Factory Automatic Control Methods

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The object of this paper is to show to what extent the Amalgamated Sugar Company has gone into automatic controls and to discuss the merits of various applications and methods used.

Fundamental Control Concepts

There are three principal control effects usually found in part or complete in all present day controllers whether they may be air, liquid or electrically operated. The three effects are "Proportional Response," "Automatic Reset," and "Derivative Response," or "Preact."

"Proportional Response" is the most common effect found in practically all controllers. Proportional response gives valve movement proportional to pen movement.

"Sensitivity" is a measure of proportional response and its units are psi per inch of pen travel. "Gain" is a measure of proportional response and its units are psi per psi. "Throttling Range" is a measure of proportional response and is defined as percent of full instrument scale through which the controlled variable must change to give full valve travel.

"Automatic Reset" may be defined as a response giving valve velocity proportional to pen displacement from the set point. The units of reset rate minutes (1)[1] or the number of times per minute that automatic reset duplicates the proportional response caused by the disparity between the pen and the set point.

In order to determine the reset rate on an instrument without a calibrated dial it is only necessary to move the pen away from the set point enough to cause a one psi change and observe the additional one psi changes per minute.

"Derivative or Preact Response" gives an additional valve movement proportional to the rate of pen movement. Since preact response is an additional output pressure change per rate of pen movement its unit is the preact time in minutes or—

(psi) per (psi per minute) = minutes

Figure 1 illustrates all three control effects:

1. The throttling range adjustment is represented by the diagonal lines.
2. The vertical translation of the family of curves shifts the control point.
3. The effect of reset is to horizontally shift the family of curves to the new control point requirement.
4. The effect of derivative response is to rotate the family of curves about the control point at a rate proportional to pen movement.

A purely mathematical approach to the problem of automatic control involves trignometrical and expotential functions which often call for an

[1] Numbers in parentheses refer to literature cited.

analog computer for the final solvition, which puts the solution beyond the scope of the average engineer. There is a matheinatical approach, however, which gives good results. The method involves the term ultimate sensitivity

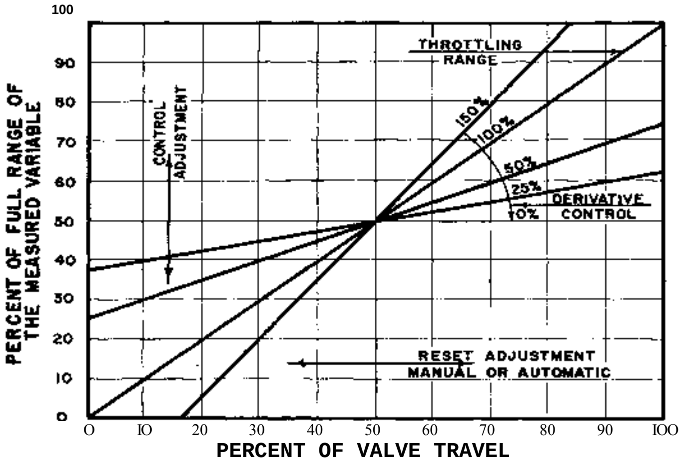

Figure 1.—Graphic Representation of Control Functions (Reference No. 1 by C. B. Moore)

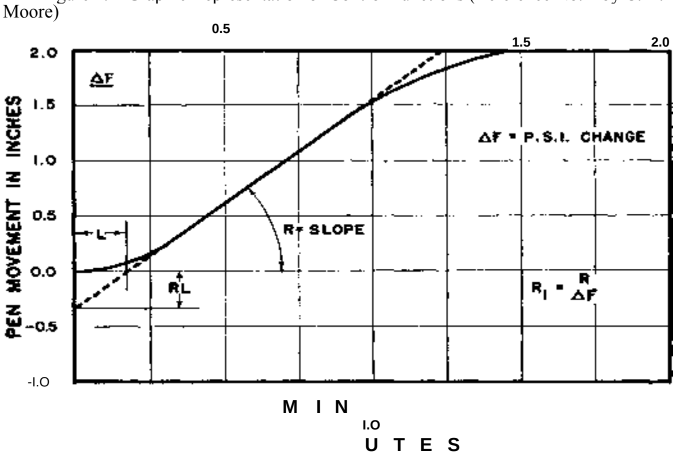

Figure 2.—Typical Process Reaction Curve (Reference Nos. 2-5 by J. G. Ziegler- N. B. Nichols)

(Su) , which may be defined as that sensitivity above which any oscillation will increase and below which it will diminish to straight line control. The term period of oscillation (Pu) at ultimate sensitivity is also involved and is defined as the time for one complete cycle.

The solution also utilizes a process reaction curve. The reaction curve may be either calculated or observed. Suppose a process is on manual control under a steady stated condition. The control output is then increased AF psi. The curve shown in Figure 2 would result.

The approximation consists of drawing a line tangent to the point of inflection of the curve and saying that the process is represented by the simpler curve consisting of a dead period "Lag L" and a reaction rate "R." If the controller is set to give a valve movement AF for pen movement "RL" stability will result or sensitivity = ΔF

Unit Reaction Rate $R_1 = \frac{R}{\Delta F}$

Summary of controller adjustments:

For proportional response: Sensitivity $= .5\ Su = \frac{1}{R_1 L}$

For Proportional plus reset: Sensitivity $= .45\ Su = \frac{.9}{R_1 L}$

Reset Rate $= \frac{1.2}{Pu} = \frac{0.3}{L}$

For Proportional plus reset plus preact: Sensitivity $= .6\ Su = \frac{1.2}{R_1 L}$

Reset Rate $= \frac{2.0}{Pu} = \frac{0.5}{L}$

Preact Time $= \frac{Pu}{8} = .5$ L[2]

Preact response is usually used on applications which give a (Pu) period of oscillation greater than .4 minutes or a lag of 6 seconds or greater.

The advantages of reset response are obvious; however, it has two disadvantages in that it decreases stability and increases the period of oscillation.

Knowledge of control instruments is increasing. We are becoming more, should we say, "automatic control conscious?" However, the finest controller made when applied to miserably designed process may not produce the desired results. It, therefore, becomes more imperative that processes be more carefully designed from a control standpoint.

A formula for process controllability would contain—

1. Recovery factor = time lag, transfer lag and transportation lag.
2. Load factor =-= point in the process that the disturbance occurs, supply and demand side capacity, load change and frequency.
3. Mobility factor ==- the ability of the process to follow demands for different values of the variable.

[2] See *(2,* 3) in literature cited for reference.

Time Lag: any reduction in time lag of a circuit is accompanied by reduction in the period of oscillation; also, the initial deviation following a load change is often reduced.

In designing a process a great deal of attention should be paid to minimizing time lag.

Transportation Lag: all transportation lags are undesirable and should be reduced to the minimum.

Transfer Lags: usually processes are made up of several transfer elements in series. A fair rule to follow is to eliminate or reduce all but the largest transfer element to a minimum value. The area under recovery curves is taken as a direct measurement of process difficulty and this area is shown to vary as the second power of the time lag. The importance of process design to reduce time lag is therefore quite obvious.

Zero load change means that perfect control would be possible with a fixed control valve setting; consequently, it is advantageous to minimize the frequency and number of load changes (4, 5).

With the above concepts in mind we have analyzed and tried to improve each station. A discussion of the Nyssa factory control system by stations follows:

Control of Beet Flow into the Factory

The rate of flow of beets into the factory is controlled by the beet feeder, which is manually remote controlled from the beet washer.

Automatic Flume Water Control

The beet lift pumps at our Nyssa and Nampa factories call for closer water control than is normally required in our factories without beet lift pumps. This is especially true during slow downs. This problem was solved by placing an 18 inch motor-driven butterfly valve in the flume supply line and controlling it from a B & W floatless control with the electrodes placed just above the suction of the beet lift pump. This control cuts off the water as it starts to rise in the flume and automatically turns it on as the water recedes.

Beet Slicer Control

The beet slicers are driven by three wound rotor motors with 50 percent speed adjustment giving a range of 62.5 rpm to 125 rpm. The drum switches are located at the diffuser control panel. The slicers are manually remote controlled to suit slicing requirements. The cossettes are weighed on an endless belt by a Merrick weightometer. The weightometer is equipped with a rateograph autosyn transmitter and a Foxborro motion transmitter. The motion transmitter transmits a pressure directly proportional to the projected hourly tonnage at that instant. The transmitted pressure is received on a recording Foxborro flow ratio controller. The tonnage slice is also recorded on a rateograph. The rateograph is used as a guide in adjusting the slicer speed to obtain the desired slice.

Automatic Water and Temperature Control of the Silver Chain Type Diffuse

The pneumatic impulse from the motion transmitter on the Merrick weightometer is used to position the set pointer on the flow ratio controller.

The ratio between air from the pressure transmitter and the positions assumed by the set pointer is adjustable, which provides a means of adjusting battery draft. The temperature of the diffuser supply water is controlled by a fixed high sensitivity controller. The diffuser water supply pressure is controlled by a pressure controller which bleeds back water from the discharge side of the diffuser supply pump to maintain a constant pressure on the orifice of the flow ratio controller at the diffuser. The controlled output of the flow ratio controller goes to a 6 inch valve in the diffuser water supply line. The valve is thus regulated according to the dictates of the flow ratio controller to maintain the desired draft.

The heating of the continuous diffuser is accomplished in the first five cells or less. Each cell has two heating compartments. The compartments are connected in multiple with a manifold on intake and discharge. The first cell can be connected directly to first vapor in an isolated manner. The diffuser is controlled by a temperature control and a pressure control. The temperature sensitive bulb can be moved from Cell 4 to Cell 3 and is usually located in Cell No. 4. Second vapor is admitted to the intake manifold through a 12 inch butterfly valve with a valve positioner. First vapor is admitted to the manifold through a six-inch throttle plug valve with a valve positioner. The valve positioner on the 12 inch valve is set to open from 2 to 7 psi of control air. The valve positioner on the 6 inch first vapor valve positioner is set to open from 7 to 15 psi of control air.

The diffuser temperature controller is a proportional response plus reset controller. The loading pressure from this controller changes the pneumatic set point on the pressure controller. The pneumatic-operated set point also has manual limit control. This is set at some limit valve, usually $5^{3/4}$ pounds, which is less than the minimum value encountered on second vapor pressure. The pressure control is a proportional response plus reset controller. The control pressure from this unit is connected in multiple to the two valve positioners. The normal operation sequence selects second vapor and controls on second vapor unless the pressure drops or some unusual heating burden is imposed on the diffuser such as frozen beets. In this case the first vapor valve opens to meet the demand. The outlet manifold is vented to the domes of the first three cells, and to the incoming cossettes.

The diffuser controls have been very satisfactory.

First Carbonation, Second Carbonation and Sulphitation Control

All of our factories utilize the continuous Benning first carbonator or equivalent. Carbonation is controlled on a titration basis with a conductivity meter to show alkalinity trend.

Second carbonation is controlled by a pH controller on effective alkalinity basis. The pH of the controller is set to give the desired alkalinity. The type controller we use is a proportional response plus rest plus derivative response. However, we have succeeded in reducing the circuit lag to the point that derivative response is not required. The controller works in conjunction with a Beckman pH meter which measures the variable pH and transmits it to the controller. The controled output from the controller is applied to the $C0_2$ gas valve in the line to the gas manifold.

2. It regulates the evaporation rate within limits to suit load fluctuations.
3. It discharges the thick juice at the desired Brix.
4. It provides a record of what has transpired.
5. It reduces the load changes on the boiler house.
6. It saves labor.

The control system as it now stands has 5 level controls, 1 juice tank level control, 1 first vapor pressure control, 1 exhaust steam make-up control, 1 fifth vapor pressure control and 1 Brix controller.

The evaporation rate is changed by the output of the juice tank level controller which positions a butterfly valve located in the vapor line between second and third effect.

The third vapor pressure controller has been replaced with an exhaust makeup controller.

The density controller has been changed to control the valve on the liquor into the fifth effect and the level control controls the valve out. The Brix control was definitely improved in all cases.

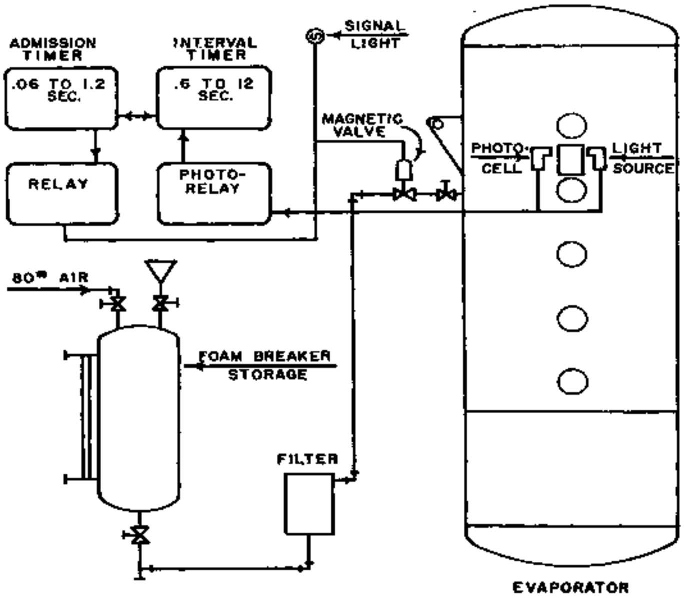

Figure 4.—Automatic Foam Control for Evaporators.

The evaporator control has been a very satisfactory piece of equipment.

The evaporator control system removed the evaporator operator and thereby left us with a potential foam carryover problem. The automatic foam control shown in Figure 4 consists of a photo electric cell, light source, photo relay, valve relay, magnetic valve and two electronic time relays and a filtered foam breaker source under pressure. A small side pocket is welded on the side of the effect which mounts two sight glasses on opposite sides. The photo cell and light sources are mounted on these glasses.

A sequence of events follows:

Assume that foam rises up in front of the photo cell. This actuates the photo relay which actuates the timers, the valve relay, and the valve. One timer (range .06 to 1.2 seconds) is set for oil admission time. The other timer (range, .6 to 12 seconds) is set for the interval between admissions. Foam breaker is added until the foam subsides. An indicating light is mounted in a conspicuous place to indicate when the magnetic valve is open.

The above system has been very effective.

Sugar End Controls

The principal controls used in the sugar end consists of Brix controllers *on* the intermediate and high green tanks and temperature controllers on high green, intergreen, standard liquor, low melter, and minglers.

We have installed Webre pan circulators on all our intermediate and raw pans with Webre's boiling point rise meter, which consists of an absolute pressure manometer and a thermometer placed in the massecuite. We have also installed contact-making Esterline Angus wattmeters on the pan circulator motors as originally conceived by Webre. The wattmeter is used to control an air-operated valve on the juice in line. All our pans at all our factories have absolute pressure controls on the condensers.

We would evaluate the pan controls as follows:

The circulators increase the heat transfer and allow the use of much lower pressures for the same heat transfer rate. The wattmeter is of value during part of the pan cycle as a density controlling method. The boiling point rise instruments provide the sugar boiler with a better mental picture of what is going on in the pan. The pressure control is a valuable means of holding uniform temperatures and is a valuable aid. The above controls have definitely been an aid in making us aware of the factors which affect sugar boiling and, in short, have definitely reduced the art of sugar boiling to a science. We have obtained our best results by utilizing the instruments as a guide.

Crystallizer Control

We have LaFueille crystallizers at three of our largest factories. We have developed the following control system for uniform cooling and heating: Tempered water is circulated from a tank through the crystallizer and back to the tank. The tank has an overflow line to the seal tank. Cold water or hot water is introduced to the pump suction. A temperature trans-aire is mounted on the crystallizer with a dairy-type bulb mounted in the fillmass. The air is transmitted to and trom crystallizer in a unique manner through telescoping Chiksan swivel joints. The second temperature transmitter is mounted in the discharge line from the pump. The controller consists of a proportional response plus reset controller with a differential element which takes the difference in the pressures from the transaires. The controller has a zero center chart with a plus 50 degrees for heating and a minus 25 degrees for cooling. The controller is synchronized at the 0 point for 10 psi. The water in and water out valves have valve precisors set for 10 to 2 psi and 10 to 18 psi operation. The transaire pressures are recorded on a temperature recorder. When the controller is set in the minus zone, the cooling water valve is opened. The crystallizer temperature is brought down in steps to suit the operator.

The above control system has been proven very valuable in providing a controlled rate of cooling, and in duplicating desired results.

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