Instrumentation Within the British Sugar Corporation

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In the early years after the war, instrumentation within the British Sugar Corporation was very sparse, and consisted mainly of indicating and recording thermometers, pressure gauges, and steam flowmeters with an occasional juice meter. There were also a few industrial pH meters used mainly on 2nd carbonation and thin juice, but these were anything but reliable.

All factory equipment was old and consisted mainly of a series of batch processes which did not lend themselves to automatic control.

In the early 1950's B.S.C. embarked upon a large reconstruction program to modernize its factories. Each year one or more factories were chosen to replace old batch plants with modern, continuous machinery. Beet-end equipment was the first to be replaced, and with continuous diffusion and continuous carbonation, the opportunity arose to increase the instrumentation.

Instrumentation at that time was the prerogative of the Works Manager (Plant Superintendent) at each factory with guidance from his Technical Supervisor, and the Chief Engineer, but there was no over-all instrumentation program. It was not until 1955 that a Control Engineering Department was formed with the purpose of designing, specifying and coordinating the instrumentation throughout the Corporation. The Works Manager still had the final word, but was now advised by a department which quickly amassed a wealth of experience and know-how. Thus, when a new project was programed, the Works Manager would discuss the instrumentation with the Control Engineer who could advise on proven practices at other factories, and would then engineer the scheme at Central Offices.

The choice of the instrument manufacturer would depend to a large extent upon competitive quotations, but with a view to standardize as much as possible at a particular factory. This presented no problems with the first schemes as all the important instruments were new, but in later years the aim was to keep the number of manufacturers represented to a minimum, and still allow competition. It was felt that standardization taken to the ultimate of one manufacturer only, would be detrimental to the factory, particularly with regard to service. In addition, some pieces of equipment were considered to be better made, or in-

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deed, only made by certain manufacturers and these could be specified irrespective of the major supplier.

Once the over-all scheme had been settled between the Works Manager and the Control Engineering Department, the latter would produce a flow schematic showing all the control loops and an outline drawing for the panel, if required. They would also accurately specify each instrument or valve so that all quotations would be truly comparable. Over a period of years several standard panel shapes were evolved, together with very complete specifications. These were found to be of real value, as panel prices often varied by as much as 200% between manufacturers, whereas the instrument prices were very close.

Orders would be placed with the selected manufacturer as early as possible, preferably in the August or September, twelve months before the equipment was due to be commissioned. Extended delivery times dictated this, but it also allowed the department to concentrate on the more immediate problems of commissioning the equipment just installed.

Whenever time permitted, and always with large installations, a reasonably comprehensive "manual" would be produced, describing in simple terms the operation and function of all the instruments being provided. This "manual" was produced primarily for the factory operating personnel, but also proved its worth within the department both as a guide (if more than one new installation was being commissioned) and as a reference when designing new instrument schemes.

Prior to the start of the campaign the department would check the installation and supervise a thorough test of all new instruments and control panels. This test would be carried out during the precampaign steam and water trials so that whenever possible the control functions could be checked. If possible, a service engineer from the instrument manufacturer would be present during these tests as he was in a good positon to obtain any spares or extra items if they were urgently needed.

At the start of the campaign one or more engineers from the department would be present to oversee the start-up and set up the controller functions. Sometimes this required being on site for a week or longer, but usually the plant would be operating efficiently within two or three days.

Setting the controller functions was undoubtedly the most important job and under start-up conditions this was not easy. The usual procedure was to set them sufficiently close so that the factory could operate adequately and then adjust them, say two weeks later, when the factory had settled down and was running at capacity.

Careful records were kept of all controller settings and these were of great assistance when commissioning similar equipment in other factories.

Records were also kept at each factory of the controller output pressures for known conditions. For instance, with a magnetic flowmeter and valve controlling the milk of lime flow to 1st carbonation, the controller output would be noted for about three definite flows. If, at any time, the flowmeter failed, the valve position could be set to give a known flow, without completely disrupting the carbonation station.

With the increase of instrumentation within the factories came the need for properly trained instrument mechanics. In the early days, instrument maintenance had been looked after by the laboratory, but this is no longer possible. As factory engineering was already split between mechanical and electrical, it was decided that the instrument mechanics should be supervised by the Works Electrician. This system has worked well, especially as many of the present day instrument men were once electricians. In order to encourage men not to consider instrument work as a dead-end job, promotion was possible either in the electrical or processing fields. Thus a skilled mechanic with a good knowledge of the process could become a beet- or sugar-end foreman and eventually a shift-superintendent.

Training was carried out both in the factory and at schools run by the instrument manufacturers. On several occasions it was possible to arrange special courses for B.S.C. personnel only. In this way, only those instruments of particular interest would be covered, and mechanics from several factories had the opportunity to meet and discuss problems among themselves.

The first big instrument scheme installed by B.S.C. was at Wissington in 1957 (1)[2] Not only was this the first factory to have over-all control from the beet washers to the thick juice tank, but it was also the first time that electronic controllers were used on a large scale by B.S.C. Much could be written on the pros and cons of pneumatics versus electronics, but suffice to say in this instance that Evershed & Vignoles was the only British company who at that time could meet the complete specification.

The reconstruction at Wissington involved primarily the replacement of a diffusion battery by a 5.4 metre R.T. diffuser. This was the first time that B.S.C. had installed such a diffuser

[2] Numbers in parentheses refer to literature cited.

on the site of the battery it replaced, and the opportunity was taken to revise much of the beet-end layout. The reconstruction was completed in under seven months and the instrumentation was installed by factory personnel in less than three weeks.

This plant was now continuous from the slicers to the thick juice tank, with an absolute minimum of intermediate receiving or waiting tanks, and the revised layout reduced the manpower requirement to a minimum. One aspect of this was that only one man was required to attend both 1st and 2nd carbonation and the evaporators. In view of this it was impossible to justify the great expense of making the evaporators completely automatic.

Several simple electric analogue computers were installed in the over-all scheme, and one of the most interesting applications was to continuously display the amount of solids present at the evaporators (4). Thus, the supervisor knew whether the inlet sugar quantity was matched with the outflow.

In order to simplify the measurements across the evaporators, the thin juice Brix was assumed to be constant. Under these conditions only three variables had to be measured, namely thin juice flow, thick juice flow and thick juice Brix.

The signals representing thick juice flow (F_1) and its specific gravity (C) were fed into the first of two simple computers, solving the following equation which is a measure of the mass of the solids leaving the evaporators.

$$M = 0.1157F_1C - 1.124F_1 \quad \ldots \quad (1)$$

The output (M) from this computer, together with the signal representing thin juice flow (F_2) were fed into the second computer solving this new equation, to give the mass flow difference across the evaporators.

$$T = M - F_2 + 15 \quad \ldots \quad (2)$$

Equations 1 and 2 were derived as follows:

Assuming all solids as sugar, the mass flow across the evaporator may be written as:

$$f_1b_1 = f_2b_2 \quad \ldots \quad (3)$$

where f_1 = thick juice flow in lb/min

f_2 = thin juice flow in lb/min

b_1 = thick juice Brix

b_2 = thin juice Brix

The thick juice specific gravity was measured by a Rotameter densitometer which transmitted 20 —30 ma over the range 1.20 — 1.45.

$$\therefore \text{sp. gr.} = \frac{C + 28}{40}, \text{ where } C = \text{current n ma.}$$

Within the range of sp. gr. 1.20 thru 1.45, Brix equals approximately [(175 × sp. gr.)] - 165, so equation (3) can therefore be written:

$$f_1 \left[175 \frac{(C + 28)}{40} - 165 \right] = f_2 b_2 \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

The thin juice Brix (b_2) was assumed to be 13.5°.

The thin juice flow transmitter was ranged 0-4480 lb/min and gave 0-30 ma for this range. (F_2).

The thick juice flow transmitter was ranged 0-1600 lb/min and gave 0-30 ma for this range (F_1).

Equation (4) then becomes:

$$\frac{1600}{30} F_1 \left[175 \frac{(C + 28)}{40} - 165 \right] = \frac{(4480 \; F_2)}{30} \times 13.5$$

$$\therefore F_2 = F_1 \; (0.1157C + 3.241 - 4.365)$$

$$= 0.1157F_1C - 1.124F_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

If the mass flow across the evaporators was in balance, then $F_2 = M$ and $T = 15$ ma. This output (T) was recorded on a 0—30 ma recorder and was normally at mid-scale. If the mass entering exceeded that leaving, the recorder fell below mid-scale and vice-versa.

Although the thin juice Brix was assumed to be 13.5°, the equations could be modified to allow for any Brix, thus equation (5) could be re-written as:

$$KF_2 = 0.1157F_1C - 1.124F_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

where the coefficient (K) represents the difference between 13.5 and the actual Brix. This coefficient could be added to the computer by placing a potentiometer across the computer coil receiving the thin juice flow signal, thus providing a simple manual correction for thin juice Brix.

Another example of the use of simple computers, or computing relays is that used at the King's Lynn factory to monitor the flow of juice into and through the purification plant. It is now universally accepted that a really steady flow of raw juice is a prerequisite of success at first carbonation using simultaneous lime and gas addition. Even in the best factories there comes a time when the raw juice flow gets out of step with the thin juice flow or beet slice rate. The following description shows the scheme used to provide automatic regulation to keep the flow rates in step without violent fluctuations.

The installation at King's Lynn used two simple pneumatic computers, and three pressure selectors. It is shown schematically in Figure 1.

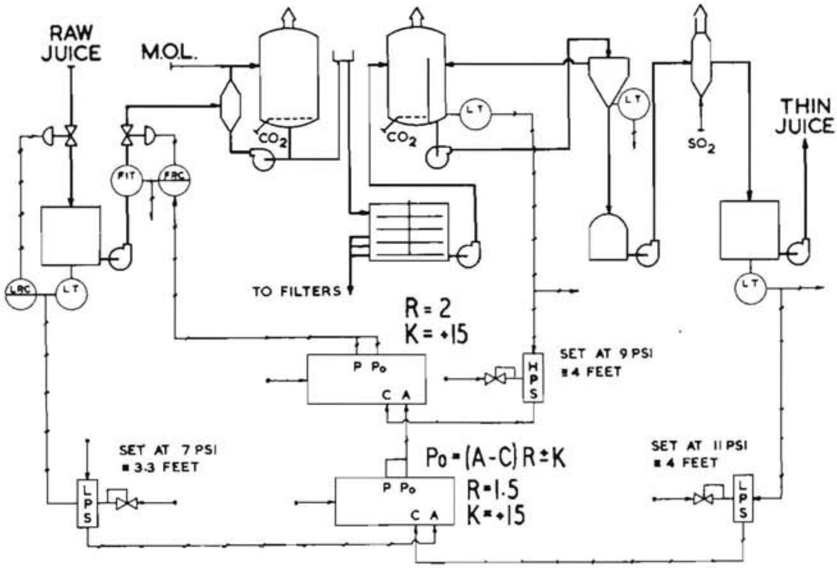

Figure 1.—Juice purification schematic at King's Lynn.

The pressure selectors were simple devices utilizing a pneumatic balanced diaphragm and an output relay. They could be arranged to select and pass either the higher or the lower of two pressures.

The primary controller was the raw juice flow controller. Under normal factory conditions the desired value of this controller was set by the shift superintendent to an estimated maximum. The simple computers automatically reduced this desired value if any one of three tank levels moved outside normal limits. The three levels were those of the thin juice, the second carbonation, and the raw juice tanks. The latter was also used as a preliming tank and was fitted with a level controller operating a valve on the inlet to it.

Although the tanks were different sizes, they were fitted with transmitters ranged to give 3 to 15 psi signals over their normal level ranges. The thin juice tank was 6 ft deep and if the level rose above 4 ft, the raw juice flow was reduced. The carbonation tank transmitter operated over the upper 8 ft of the tank; if the level rose into the upper half of this range, the raw juice flow was also reduced. The raw juice tank was 10 ft deep and if the level fell below 3 ft-4 in, then the raw juice flow was again reduced. In addition, whenever any of these off-normal level zones were entered, an audible alarm attracted the attention of the supervisor.

The thin juice level signal was fed into a high pressure selector, together with a pre-set 11 psi signal derived from a pressure regulator. This selecter would therefore normally pass 11 psi and would only pass a higher signal if the tank level rose above 4 ft.

The raw juice level signal was fed into a low pressure selector, together with a pre-set 7 psi. This selector would therefore normally pass 7 psi and would only pass a lower signal if the tank level fell below 3 ft-4 in.

The signals from these two selectors were fed into the first computer, solving the equation:

$$Po = (A\text{-}C)\,R \pm K, \text{ where } R = 1.5 \text{ and } K = +15.$$

The output of this computer was normally 9 psi, but would reduce to 3 psi if the thin juice level rose to 6 ft, or the raw juice level fell to zero. The output from this computer was fed into the second computer, together with the output from a second high pressure selector. The inputs to this were the carbonation tank level signal and a pre-set 9 psi. The output was therefore normally 9 psi rising to 15 psi, as the carbonation tank level rose above normal.

The second computer was also solving the equation:

$$Po = (A\text{-}C)\,R \pm K, \text{ but with } R = 2 \text{ and } K = +15.$$

With two normal inputs of 9 psi, this computer's output was 15 psi, but if the carbonation tank level rose, or the output from the first computer fell, then the output from this second computer would fall to 3 psi.

The output from the second computer was coupled to the adjustable pneumatic set point of the raw juice flow controller, and being normally 15 psi, allowed the flow to be set manually at any desired value. If any of the three levels changed from their normal state, then the output of the second computer would slowly reduce to 3 psi, and this would automatically rêduce the desired value setting of the raw juice flow.

The successful control of milk of lime density in the B.S.C. dates back to 1955 (2) when the continuous density transmitter conceived at Spalding factory was commercially developed. This instrument is now in wide use throughout Europe and consists basically of a balanced 1" stainless steel U-tube, fitted with either an electric or pneumatic force balance transmitter. The tube is mounted horizontally and the liquid to be measured flows through it. By keeping the tube horizontal, changes in liquid velocity do not affect the transmitted output.

The standard instrument has a span of 0.2 specific gravity, and for milk of lime measurement the normal range would be

1.00-1.20 sp. gr. Special models with spans down to 0.05 sp. gr. and fitted with temperature compensation are manufactured, but the standard instrument has a certain amount of inherent temperature compensation due to the expansion of the U-tube, and is adequate for most sugar factory purposes.

Apart from being totally enclosed and therefore clean, this instrument has the added advantage that it can be positively checked. It is supplied with weights proportional to the sp. gr. to be measured and these can be hung on the U-tube for direct calibration.

Milk of lime is produced at B.S.C. factories by slaking uncrushed burnt lime with 8° to 9° Brix sweet water in conventional rotary drum slakers. The milk of lime is fed from the slaker to a "thick lime" tank via a vibrating screen to remove the fines. This tank is the key to the automatic control of both the limekiln and the slaker, and must be sized correctly due to the intermittent discharge from the slaker (3).

The level in the thick lime tank is used to control the burnt lime and sweet water feeds to the slaker. The level in the limekiln is controlled by a gamma-switch so that as burnt lime is drawn from the bottom, the level is automatically maintained. Coke and limestone are added in a pre-set but adjustable ratio via a completely automatic load-cell weigher and skip hoist.

The thick lime tank level controls are arranged to give a working zone in the tank. Thus the level will fall to 40% before the feeds to the slaker are started, and will rise to 80% before the feeds are stopped. The sweet water feed to the slaker is manually adjusted so that the milk of lime produced is slightly heavier than that required by the process.

The milk of lime is pumped from the thick lime tank to a constant head tank above 1st carbonation and overflows back. It is sampled immediately after the pump and the density is regulated by a control valve adding sweet water into the suction of the pump. A position alarm is usually fitted so that the main slaking valve may be adjusted if the dosing valve shuts or goes wide open. With this type of control it is possible to regulate the milk of lime density to within ± 0.5° Brix.

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