image)
We consider that this type of automatic control scheme best consists of a central electrical circuit operating at low voltage. This central circuit is successively connected to the filter which is being cleaned. The electric signals are then converted to the power air signals which move the valves. There must also be an operator display containing the master timer which dictates the frequency of system operation and a set of indicators which shows the operations being carried out. Provision must be given to run the filter totally on manual control in order to allow for any nonstandard operations which may be required.

Such systems using relay logic were constructed in the sixties and it has been found that the automation generally only requires a few hours per year maintenance, most of it being on parts in contact with the process.

Where systems are being designated today, advantage can be taken of solid state technology and it is comparatively simple to extend the flexibility of the system so that in place of the filters being cleaned on a fixed time cycle, they can be cleaned after they have serviced a known quantity of process liquid, this quantity being set manually on digital switches by the supervisor.

We further advocate that with systems of this type, great care should be taken with the operator display so that a simple scan of the control board even from a distance of 30m, will determine from the pattern of the lights on the control board that the system is functioning correctly. We also consider that with the relatively low speed and infrequent operations of such systems, it is sound engineering to design on the premise that once an electric signal is generated by the control scheme, the commanded valve invariably opens. This happy state of affairs is realized by the use of good quality components which are run well within their rating. Our experience showed that such an approach is an order

![Diagram of manual milk of line density control](image)

**FIGURE 3.** Manual milk of line density control
of magnitude more reliable than proving valve action by means of limit switches before allowing the system to proceed.

**TABLE 1.** Final control elements required for the automation of individual filters of various types.

<table>
<thead>
<tr>
<th>Hydro-cyclone</th>
<th>Bag filter</th>
<th>Rotary vacuum filter</th>
<th>Schenk filter</th>
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<tbody>
<tr>
<td>Dump valve</td>
<td>Valves</td>
<td>Inlet</td>
<td>Valves</td>
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<tr>
<td>Dump valve</td>
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<td>Recycle</td>
<td>Juvenile</td>
<td>Wash vacuum</td>
<td>Drain juice</td>
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<td>Wash water</td>
<td>Air blow</td>
<td>Water in</td>
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<td></td>
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<td>Coarse spray</td>
<td>Backwash in</td>
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<td></td>
<td></td>
<td>Brush cylinder</td>
<td>Air vent</td>
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<td>Drives</td>
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<td>Drum</td>
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<td>Agitator</td>
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<td></td>
<td>Brush</td>
<td>Gland water</td>
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<td></td>
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<td>Repulper</td>
<td>Flowmeter flush</td>
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<td></td>
<td>Sludge pump</td>
<td>Juice pumps</td>
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<td>Spin motor</td>
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As European factories became more capital intensive and less labor intensive, ways of capital cost saving became paramount in importance. A major way is to increase the unit process size. For many items of equipment, the capital cost is proportional to the ratio of the plant capacity raised to a typical power of 0.6. Thus, for example, if a process vessel or tank of a capacity of 100 cu m costs £7,000, a 200 cu m vessel will only cost 2^{0.6} as much or £11,600. There is, therefore, a strong incentive in capital-intensive industries to build large. Over the period of 1950-1980, we have seen the capacity of single RT diffusers increase from 2,000 to 11,000 per day, and similar increases have been seen in most items of sugar factory equipment.

At the time, the savings in capital costs caused by increases in unit sizes were reinforced by a saving in operating costs because only the same number of people are needed for a large diffuser as a small one, and very often there are savings in efficiency too. Thus, for example, a large steam turbine gives more power per ton of steam than a small one.

The increase in factory size combined with the relatively few personnel, increased the need for modern methods of communication further. Closed circuit television systems and automatic data logging are commonplace in the large European beet factories.

Working life in a modern beet factory today has indeed changed dramatically from what it was only a generation ago. This is dramatically illustrated by the
change in electrical horsepower available in the British Sugar Corporation to each process worker from around 30 in 1950 to around 90 today. (See Fig. 1)

With the creation of the European Economic Community, conditions of a stable and protected market combined with the favorable technological and economic factors listed above to provide for a significant expansion in the European industry, together with a program of rationalization. Thus, small factories were either closed down or enlarged and a few quite new factories of large size were built.

The new factories built by the South German Sugar Company are particularly noted for their attractive layout, large unit process size and high level of automation, and these together with the British Sugar Wissington factory, enlarged from 2,500 tpd in 1951 to 12,000 tpd in 1979. They are also renowned for their advanced systems of computer control (Withers et al.10), are visited each year by many sugar technologists from all over the world.

**Influence of Control Technology on Process Technology**

The effect of these large changes in unit size and increasing levels of automation, inevitably produced changes in the technology of the sugar factory itself. The most significant of these is the virtual elimination of batch processes and their replacement by continuous ones. There is no doubt that the modern continuous unit processes are helped considerably by the on-line systems of process control.

Milk of lime in beet factories provides a simple example of such a major change due to automation. Beet factories burn limestone in a kiln and then slake the quicklime to give milk of lime. Kiln loading nowadays is automatic, as demanded by kiln level, with manual attention confined to daily filling of the coke and rock hoppers.
Extraction is also automatic, the unloaders being run on demand from the lime tank which follows the slaker. The water to the slaker is pre-set to give a heavy mix. Earlier, manual arrangements involved making a heavy milk of a lime mix in one tank, transferring this mix from time to time to the "correct lime tank" where it was diluted and pumped to the process.

This operation demanded continuous attention and a good degree of skill because of the long time constants of slaking and tank capacities. Mal-operation gave far reaching effects throughout the process.

Nowadays there is no "correct" tank. The lime going to the factory are continuously dosed with sweet water injected before the lime pump to give correct density. The lime is measured automatically and continuously, immediately after the pump, the short time between output measurement and input dosing permits very tight closed loop control to close limits of density.

The reliable supply of correct density of milk of lime is a key factor for successful results in the continuous carbonatation process in beet factories.

It is interesting to note the change in management styles that have occurred. Whereas 30 years ago, slice rates were often governed by competitive shift working with notice boards placed around the factory for the purpose of emulation, nowadays, slice rates are normally held constant for days on end to within a few percent, and the emulation board is redundant.

In the fifties and early sixties, quite sophisticated control schemes involving cascade and ratio controls were being introduced with a view to regularizing operations and to optimize performance (Withers®). Now that operations in steady state have become so normal, the ratio controls are often switched out if only to give the operators something to do.

**FIGURE 5.** Batangas magma mingler basic control system.
The only remaining batch processes which still predominate are, of course, the white sugar centrifuges and the vacuum pans. Both of these processes have been made continuous in recent years but to date, the continuous systems offer no advantage over the batch and are very much less flexible in operation. It is interesting to note that the operation of these two batch processes have been significantly affected by modern electronic systems of control and recently augmented by the advent of the microprocessor (Bass1), and it seems likely that these processes can no longer be justified as a continuous concept.

Some Contrasts Between Beet and Cane

Whereas the cost effectiveness of the European beet industry has improved enormously, there has been little change in the market demand for sugar. Indeed with current consumption per head at the highest level in the world and with a stagnant total population level, the buoyancy of the beet business inevitably caused a decline in cane raw refineries.

This has caused business problems to the European refiners who in consequence, have had to close down refineries and divert their business and technology into other activities.

The raw cane sugar factories in the developing world, however, have prospered because of their still increasing population and still increasing consumption per head of population. With the majority of these countries becoming independent, the ownership links between the refineries and the raw factories have largely disappeared and the raw factories have not merely become larger and more numerous, but they have also turned their output more and more to ever increasing standards of white sugar production.

In this connection, it is interesting to note that the business opportunities

SERVICES
rate of vacuum rise
vacuum break
steaming out
instrument flush
pan door
 circular on/off
seed valve

EXTERNAL
feed & dropping tank levels
status of other vacuum pans
purities
demanded throughput.

CALANDRIA
choice of steam
* pressure
steam flow rate
condensate flow rate

*absolute pressure vacuum

MASSE
choice of charge
* level
 temperature
 boiling point elevation
* conductivity
 viscosity
dielectric constant
refractive index
microscope
feed rate
water flow rate
circulator trip

The measurements marked * are those normally used in the more basic schemes.

FIGURE 6. Measurements and controls available for automatic pan control.
provided by this expansion in cane have been such that Fletcher and Stewart, who provide equipment for both beet and cane, have in recent years been devoting 90% of their effort to cane, inspite of the expansion of the beet business in Europe and in England particularly.

Of course, the laws of capital apply equally to beet and cane and so this investment in cane raw capacity has been characterized by the same increase in unit process size as has been remarked in beet. There is currently being erected at Kenana in the Sudan, for example, one of the largest sugar factories in the world with a designed capacity of 18,000 tons per day on two seven stand mill trains, each having a capacity of 9,000 tcd. Such a factory must of necessity install modern aids to process control and information display.

However, it should be mentioned that there are some disadvantages in the European situation with respect to large scale plants, and these disadvantages may also apply to the developing world.

- Increased vulnerability to human weaknesses and disputes both in start-up and subsequent operations, causing a poor return on investment, particularly applicable to seasonal working of perishable crops.

- A loss of flexibility in operation, causing high operating costs under part load conditions; this often happens in the first year or two of operations due to agricultural problems.

- The plant may become so large that there are technological and management problems in the construction, causing unforeseen delays and expense prior to commissioning. These problems can be enhanced sharply by long lines of communication and supply.

- Kenana is already well over both time and cost budgets and Fletcher and Stewart had a similar experience with its Sennar factory of capacity 6,500 tcd, also in the Sudan.

Labor saving by automation is not so attractive a proposition in cane as in beet. Thus, for example, at the Mumias factory in Kenya, which is among the best managed and profitable factories in the world, there are four times the number of people employed as in a similar sized beet factory in Europe. Australia, of course, provides a noticeable exception to this cheap labor situation. There, advanced systems of automation including computer aids, are being developed for many years (Maclean at al).

Since the fuel comes for nothing, the only justification for automatic control systems has to be in such cases where improvements in sugar quality or overall recovery accrue. Exceptions to this general situation occur in those countries where the bagasse is wanted as a by-product or where a refinery is added on to a raw factory so as to produce the highest quality white sugar for export purposes. Such a case is Batangas in the Philippines.

For this factory, Philsucorn has specified a number of advanced features, such as, mixed bed ion exchange and regeneration, and use of activated granulated
carbon. An appropriate level of automation has been specified with central display and control of all the main process parameters.

Magma Mingler Control at Batangas Refinery

Since the mingler is the start of the refinery, irregularities in its output will affect the smooth running of the plant. Instrumentation is fitted to automatically control the process and also to cater for common failures, such as loss of feeds.

The operator decides the input sugar flow rate. The actual flow rate is measured and controls the affination wash syrup flow rate. The magma viscosity is measured and trims the ratio of syrup to sugar.

Failure of sugar flow stops the affination wash syrup and alarms. Failure of the wash syrup supply brings in (as emergency) sweet/hot water. Zero liquid flow to the mingler stops the sugar flow and locks out the system until a manual reset.

Centrifugal feed trough high level, locks out the system until a manual reset.

Milk of lime is added to the mingler as a pulse of varying time, starting at regular intervals. The lime stops if the diluent stops.

Full manual controls are provided, the lockout operates whether in manual or automatic.

Modes of operation are as follows:

Hand set sugar input, affination wash on hand or auto. Mingler viscosity and temperature recorded.

Hand set sugar input, actual sugar flow gives constant ratio of affination wash.

Full auto, with operator setting only sugar flow rate and viscosity set point.

Sugar input is measured by an impact flow meter, viscosity inferred by the power required to drive the mixing paddles.

The impact flow meter consists of an inclined plate which is free to move horizontally within narrow limits. The sugar falls on the plate from a fixed height via a special spout. The instrument measures the momentum interchange between the sugar and the plate and resolves mass flow rate.

During calibration, the meter becomes an integrator and a test quantity may either be fed into the meter, or collected at meter exit. For structural reasons we have elected to feed a known quantity into the meter. Check weights may also be hung onto the instrument inside the meter housing to give a routine "confidence check".
The Levels of Automation and the Work Organization

While there are very backward places in the developing countries, there are many situations where the people concerned are indeed very able, and where the agricultural and raw material resource could lend itself to a rapid jump to the technological level of the European factories. An obvious example at the present time is in China where, for example, 1200 people are currently employed in a 1500 tpd factory with small sized unit equipment and little automation and where there is now a sudden aspiration to install 4000 tpd high technology factories. In such a case, special care will have to be taken with respect to the human factors.

A completely different mental approach is required by all concerned at all levels in a small, labor intensive factory from that in a large automated plant. For example, in a labor intensive factory such as Mumias, engineering maintenance can be managed on a predominantly breakdown basis, whereas at a highly automated factory such as Wissington, engineering maintenance must be managed predominantly on a preventive basis. This leads to a big change in the structure of the work organization and to the expectations of the personnel employed (Bass and Dixon).

When discussing systems of automatic control, it is necessary to distinguish between levels or degrees of automation. They are as follows:

A first level where control is manual and local to the plant, automation can be restricted in the main to power assistance.

A second level where control is automatic by closed loops and scheduled systems from instruments grouped on a console, not necessarily positioned in a central control room. These controls may have their set points under manual control, from cascaded auto systems or from a central computer.

A third level where control is automatic from a central computer. This computer control can either be directly coupled by microprocessors locally distributed, or by central computer, and may be part of a hierarchy of controls embracing the second and first level systems previously described.

Automatic pan controls provide good illustrations of all three concepts.

When the vacuum pan floor was designed by British Sugar Corporation for its Wissington factory in 1967, it was arranged that all 13 vacuum pans would be placed under automatic control so as to permit the control of all 13 pans from one computer. The system was designed for use by two operators and was designed with the possibility of the following five levels of control.

1. Remote hand operation of the valves from a sub-console placed at the pan face using pressure gauges and thermometers on the pan.

2. Remote hand operation of the pan from the control room situated on the
pan floor.

3. Operation from the control room with individual process control instruments such as absolute pressure on closed loop control.

4. Automatic operation from a relay type system provided in the control room.

5. Direct digital control of the vacuum pans completely by-passing the process controllers installed in the control room. Transmission signals led to a central computer which was situated in another control room, computer outputs went to incremental type pneumatic generators and from there to the valves.

The relay system was successfully commissioned at all its 4 levels. It was soon found with 13 pans under full computer control (level five), that the operator has to pick up control due to a system malfunction or to irregular factory with the situation. To remedy this, the vacuum pan cycle was divided into 13 steps in the interests of agronomics and pan management. The completion of each step was signalled to the operator by a flashing lamp with an appropriate legend. The operator then retained command of the system of pushing the flashing light to give the automatic control permission to proceed. The act of pushing the button required the operator to update himself with the status of the process. The subsequent development by BSC of a micro computer control of vacuum pan, where each vacuum pan has its own microprocessor controller, has retained this particular feature in the interests of operator involvement.

There are at least five companies now offering fully automatic vacuum pan systems of varying degrees of sophistication. One of these companies claims sales exceeding 400 systems so that the incentive for development is considerable even for such an apparently specialized system.

Social Effects of Automation

We return, finally, to a subject touched upon earlier, namely the social effects of automation. This is a subject which has become of increasing concern not merely to trade unions, but also to the professional institutions concerned with control engineering and to management. For example, IFAC has acted as a focal point for some years in this respect (Sprague and Schuh7, Bibby et al3);

There can be no doubt that the introduction of automated large factories in such organizations as the British Sugar Corporation, in addition to the benefits of cost effectiveness already outlined, have greatly improved working conditions.
The working environment is better, accidents are fewer, monetary rewards are higher in real terms and there is greater job security. But inspite of these changes, attitudes to work present many problems and great care has to be taken in considering the social effects of automation and to consult with all people who are or will be involved with the system so as to enrich man's role in the work system. Today's situation in the British Sugar Corporation is indeed different from that in 1950 when the work force had no record of industrial dissatisfaction. Few men belong to trade unions, and there were no specialists in industrial relations in its management team.

CONCLUSIONS

The application of technology today is a very complex process. To be effective, it needs inputs from many quarters. There is no simple formula for evaluating the consequences and no uniform answer to the relationships between new technology and work changes. Each case has to be carefully examined on its own merits so as to secure lasting benefits from the considerable opportunities for improvement made possible by today's technology.

REFERENCES

RESUMEN

Este trabajo hace una revisión de la tendencia mundial en el desarrollo de los controles automáticos aplicados al proceso en los ingenios azucareros.

Se hará referencia especial al automatismo de procesos unitario clave, como el cocimiento. Se hace la comparación del uso de controles en los ingenios azucareros de remolacha y de caña.