MOORE

APPLICATION DATA

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COARSE/FINE CONTROL STRATEGIES USING THE MYCRO™ 352 SINGLE-LOOP CONTROLLER

PURPOSE

A coarse/fine control strategy uses two final control elements (FCEs), one large and one small, that are connected for an additive effect on the process. The large FCE supports large changes in the manipulated variable, but often lacks resolution. To improve resolution and increase turndown, a small FCE, which has better resolution, is used to trim the large FCE.

Coarse/fine control is sometimes called "big valve/little valve" control. Figure 1 shows a system that employs this strategy for pH control.

There are several ways to implement coarse/fine control. They are split-range control, floating control, center-seeking control, and a combination of split-range and center-seeking control.

HIGHLIGHTS

The coarse/fine control strategies outlined in this document enable precise flow control, which improves product consistency. The various strategies offer different ways of achieving this according to the process' flow characteristics.

DESIGN

All four coarse/fine control strategies can be implemented in a MYCRO 352 single-loop controller. The following sections discuss each method, including the theory of operation, its advantages and disadvantages, and how it can be implemented in the 352.

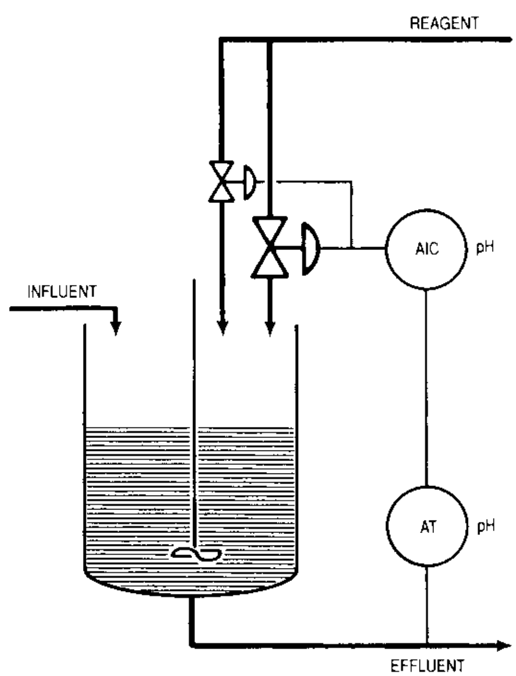

FIGURE 1 Coarse/Fine pH Control

Split-Range Control

The split-range control strategy involves closing the coarse valve and manipulating only the fine valve when the flow demand is low. As flow demand increases, the fine valve is opened fully and remains open as the coarse valve is manipulated.

This scheme features immediate response to demand changes and fine resolution for low flow demands. However, the resolution becomes coarse when the demand exceeds the capacity of the fine valve. This is a simple way to provide high turndown.

A split-range control configuration is shown in Figure 2. This configuration has been developed by modifying the 352's Factory-Configured Option (FCO) 01, which is the Single-Loop PID Controller with Tracking Setpoint.

The PID Controller block (FB13) determines the flow demand after comparing a controlled variable signal (from FB01) to a setpoint signal (from FB17). The A/M Transfer block (FB14) supports manual control of the valve positions via adjustments to the flow demand.

The Deviation Amplifier block (FB22), performing the functions of a gain block, multiples the demand signal by a factor which ensures the fine valve is fully open at the point of switchover. The Gain and Bias block (FB38) biases the demand signal to ensure the coarse valve does not begin to open until the fine valve is fully open. Also, the demand signal is multiplied by a factor which allows the coarse valve to open fully at the highest flow demand.

This configuration requires the expanded version of the MYCRO 352 (Model 352E). The station can be running B or C Level software.

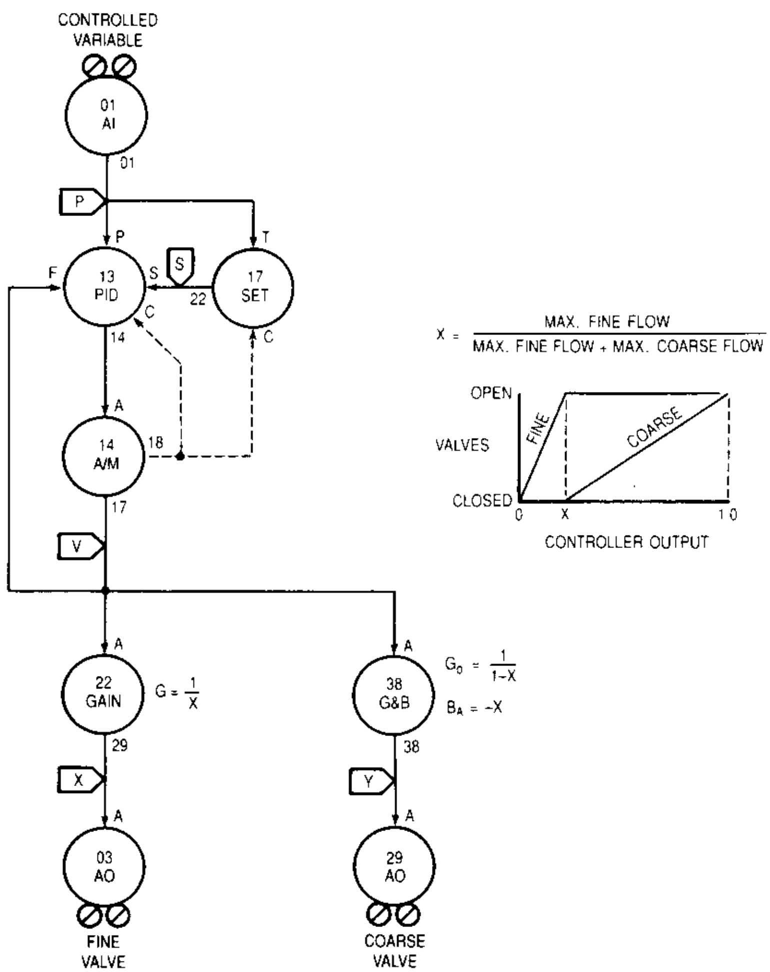

FIGURE 2 Split-Range Control Configuration

Floating Control

The floating control strategy only adjusts the fine valve while its position is within fixed limits (between 25% and 75% of scale, for instance) and adjusts the coarse valve only when required to keep the fine valve near midstroke. In this strategy, a controller block manipulates the fine valve; when the controller output exceeds the limits on the fine valve, a separate integral-only controller moves the coarse valve.

The rate at which the coarse valve moves is relatively slow and is proportional to the difference between the fine valve signal and its exceeded limit. As the coarse valve moves, the fine flow controller responds by returning the fine valve to within its limits, at which time the coarse valve holds at its new position. The coarse flow controller must be tuned for slow response to ensure that the fine flow loop remains stable.

This strategy responds quickly to small flow demand changes over the entire demand range by directly adjusting the fine valve. However, it responds slowly to a large demand change that saturates the fine valve. This is an easy way to get accurate flow control over a large flow range.

Figure 3 shows a floating control configuration. It has been created by modifying the 352's FCO for single-loop controller with setpoint tracking (FCO01).

In this configuration, the first Controller block (FB13) determines the fine valve signal. The A/M Transfer block (FB14) allows manual control of the valve positions. The second Controller block (FB45) is used as a floating, or integral-only (ID), controller.

The Hi/Lo Limit block (FB09) limits the fine valve signal to between 25% and 75%. This allows a difference to develop between the P and S inputs to the second Controller block (FB45) when the fine valve signal moves outside the limits. This error causes the coarse flow controller to move the coarse valve.

The first controller (FB13), which is the fine flow controller, responds to the changes produced by the coarse valve by returning the fine valve to a position within its limits. This causes the error at the coarse flow controller to become zero, which holds the coarse valve at its new position.

This configuration can be implemented in a Model 352E, which is the expanded version of the MYCRO 352. The station can be running B or C Level software.

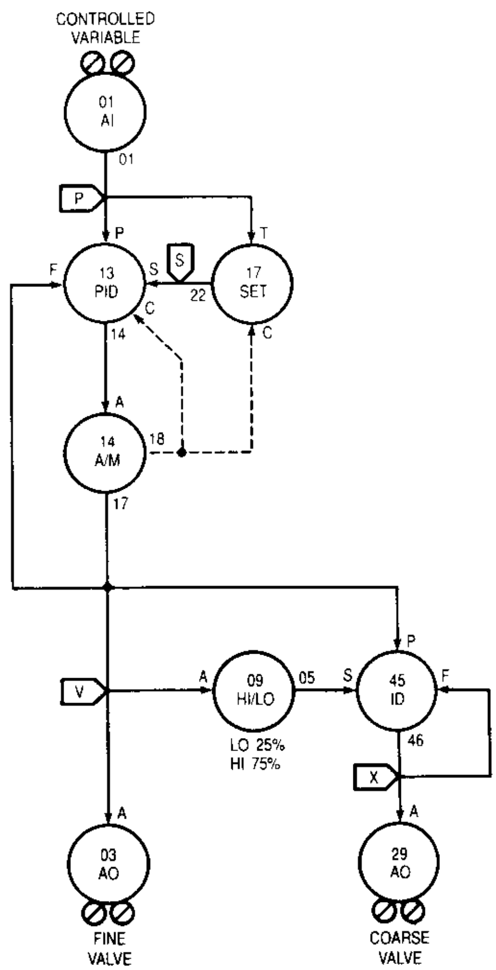

FIGURE 3 Floating Control Configuration

Center-Seeking Control

The center-seeking control strategy is similar to the floating control strategy. It involves manipulating only the fine valve when its signal is between certain trip points, but when a trip point is reached, the coarse valve is adjusted until the fine valve is returned to 50%. This differs from floating control, which returns the fine valve to the trip point rather than 50%.

Like floating control, this strategy responds quickly to small changes in flow demand over the entire demand range by directly adjusting the fine valve. However, it responds slowly to a large demand change that saturates the fine valve. The advantage of center-seeking control is that it returns the fine valve to where it can respond alone to large changes in either direction.

A center-seeking configuration is shown Figure 4. This configuration has been developed by modifying the 352's FCO for single-loop control with setpoint tracking (FCO01).

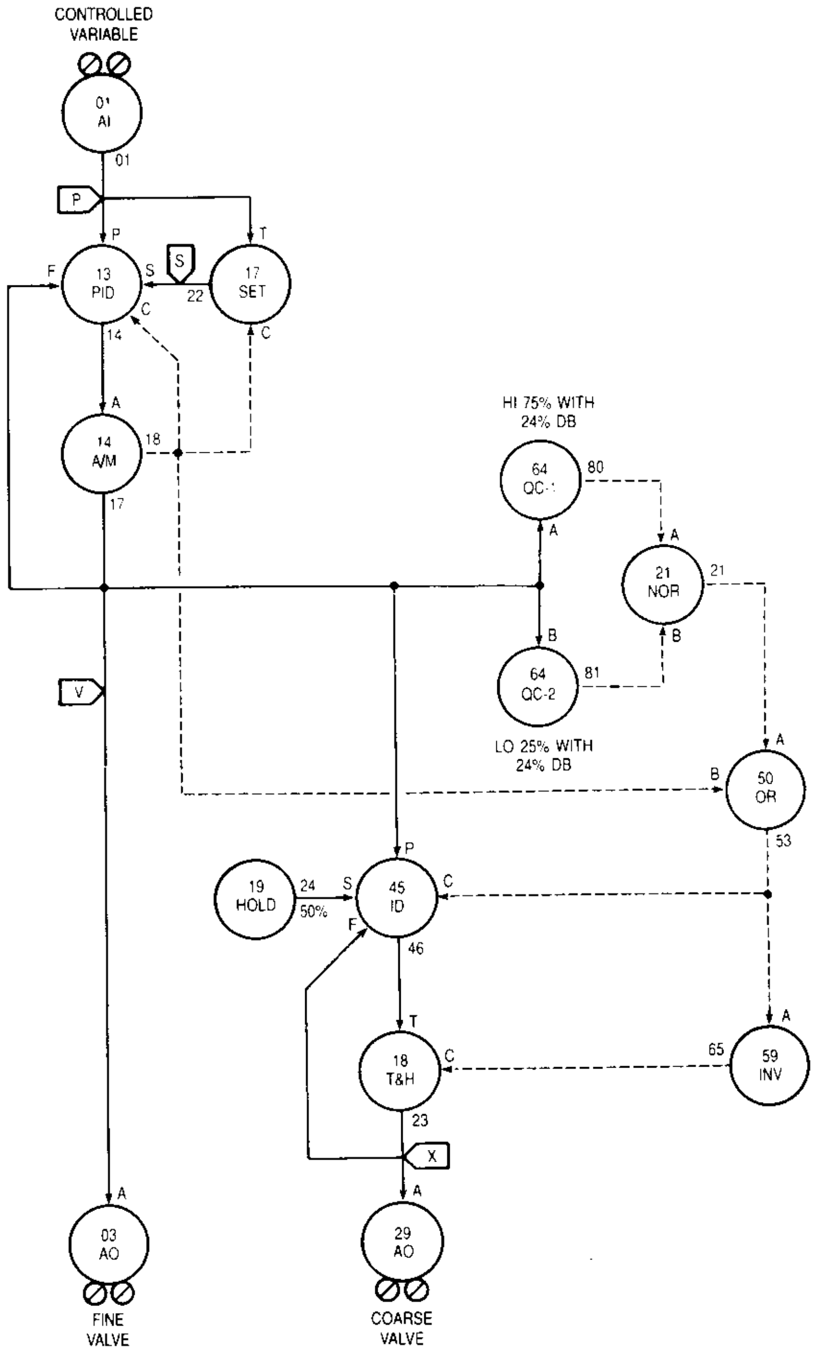

FIGURE 4 Center-Seeking Control Configuration for a C Level Station

The first Controller block (FB13) determines the fine valve signal. The A/M Transfer block (FB14) allows manual adjustment of the valve positions. The second Controller block (FB45) is an integral-only (ID) controller that adjusts the coarse valve position when a fine valve trip point has been reached. The setpoint for the coarse flow controller is a constant value of 50% from the Hold block (FB19).

The Quad Comparator block (FB64) determines when the signal to the fine valve has reached either the high or low trip point. Via the deadbands, the Comparator block also determines when the fine valve has returned to near 50%.

The NOR block (FB21) and the OR block (FB50) provide the track command for the coarse flow controller. The coarse flow controller tracks (holds its output) if the fine valve trip points have not been crossed or if the station is in manual mode. The General Purpose Track & Hold block (FB18) is used to allow manual adjustment of the coarse valve independent of the fine valve.

This configuration requires a Model 352E with C Level software. With modification, a 352E with B Level software can also be used (Figure 5). Due to the narrow range of the deadband settings in B Level's Quad Comparator block (FB64), the comparator input signal is first multiplied by a gain of 0.333 (FB38), and the trip points and deadbands entered in the Comparator block are one-third of the intended values.

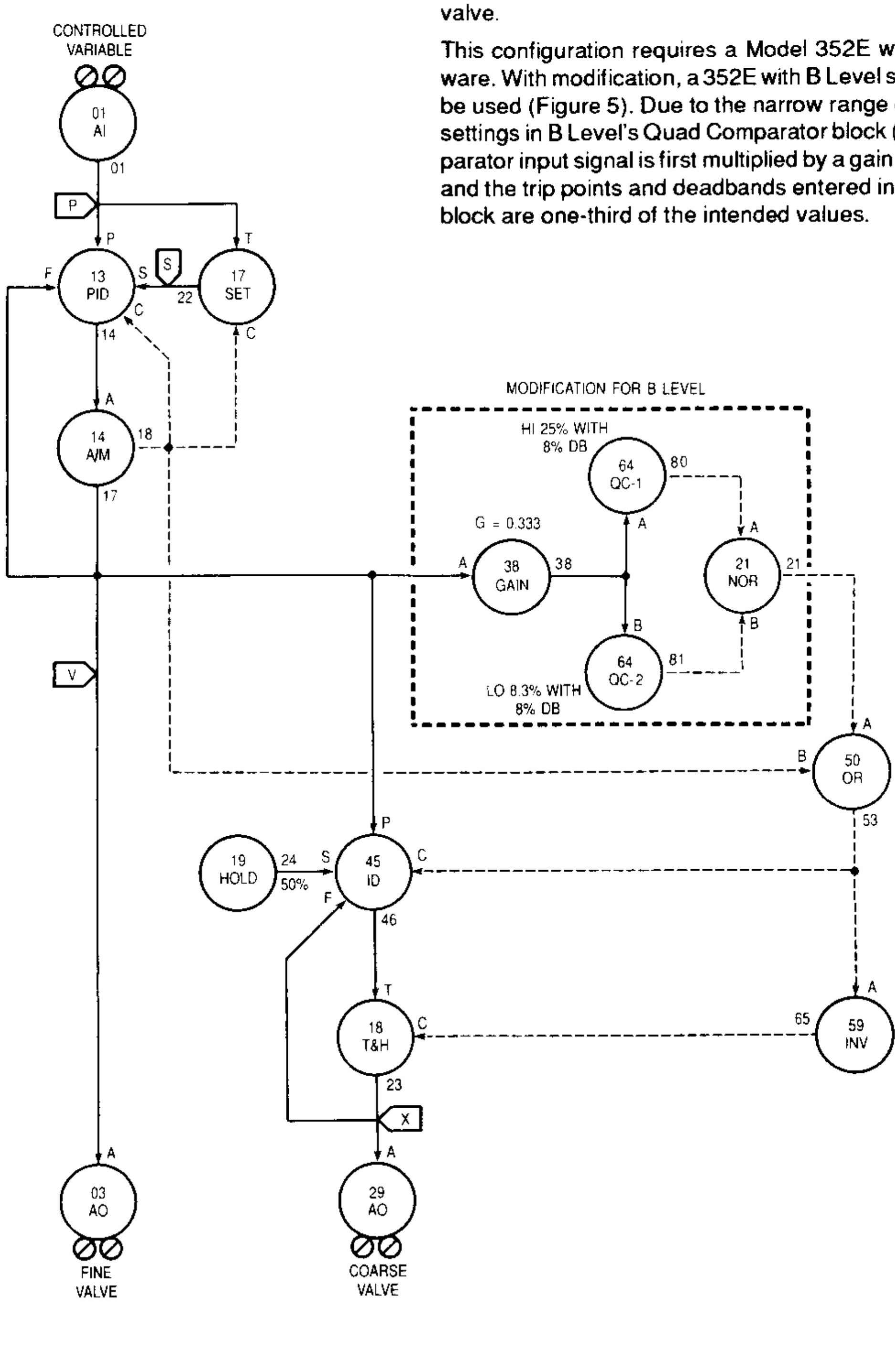

FIGURE 5 Center-Seeking Control Configuration for a B Level Station

Combination of Split-Range and Center-Seeking Control

A combination of split-range and center-seeking control can be used to provide the quick response of split-range control with the full-range resolution of center-seeking control. This combination strategy involves adjusting only the fine valve as an immediate response to small flow demand changes. If a flow demand change saturates the fine valve, the fine valve signal is returned to 50% as the coarse valve is adjusted to the position required to maintain the desired flow. The flow demand signal is sent to both valves (in different proportions) to enable quick response to small and large demand changes over the entire demand range.

A split-range/center-seeking combination control configuration is shown in Figure 6. This configuration has been created by modifying the 352's FCO for single-loop control with set-point tracking (FCO01).

In this configuration, the Controller block (FB13) determines the flow demand signal, which positions both the fine and coarse valves. The A/M Transfer block (FB14) allows manual control of the valve positions. The Bias block (FB08) is used to bias the flow demand signal down into the range of flow through the fine valve. The Deviation Amplifier block (FB22), performing the functions of a gain block, scales the fine flow signal into the 0-100% range of the fine valve position.

The flow provided by the fine valve is subtracted from the flow demand signal via the Subtracter block (FB34), and the resulting scaled signal is sent to the coarse valve. Subtracting the fine signal from the flow demand signal allows the coarse valve signal to remain unchanged as the fine valve is responding to fluctuations in demand.

Part of the Quad Comparator block (FB64) determines if the fine valve is saturated (see bottom of loop diagram). Another part of the Quad Comparator block determines if the total flow demand is low or high enough for the coarse valve to be forced to saturation, requiring only the fine valve to move (see top of loop diagram). The transition into each of these conditions determines when the fine valve is repositioned to 50%.

Logic blocks 60, 20, 21, 48, and 50 determine if the fine valve is saturated while not at low or high total flow demand. Logic blocks 56 and 57, executed in that order, act as a one-shot. Logic blocks 69 and 67 generate a one-shot when the coarse valve should be forced to saturation.

OR block 70 provides a momentary recalculate command (C input) to the Bias block (FB08), which forces the block to recalculate its bias value so the block output is equal to the desired output value (D input). This desired output value, from the Ho' block (FB19), is the value which positions the fine valve at 50'.

For the case where the total flow demand becomes low or high enough that the coarse valve is forced to saturation, the Bias block must recalculate the bias value while the value of the A input is exactly at the trip value. This ensures that both valve signals are 0% for a 0% flow demand and 100% for a 100% flow demand. The Inverter block (FB59) calculates the trip value for the case of high flow demand. The Transfer blocks (FB49 and FB55) provide the correct value to the Bias block for bias recalculation.

The coarse valve typically cannot change position as quickly as the fine valve. To avoid repositioning the fine valve at 50% before the coarse valve can react, the Rate Limiter block (FB42) slows the transition of the fine valve signal. Rate limit values of only a few seconds should account for the slow speed of the coarse valve since, upon repositioning, it has only a fraction of full stroke to travel. The Off Delay block (FB65) enables the rate limiter during repositioning; the delay configured is one half the time of the rate limit.

This configuration requires the expanded version of the MYCRO 352 (Model 352E). The station must be running C Level software.

APPLICATIONS

In addition to the pH control system shown in Figure 1, coarse/fine control strategy can be implemented on any prc ess requiring precise flow control. One of the above strategı can be implemented based on the characteristics of the flow, such as frequency of changes in flow demand and the range of those changes.

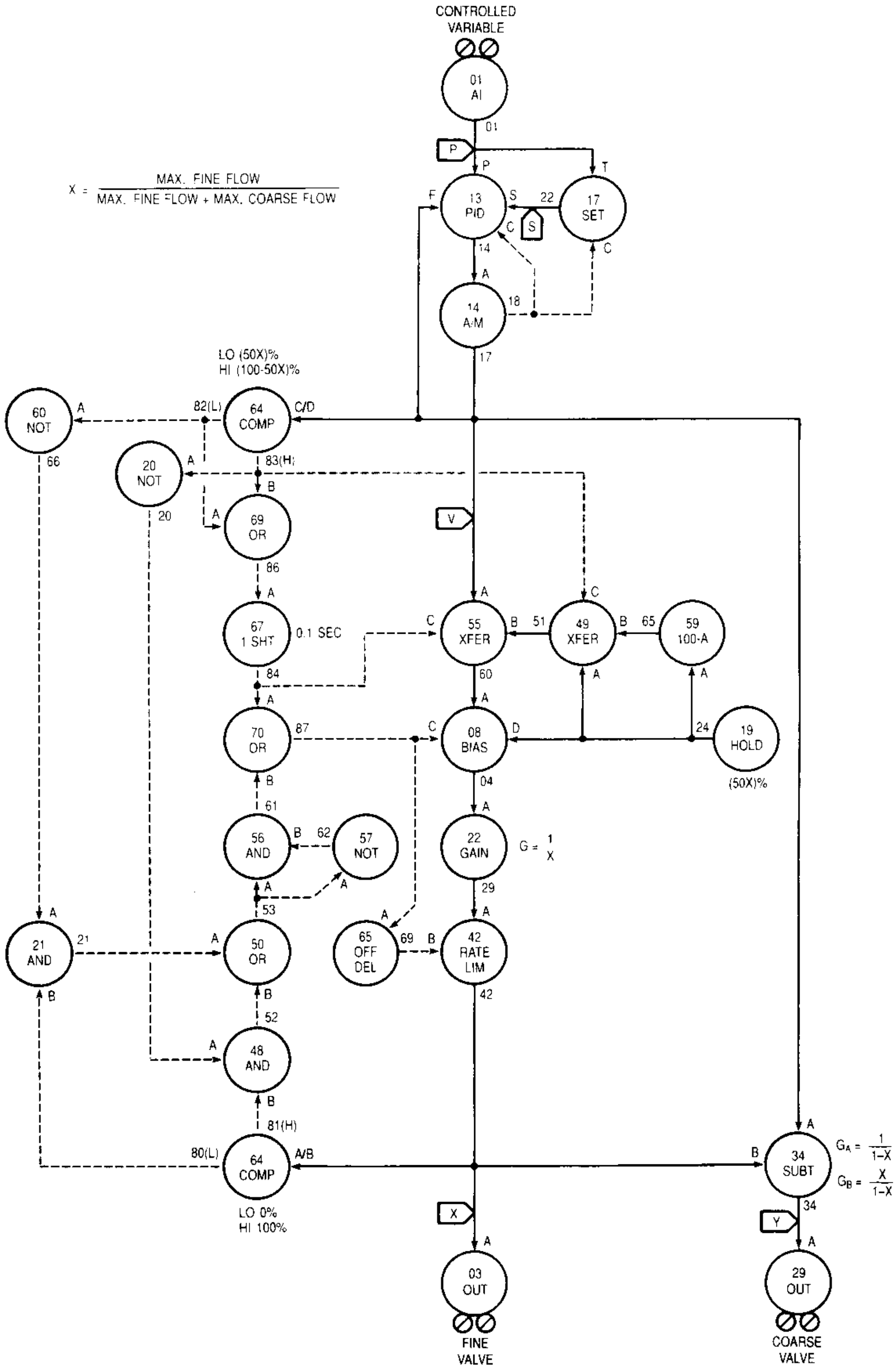

FIGURE 6 Configuration for a Combination of Split-Range and Center Seeking Control