HVA 240

LABORATORY STUDY #4 & 5

PNEUMATIC-TYPE RECEIVER-CONTROLLER STUDY

OBJECTIVE

The objective of the study is to establish the operating characteristics of a typical pneumatic-type receiver-controller of the type commonly used in the control of HVAC systems, including the methods used to set up such characteristics to match the requirements of specific applications.

APPROACH

The approach used is to set up a typical pneumatic-type receiver-controller in a series of simulated operating conditions with a properly filtered and regulated air supply. These simulated conditions include:

1) Single-input controller set-up
2) Dual-input controller set-up (Reset)
    a) Dual Sensor
    b) Master/Submaster
3) Control Point Adjustment (CPA)

An appropriate simulator/calibrator unit is used to facilitate making adjustments of the receiver-controller and to demonstrate the validity of these settings.

In turn, a selection of several typical HVAC system applications is defined. For each of the applications an appropriate selection of transmitter(s) and an actuator-motor is made. For each application, an arbitrary set of values of set point and proportional band is established. The set point is, in each case, selected within the operating range of the corresponding transmitter.

Each student is assigned one case of each of the above listed general conditions and is called upon to establish, for the receiver-controller, the controller sensitivity, the proportional band setting (in units of "per cent") or the gain (Johnson Controllers) for the particular controller in use and the value of input signal (in units of "psig") corresponding to the prescribed set point. In establishing these values, use is made of a prescribed analysis form.

In turn, each student will demonstrate with the actual controller, using the simulator-calibrator, his/her analysis is correct. For this demonstration, the receiver-controller is calibrated and adjusted to match the results of the analysis. The simulator-calibrator is used to simulate the transmitter signal to the receiver-controller, and to show the resultant pressure signal to the actuator-motor. This output signal should be the mid-point of the actuator's spring range. The student will also demonstrate the input pressure signals corresponding to the prescribed proportional range does indeed cause the actuator-motor to span its spring range.

BASIC THEORY

Direct or Reverse Acting

The first thing one must determine when setting up any controller is whether or not the controller is direct or reverse acting. A direct acting controller means the output signal of the controller will increase with a corresponding increase in the value of the controlled variable. If a controller is reverse acting, the output signal will decrease with an increase in the value of the controlled variable (Fig. 1).

For example, suppose a heating valve is normally open. If the space temperature rises, we want the valve to close to allow space temperature to fall to the desired setpoint. For a normally open heating valve to close, the controller output signal must increase with an increase in space temperature. A direct acting controller is required. However, if the heating valve is a normally closed valve and space temperature is rising, then the controller must reduce its output signal allowing the normally closed valve to close and bring the space temperature down. This requires a reverse acting controller.

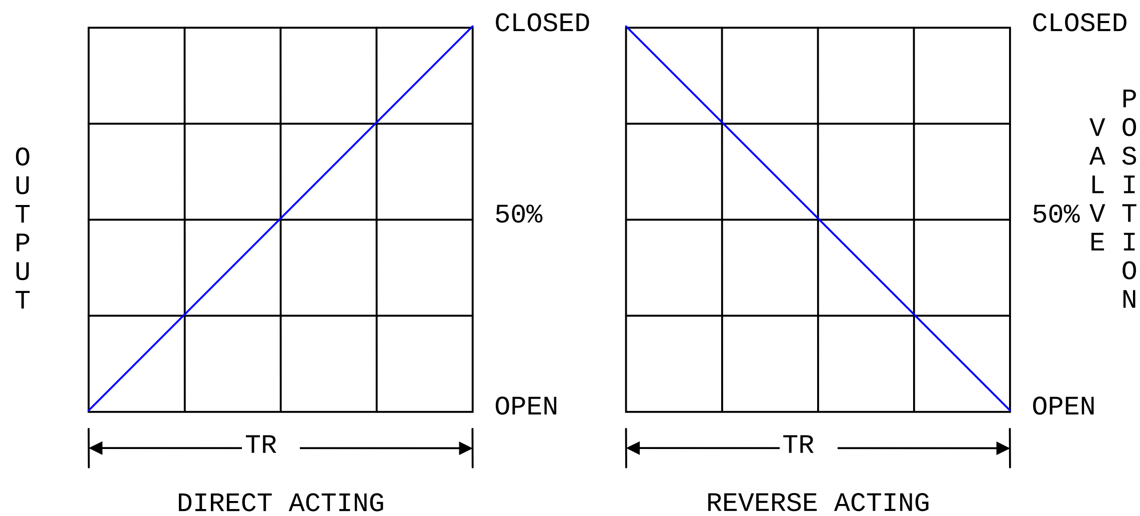


Figure 1 Direct vs. Reverse Acting Control

As one can see from the example, the selection of reverse or direct action is dependent upon whether or not the actuating device is normally open or normally closed as well as the purpose of the device (i.e.: heating or cooling). In turn, this selection is based on the 'fail-safe' condition of the actuating device.

For example, in most cases, the fail-safe condition of a heating valve is for the valve to fail open. One reason for this is to allow full flow through a coil to prevent freezing the coil in the event of a control system failure. This requires a normally open heating valve, thus a direct acting controller.

On the other hand, one may want the heating valve on a reheat coil serving a data processing center to fail closed to prevent overheating the center in the case of a control system failure.

The fail-safe condition selected is up to the judgment of the designer and the specific application under design.

Controller Sensitivity

A typical closed-loop control schematic is shown in Fig. 2. In Fig. 2(a), the sensor is shown in the feedback loop as providing information to the controller as to the effect of a change in the manipulated variable. This information is provided as a pressure signal. Figure 2(b) rearranges the schematic shown in Figure 2(a) to separate the control from the process. In Figure 2(c), we break the loop as shown. If we measure the change in the process variable and the change in output signal from the controller as a result of the change in the process variable, we can define controller sensitivity as:

$$CS = \frac{Change\ \ in\ \ output\ \ signal}{Change\ \ in\ \ input\ \ variable}$$

For example, suppose a temperature control loop is setup so a 10^{o}F change in the process variable causes a 5 psi change in output pressure from the controller. The controller sensitivity is then calculated as:

$$CS = \frac{5\ psi}{10^{\circ}} = 0.5\ {}^{psi}\!/_{^{\circ}F}$$

Proper controller adjustment is crucial to obtain the desired control loop sensitivity so the control system will react properly. Unfortunately, different manufacturers use different methods of setting control loop sensitivity. Some manufacturers, most notably Johnson Controls, use the concept of gain while most others use the concept of proportional band. Whichever method is used, the adjustment of the controller gain or proportional band (throttling range on some controllers) dial or slide is the controller adjustment allowing one to establish the desired controller sensitivity.

Gain

The concept of gain is slightly different from control loop sensitivity, although it does accomplish the same end purpose. Referring again to Fig. 2(c), consider breaking the loop at two points as shown. If we were to measure the input pressure to the controller (transmitter output pressure) and the output pressure from the controller (actuator input pressure), we can define controller gain as:

$$Gain = \frac{Change\,in\,output\,signal}{Change\,in\,input\,signal}$$

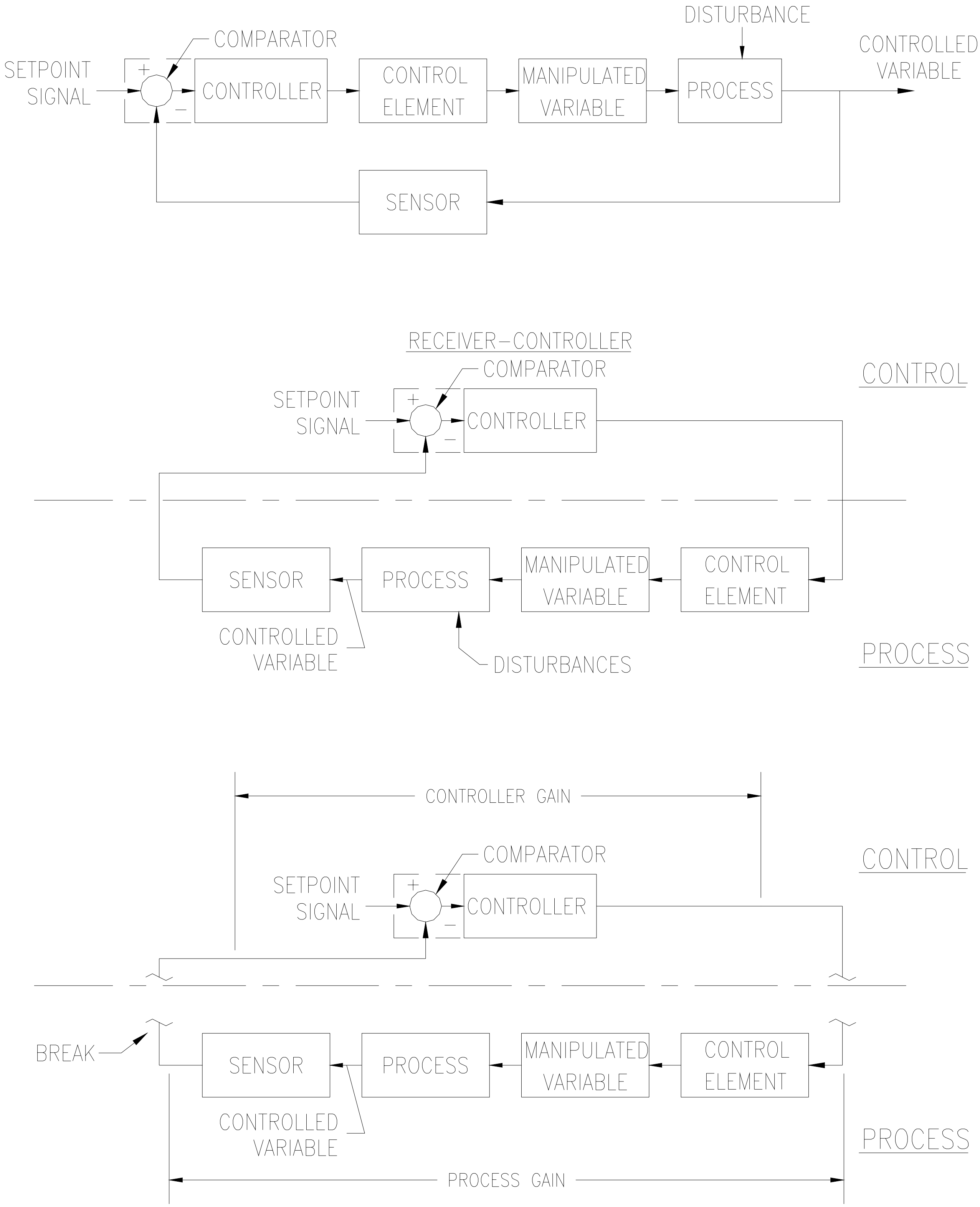


Figure 2 Control System Block Diagram

Suppose the range of the sensor in the example above is 50^{o}F - 150^{o}F (100 ^{o}F span) with a standard output of 3 - 15 psi (12 psi span). The sensor has a sensitivity of 12 psi/100 ^{o}F or 0.12 psi/^{o}F. This means a 10 ^{o}F change in temperature results in a 10^{o}F x 0.12 psi/^{o}F = 1.2 psi change in input pressure to the controller. Assuming the same 5 psi change in controller output, controller gain is easily calculated as:

$$Gain = \frac{5\ psi}{1.2\ psi} = 4.16$$

Notice the value of gain is dimensionless as opposed to the value of controller sensitivity.

Percent Proportional Band

Most HVAC controller manufacturers use the concept of percent proportional band. A notable exception is Johnson Control. Some manufacturers (notably Krueter) use the term percent throttling range in lieu of percent proportional band. Both terms have the same meaning. The definition of proportional band is the amount of change in the controlled variable required to run the actuator from one end of its stroke to the other. Percent proportional band is simply expressing the proportional band as a percentage of primary sensor span. This definition then implies:

$$\%PB = \frac{Proportional\ Band}{Sensor\ Span}$$

Unfortunately, there are problems with this definition. Note this definition includes stroking the actuator from one end of its spring range to the other; a requirement not addressed in the above relationship. But actuators are available with differing spring ranges, so what spring range (controller output) constitutes stroking the actuator through its span? This output needs to be standardized since the manufacturer must provide a scale on the proportional band slide (or dial) in percent proportional band. Herein lies the problem; manufacturers disagree on the definition of standard controller output. Table 1 lists standard outputs for various manufacturers.

Using 'standard controller output', we rewrite the equation for percent proportional band by indexing the sensor to both the controller (with standard output) and the actuator (with several available spring ranges) as follows:

$$\%PB = \frac{Proportional\ Band}{Sensor\ Span} \times \frac{Std\ Controller\ Output}{Actuator\ Spring\ Range}$$

MANUFACTURER	STANDARD OUTPUT
Powers	5 psi
Honeywell	10 psi
Barber Colman	10 psi
Robertshaw	12 psi
Kreuter	12 psi

Table 1 Standard Controller Outputs for Pneumatic Controllers

Let us further develop this concept by redefining the terms in the above equation. We defined proportional band as:

> "The amount of change in the controlled variable..."
>
> > This is a temperature, pressure, or humidity range, in engineering units, over which we wish to control. But this may be expressed as a signal change in sensor output rather than engineering units. In other words, a change in [controller] input signal. This could be a pneumatic pressure, a current signal or a voltage signal.
>
> "...required to run the actuator over its full stroke."
>
> > In other words, over the actuator spring range expressed in units of pressure. This means a change in [controller] output pressure.

Also, since a sensor has a standard output of 3 psi to 15 psi over its sensing range, we may express sensor span in units of pressure, specifically 12 psi regardless of the variable sensed or its span (in engineering units). Since a standard controller output is already in units of pressure, we may rewrite the above equation as:

$$\%PB = \frac{Proportional\ Band}{12} \times \frac{Std\ Controller\ Output}{Actuator\ Spring\ Range}$$

But we earlier defined gain as:

$$Gain = \frac{Change\ in\ output\ signal}{Change\ in\ input\ signal}$$

Thus:

$$\%PB = \frac{1}{Gain} \times \frac{Std\ Controller\ Output}{12\ psi}$$

Note when the standard controller output is 12 psi (Robertshaw, Kreuter), the percent proportional band is the reciprocal of controller gain.

In the previous example, the sensor has a range of 50 ^oF - 150 ^oF (100 ^oF span). Assume a proportional band (throttling range) of 10 ^oF and an actuator with a 5 psi spring span. Proportional band each controller is:

Powers

$$\%PB = \frac{10°F}{100°F} \times \frac{5\ psi}{5\ psi} = 0.10 = 10\%$$

Honeywell
Barber-Colman

$$\%PB = \frac{10°F}{100°F} \times \frac{10\ psi}{5\ psi} = 0.20 = 20\%$$

Kreuter
Robertshaw

$$\%PB = \frac{10°F}{100°F} \times \frac{12\ psi}{5\ psi} = 0.24 = 24\%$$

Note the reciprocal of the percent proportional band matches the previous gain calculation only in the last case!

It is important to note the above discussion is for pneumatic controllers only. When you are working with a current or voltage controller, the input span and output span of the controller are equal. As such, gain is the true reciprocal of the percent proportional band. Let's do an example using the same data as above. That is, a 50 ^oF - 150 ^oF (100 ^oF span) sensor, a throttling range of 10 ^oF and an actuator that accepts a 4 ma to 20 ma signal from full open to full closed. By using the fundamental definition of Percent Proportional band:

$$\%PB = \frac{Proportional\ Band}{Sensor\ Span}$$

we can calculate the percent proportional band as:

$$\%PB = \frac{10°F}{100°F} = 0.10 = 10\%$$

In a similar fashion, the calculation of controller gain is:

$$Gain = \frac{Change\,in\,output\,signal}{Change\,in\,input\,signal}$$

The change in output signal is 20 ma – 4 ma = 16 ma; the full stroke of the electronic actuator. The change in input signal is based on the 10 ^oF throttling range. The sensor has a sensitivity of:

$$Sensor\ Sensitivity = \frac{16\,ma\,output}{100°F\ input} = 0.16\,{}^{ma}\!/_{°F}$$

From this, we can determine the sensor output (controller input) over the throttling range as:

$$Sensor\,Output = 0.16\,{}^{ma}\!/_{^\circ F} \times 10^\circ F = 1.6\,ma \qquad \text{(controller input)}$$

Thus the controller gain is:

$$Gain = \frac{16\,ma}{1.6\,ma} = 10$$

Note this is indeed the reciprocal of the proportional band. This calculation will always hold true as long as the range of controller output and the range of controller input is equal.

Finding controller gain for a hybrid system

Assume you have an electronic controller receiving a current input from a sensor. However, the valve is a pneumatic valve. In order to convert the current output of the controller to a pneumatic signal required by the valve, you must install an I/P valve (current to pneumatic transducer). In most cases, the I/P will output a pneumatic signal of 3 psi to 15 psi with an input signal of 4 ma to 20 ma. However, if the valve has a spring range of 5 psi to 9 psi, the valve will stroke from full open to full-closed over only a portion of the controller's output. As such, we cannot calculate controller gain in the same way as we did above. Let's use the same example as above. That is, we have a 50 ^{o}F - 150 ^{o}F (100 ^{o}F span) sensor, a throttling range of 10 ^{o}F and an actuator with a spring range of 7 psi to 12 psi (5 psi spring span). The controller accepts a current input and sends its output through an I/P valve with specifications as described above. By definition, the controllers percent proportional band is the same as calculated above; 10%. However, the controller gain will not be the reciprocal of the proportional band.

The change in input signal is still as calculated above, 1.6 ma. However, what is the output signal? The output signal over the full throttling range is that current that causes a 5 psi to 12 psi signal from the I/P valve. The sensitivity of the I/P valve is:

$$IP\,Sensitivity = \frac{12\ psi\ output}{16\ ma\ input} = 0.75\ {}^{psi}\!/_{ma}$$

Then the controller output that causes full stroke of the pneumatic valve can be found as:

$$Controller\ Output = 5\ psi \div 0.75\ {}^{psi}\!/_{ma} = 6.6\bar{6}\,ma$$

$$Gain = \frac{6.66\,ma}{1.6\,ma} = 4.16$$

Comments on Controller Sensitivity, Gain, and %PB

Controller sensitivity is a generic concept applicable to all controllers. The specification of controller sensitivity ensures competitiveness when 'bidding' a job. If one specified gain for a particular job, this may imply a Johnson controller, since Johnson is the only controller using this concept. If one specified proportional band, the choice is limited to controllers using the proportional band concept (i.e.: leave out Johnson). At the same time, this may generate confusion if you specify a proportional band based on a 12 psi standard controller output while the contractor plans on using a controller with a 5 psi standard controller output. The following two equations relate controller sensitivity to gain and proportional band allowing one to take a more generic approach when specifying *pneumatic* controllers.

$$CS = \frac{Std\ Controller\ Output}{\%PB \times Sensor\ Span}$$

$$CS = \frac{Gain \times 12}{Sensor\ Span}$$

Reset

Sometimes it is desirable to change the setpoint of the process variable based on the value of a second variable. In other words, we use two seemingly unrelated variables to determine final controller output. This concept is known as reset. This strategy is used in such cases as:

1) Hot water reset based on outdoor air temperature
2) Hot deck reset based on outdoor air temperature
3) Discharge air reset based on space air temperature

As with control action, reset action may be either direct or reverse. Reset action is direct acting when a rise (or fall) in the controller received reset signal causes a rise (or fall) in controllers output signal. Reset action is reverse acting when a rise (or fall) in the controller received reset signal causes a fall (or rise) in the controller's output signal.

Reset Performance is defined as the change in the controlled variable's controller setpoint occurring from a change in the reset signal. If the controller's setpoint increases (or decreases) with an increase (or decrease) in the received reset signal, the reset performance is "direct". If the controller set point increases (or decreases) upon receiving a decrease (or increase) in reset signal, the reset performance is "reverse".

CONTROL ACTION	RESET ACTION	RESET PERFORMANCE
Direct	Direct	Reverse
Reverse	Reverse	Reverse
Direct	Reverse	Direct
Reverse	Direct	Direct

Table 2 Determining Overall Reset Performance

The four combinations of control action, reset action and reset performance are shown in Table 2. Notice when control action and reset action are the same; the result is reverse reset performance. When control and reset action differ, the result is direct reset performance. Do not confuse reset performance with reset action. They are two different concepts. Some examples are:

1) Direct acting controller with direct acting reset (Reverse Reset Performance):

   Control of discharge air temperature via a NO heating valve with discharge air reset based on outdoor air. Assume a dual-input controller operates at bias condition. The controller must close the valve (increase control signal) with an increase in discharge air temperature (direct action). We also want a *decrease* in discharge air setpoint with an *increase* in outdoor air temperature (reverse reset performance). When outdoor air temperature does increase, the outdoor air sensor increases pressure to the controller-reset port. This has a *tendency* to increase controller output (direct acting reset). This increase in controller output causes the valve to close decreasing the value of the controlled variable. The primary sensor senses this and signals the controller to compensate by reducing output. Due to the internal force balance in the controller, this effectively shifts bias pressure (50% output) to a point lower than it was. In other words, setpoint is effectively decreased with an increase in reset pressure (reverse reset performance). An example in the next section makes this clearer.

2) Reverse acting controller with reverse acting reset (Reverse Reset Performance):

   Control of discharge air temperature via a NC heating valve with discharge air reset based on outdoor air. Assume a dual-input controller operates at bias condition. The controller must close the valve (decrease control signal) with an increase in discharge air temperature (reverse action). We also want a decrease in discharge air setpoint with an increase in outdoor air temperature (reverse reset performance). When outdoor air temperature does increase, the outdoor air sensor increases pressure to the controller-reset port. This has a tendency to decrease controller output (reverse acting reset). This decrease in controller output causes the valve to close decreasing the value of the controlled variable. The primary sensor senses this and signals the controller to compensate by increasing output. Due to the internal force balance in the controller, this effectively shifts bias pressure (50% output) to a point lower than it was. In other words, setpoint is effectively decreased with an increase in reset pressure (reverse reset performance).

3) Direct acting controller with reverse acting reset (Direct Reset Performance):

   Control of space humidification via a NO water valve with humidity reset based on outdoor air. Assume a dual-input controller operates at bias condition. The controller must close the valve (increase control signal) with an increase in space humidity conditions (direct action). We also want a decrease in space humidity setpoint with a decrease in outdoor air temperature (direct reset performance).

When outdoor air temperature does decrease, the outdoor air sensor decreases pressure to the controller-reset port. This has a tendency to increase controller output (reverse acting reset). This increase in controller output causes the valve to close decreasing the value of the controlled variable. The primary sensor senses this and signals the controller to compensate by decreasing output. Due to the internal force balance in the controller, this effectively shifts bias pressure (50% output) to a point lower than it was. In other words, setpoint is effectively decreased with a decrease in reset pressure (direct reset performance).

4) Reverse acting controller with direct acting reset (Direct Reset Performance)

Control of space humidification via a NC water valve with humidity reset based on outdoor air. Assume a dual-input controller operates at bias condition. The controller must close the valve (decrease control signal) with an increase in space humidity conditions (reverse action). We also want a decrease in space humidity setpoint with a decrease in outdoor air temperature (direct reset performance). When outdoor air temperature does decrease, the outdoor air sensor decreases pressure to the controller-reset port. This has a tendency to decrease controller output (direct acting reset). This decrease in controller output causes the valve to close decreasing the value of the controlled variable. The primary sensor senses this and signals the controller to compensate by increasing output. Due to the internal force balance in the controller, this effectively shifts bias pressure (50% output) to a point lower than it was. In other words, setpoint is effectively decreased with a decrease in reset pressure (direct reset performance).

There are two points one must be aware of in the above examples, first, the examples assume the controller is capable of being configured for direct or reverse action as well as direct or reverse reset action. This is not always the case. When a controller cannot be configured as such, a reversing relay must be used to do so.

Second, a situation may occur requiring a fail-safe condition as described in examples two and three. However, these examples are generally an improper application of NC and NO water valves. As such, the examples are illustrative only.

Reset may be accomplished two ways. These are:

1) Reset using dual sensor input
2) Reset using Master/Submaster systems

Reset with dual sensor input

Reset using dual sensor input is perhaps the most common reset strategy. Figure 5 shows a typical reset system; in this case, the reset of discharge air temperature based on outside air temperature via a hot water control valve feeding a hot water coil. To properly setup a controller for reset action, one must set the controller percent proportional band, as explained above, and the controller percent authority (ratio in Johnson Control terminology).

Using the schematic in Fig. 4, we note the primary sensor has a range of 25 ^oF to 125 ^oF, the outdoor sensor has a range of -20 ^oF to 80 ^oF, and the control valve is normally open with a spring range of 5-10 lbs. The first step is to establish the reset schedule. Refer to Fig. 3.

CONDITION	DISCHARGE AIR SETPOINT	O.A. TEMP (RESET)
1	100 ^oF	0 ^oF
2	70 ^oF	60 ^oF

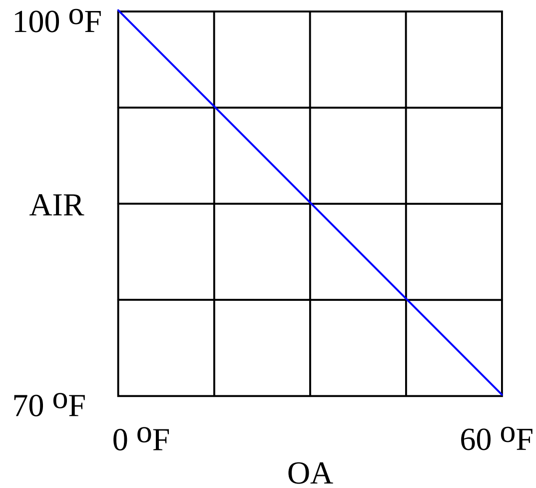


Figure 3 Graph of Reset Schedule for Figures 4 and 5

Once the reset schedule is established, determine the percent authority for the controller. Percent authority is defined as the ratio of the effect of the reset sensor relative to the effect of the primary sensor. To calculate:

$$\% Authority = \frac{Change\ in\ Setpoint\ Signal}{Change\ in\ Reset\ Signal}$$

The change in setpoint pressure is determined by finding the primary transmitter output at the extremes of the reset setpoint. Primary sensor sensitivity is 12 psi/100 ^oF = 0.12 psi/^oF. Therefore, at a setpoint of 100 ^oF, transmitter output is 12.0 psi. At 70 ^oF, transmitter output is 8.4 psi. The change in setpoint pressure is 12.0 - 8.4 = 3.6 psi.

Similarly, the outdoor air sensor has a sensitivity of 0.12 psi/^oF. At 0 ^oF, transmitter output is 5.4 psi. At 60 ^oF, output is 12.6 psi. The change in reset pressure is 12.6 - 5.4 = 7.2 psi. Calculate percent authority as:

$$\% Authority = \frac{3.6\ psi}{7.2\ psi} = 0.50 = 50\%$$

Assuming a throttling range of 8 ^oF and a controller with a standard output of 5 psi, percent proportional band is:

$$\% PB = \frac{8°F}{100°F} \times \frac{5\ psi}{5\ psi} = 0.08 = 8\%$$

A graph of controller output at each condition is shown in Fig. 5. Note the controller calibration output is 7.5 psi in either case.

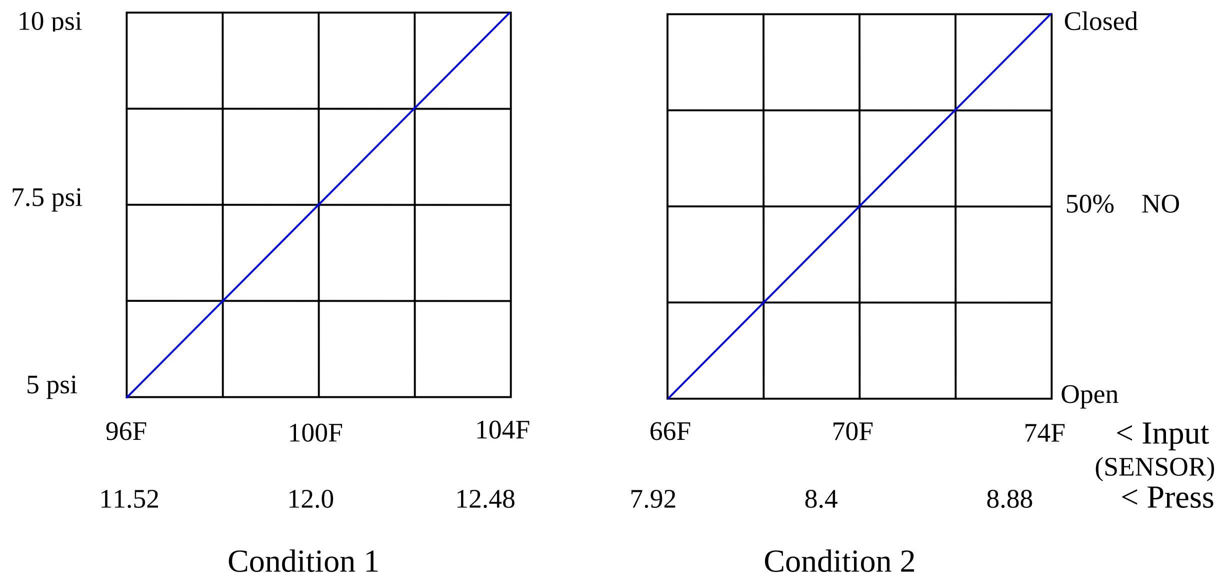


Figure 4 Action Charts for Reset Example

Reset using Master/Submaster systems

Reset may also be accomplished using the master/submaster strategy. The difference between dual sensor strategy and master/submaster strategy is the source of the reset signal. In dual sensor strategy, the reset signal is from a second sensor. In master/submaster strategy, the reset signal is from another source. This source may be an energy management and control system (EMCS), another controller or thermostat, or perhaps a high/low selector or other adaptor. An example of this is shown in Fig. 6. This example is the familiar control of discharge air temperature, but reset is now based on space temperature. Since this system serves multiple zones, each zone reports space temperature to a low selector, which in turn transmits the low signal (low temperature) to the reset port of the controller. Authority and proportional band are calculated as before.

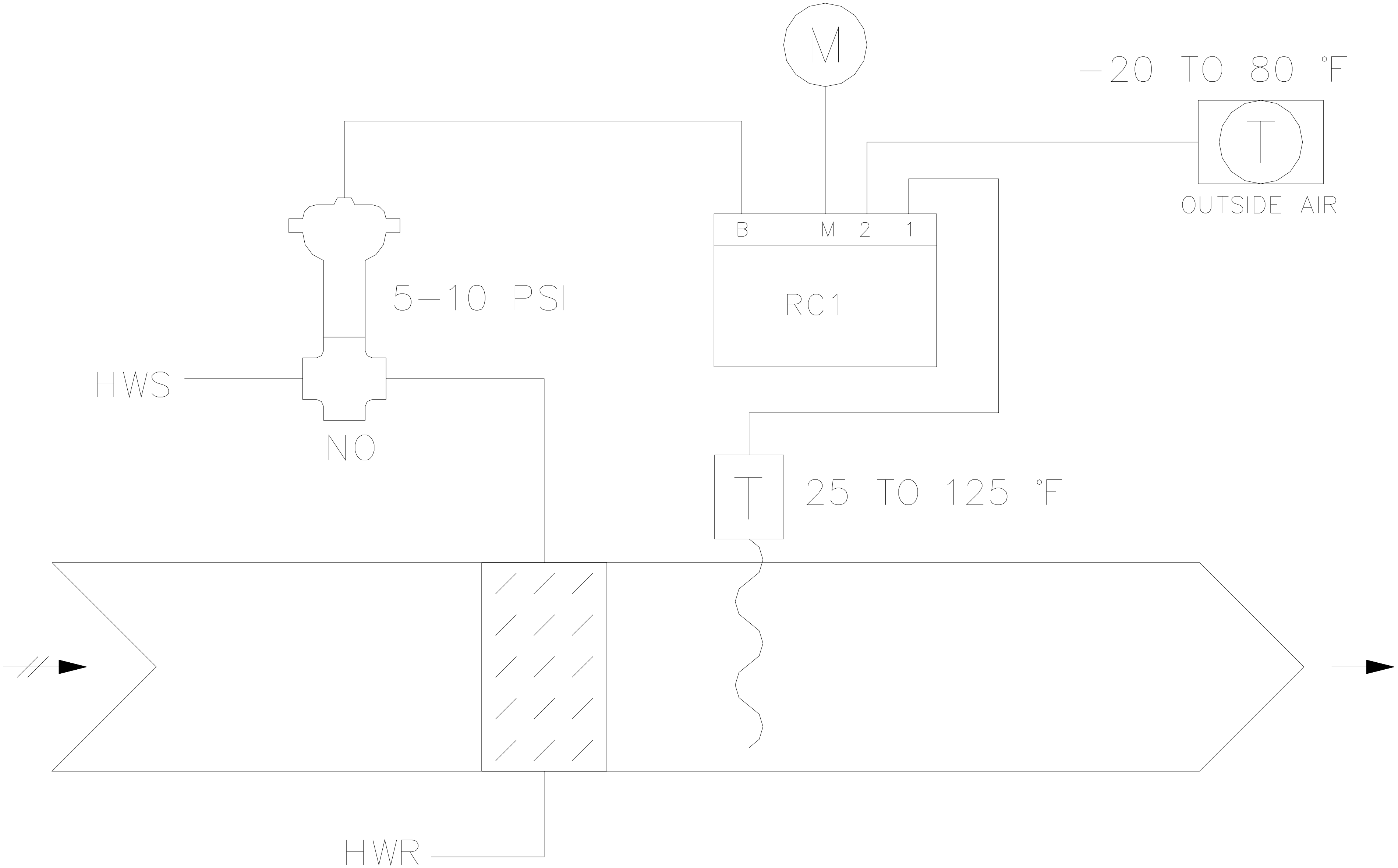


Figure 5 O.A. Reset of Discharge Air

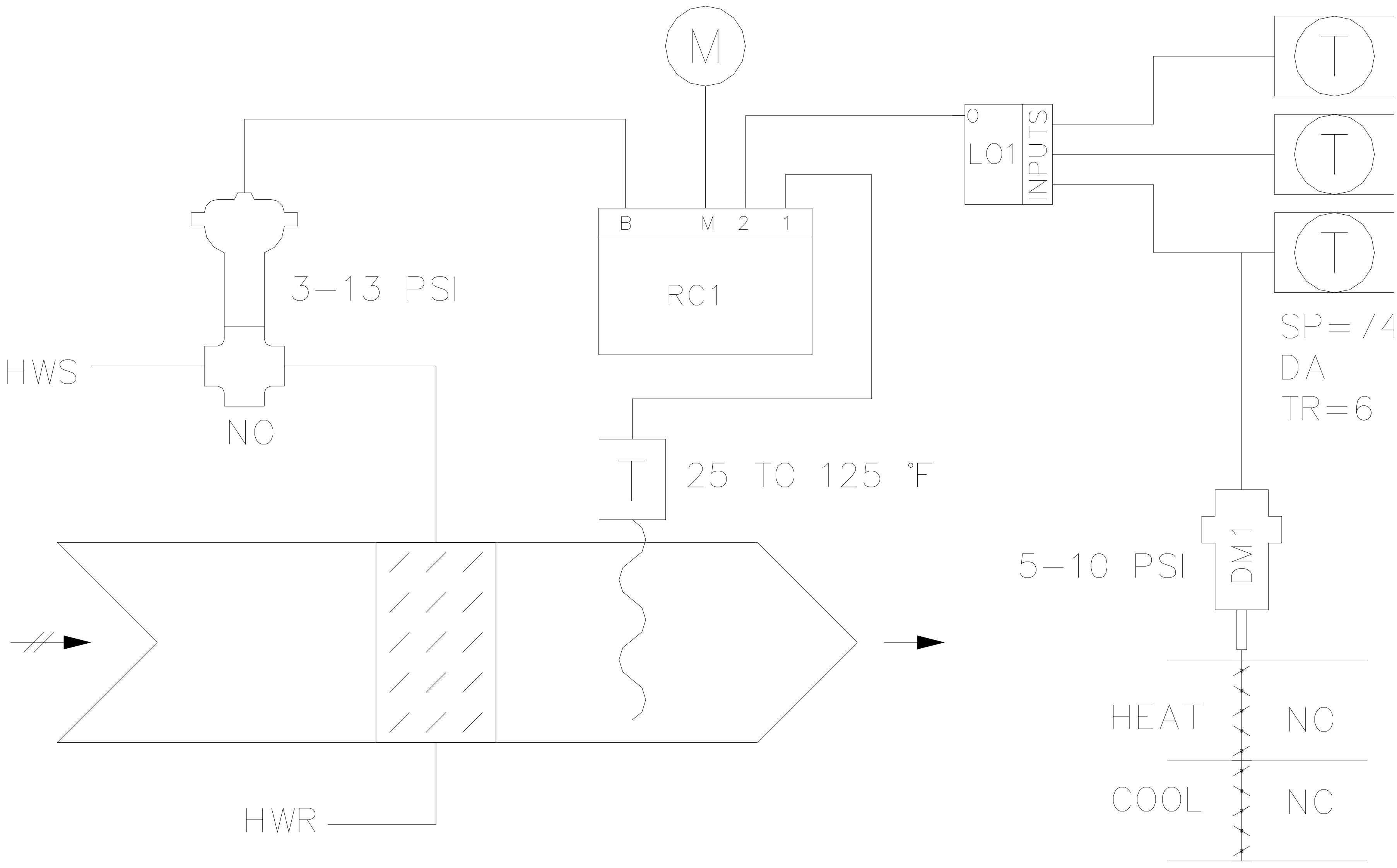


Figure 6 Master/Submaster Reset Strategy

Control Point Adjustment (CPA)

The University of Wisconsin-Extension faculty and staff developed the following discussion on CPA. I am able to present this material as a result of their work and discovery of 'unpublished' controller specifications.

Control point adjustment (CPA) is a strategy used to change a controller setpoint for day/night and/or summer/winter operation. It is similar to reset in that a CPA pressure is applied corresponding to the desired setpoint at some desired time. Generally speaking, the approach to take is to choose the lowest CPA pressure for the lowest setpoint desired. The CPA pressure for other setpoints is then calculated by:

$$Change\ \ in\ \ CPA = \frac{100 \times Change\ in\ Setpoint}{X\ \text{-}\ Factor \times Sensor\ Span}$$

and

$$Change\ in\ Setpoint = \frac{X\ \text{-}\ Factor \times Change\ in\ CPA\ x\ Span}{100}$$

The X-factor is defined as the percent of sensor span causing a one-psi change in output. Unfortunately, the control manufacturers do not publish these data. Table 3 lists the X-factors for various controllers. It is this data determined by UW-Extension faculty and staff.

CONTROLLER	X-FACTOR
Honeywell 908	2.0%
Honeywell 920	2.5%
Johnson 9000	8.0%
Robertshaw	2.5%
Kreuter	2.5%
Barber-Colman	1.66%
Powers	8.33%
Johnson PPR	8.33%

Table 3 X-Factors for Various Controllers

An example of a CPA loop is given in Fig. 7. This loop provides space temperature control with night setback. Note the addition of two adaptors not included in previous discussions. The first is PS-R, an electrically operated pneumatic switch. This switch may be operated from a time clock. The second is the addition of a pressure regulator providing the required CPA pressure.

To determine proper controller setup, we must determine controller action, percent proportional band (or gain), and the calibration pressure (transmitter output). For this example, assume a Powers controller. The action chart in Table 4 indicates the controller must be direct acting.

Sensor	Valve Position	Controller Output
74^o	CLOSED	13 PSI
70^o	OPEN	3 PSI

Table 4 Action Table

The proportional band is calculated as:

$$\%PB = \frac{4°F}{50°F} \times \frac{5\ psi}{10\ psi} = 0.04 = 4\%$$

If we select a CPA pressure of zero psi for the nighttime setpoint of 60 ^{o}F, we can calculate the change in CPA pressure for the daytime setpoint as:

$$Change\ in\ CPA = \frac{100 \times 12°F}{8.33 \times 50} = 2.88\ psi$$

The change in CPA pressure (2.88 psi) is added to the low value of CPA pressure selected for the low setpoint (0 psi in this example) to get the CPA pressure necessary for the high setpoint (2.88 psi). Referencing Fig. 8, the pressure regulator must be set to provide a pressure of 2.88 psi to the electrically operated pneumatic switch. The switch may be operated by a time clock. When the system goes into night setback, the contacts close, blocking the normally open port of the switch, and reduce CPA pressure to zero. This resets the setpoint to 60 ^{o}F. When the system goes to occupied mode, the contacts open applying the preset 2.88 psi to the CPA port to reset the setpoint to 72 ^{o}F. The performance diagrams are shown in Fig. 7.

It is worth noting the affect the X-factor has on applying any given controller to CPA duty. Suppose we wanted to apply a Barber-Colman controller to this example. From Table 1, Barber-Colman controllers have an X-factor of 1.66%. Assuming zero (0) psi CPA pressure at night setback of 60 ^{o}F, we can calculate the required change in CPA pressure for occupied periods as:

$$Change\ in\ CPA = \frac{100 \times 12°F}{1.66 \times 50} = 14.46\ psi$$

This is still in the range of normal main pressures. But if we increase our setback to 20 ^{o}F, the change in CPA is now:

$$Change\ in\ CPA = \frac{100 \times 20°F}{1.66 \times 50} = 24.09\ psi$$

This is outside the range of a normal pressure main (although most controllers accept main pressure safely to 30 psi). The Powers controller requires a change in CPA pressure of 4.8 psi. It becomes evident certain controllers may not be able to provide the desired change in setpoint under certain conditions.

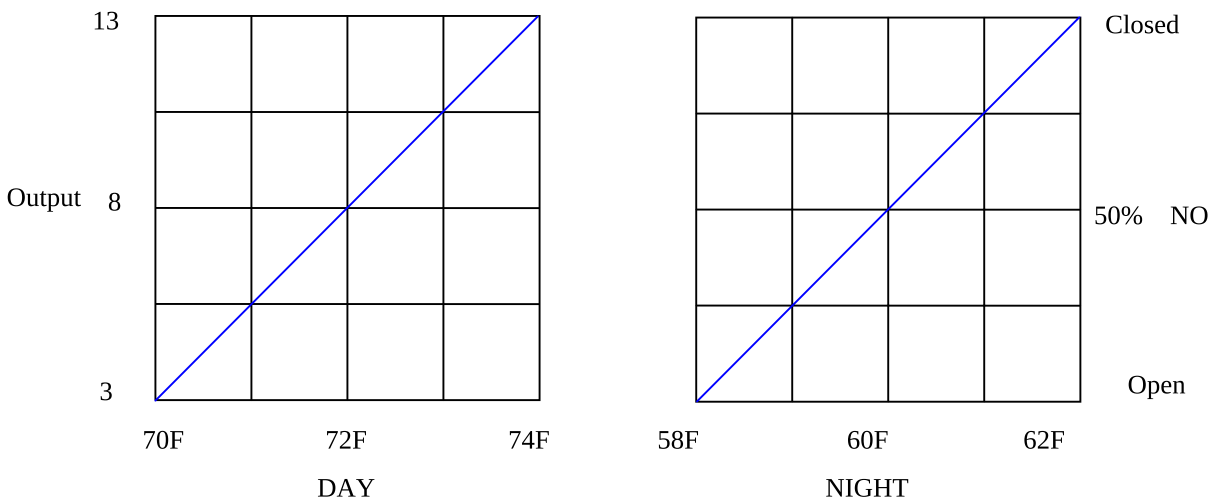
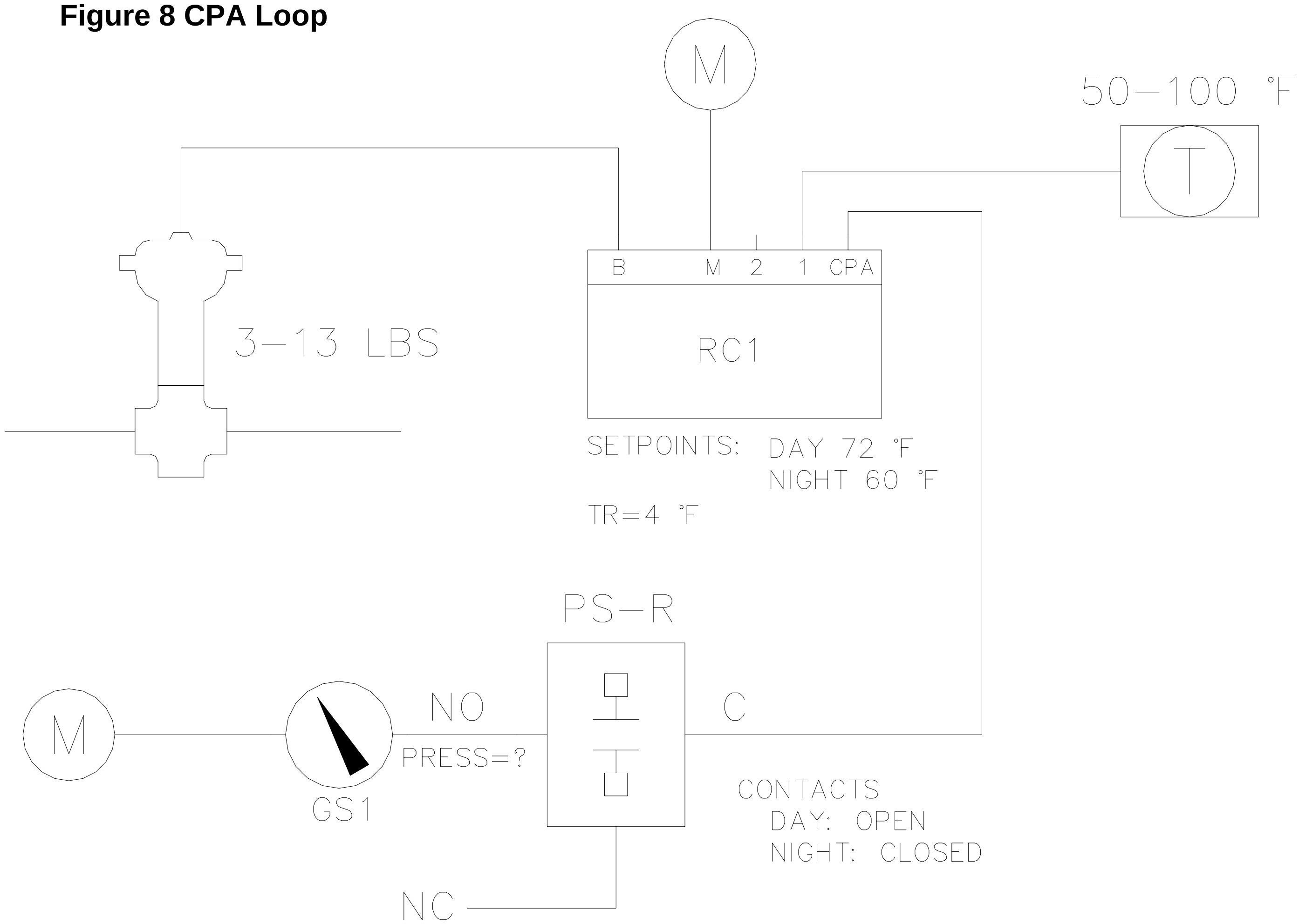


Figure 7 Action Charts For CPA Example

Figure 8 CPA Loop



CASES EXAMINED

Several cases are established for the analysis and demonstration phases of the present study, as listed on the attached sheets marked, "RECEIVER-CONTROLLER STUDY: LIST OF CASES TO BE ANALYZED."

The necessary data defining the characteristics of the particular pieces of equipment involved in each case are found in available manufacturer's catalogs and catalog sheets.

The adjustment and calibration is done by use of a Landis and Gyr-Powers RC195 simulator (product number 195-070) or the locally fabricated simulators. The simulators provide controlled and accurately measured input pressure signals to the controller to simulate the action of various pneumatic-type temperature and static/differential transmitters. A schematic of the locally fabricated simulators is attached.

ANALYSIS

Each student will analyze the case assigned to him/her by use of the attached analysis sheets marked, "RECEIVER-CONTROLLER STUDY: ANALYSIS SHEETS." The analysis will be based upon the design values of the parameters given for each case.

Establishing these values is facilitated by use of the pneumatic transmitter tables in the appendix of this manual. In the absence of such a table, one may establish these values in a manner similar to the examples in the preceding discussion.

Completion of the analysis will give the values of the required controller settings. List these values on the chart provided. Also complete the sheet entitled "DATA FOR EXPERIMENTAL CHECK" for each type of case under study (i.e.: Single input, Reset, and CPA).

DEMONSTRATION

The demonstration phase of the laboratory study is to make use of the experimental setup for each case as you so determine, and by making use of the calibrator-simulator.

Each student is to connect the receiver-controller to the calibrator-simulator. Use tables 1, 3, and 5 in this laboratory write-up to facilitate your connections. By using the appropriate controller, transmitter, and actuator data from catalog data available in the laboratory (single input study), or by using the data provided in each case study (reset and CPA), the student will determine the appropriate controller settings to match the specifications of the assigned case. The student will adjust the settings of the proportional band, the setpoint, and authority (if appropriate) to match the results of the analysis of that case.

When the student completes the adjustments, he/she will demonstrate the input signal from the simulator matches the setpoint and the actuator is indeed at or near the mid-point of its spring range. The student will also demonstrate the proportional band of the receiver controller is correctly adjusted by demonstrating the simulated input signals, are adjusted to the lower and upper ends of the prescribed proportional bands cause the actuator-motor to travel from one end of its spring range to the other.

MANUFACTURER	MAIN	OUTPUT	SENSOR1	SENSOR2	CPA
Honeywell 920	1	2	3	5	9
Johnson	S	O	CV	M	SP
Kreuter	M	B	1	3	2
Powers	S	C	1 if DA 2 if RA	3	2 if DA 1 if RA
Robertshaw	M	B	1	3	2

Table 5 Controller Connections

A practical tolerance must be applied in regard to the accuracy with which these adjustments are made; an exact match is not expected in every instance and, in any case, is not required in the practical application of such equipment. Indeed, in practice, any slight discrepancy between the desired set point and attained operating values is commonly overcome by a slight resetting ("tweaking") of the set point on the receiver-controller.

In addition, almost all pneumatic controls used in HVAC applications are of the proportional ("P") type, providing pure proportional control action. Such controls inherently exhibit a certain amount of "offset" or "droop," so the "control point" at which such a control system actually operates differs somewhat from the "set point" to which the control is adjusted. Such deviations will vary with changing operating conditions. Again, when such slight deviations are significant, they are commonly overcome by a slight readjustment of the set point - as people commonly do with their residential wall thermostats in the depth of winter (heating) or extreme heat of summer (cooling).

In those cases where such readjustments are inappropriate, use is made of controls of the proportional-integral ("PI") type. Controls with PI characteristics, properly set or "tuned," do not exhibit "offset" or "droop." Such PI control characteristics are most commonly obtained by the use of microprocessor-controlled ("direct-digital controls" - "DDC") type controls, although pneumatic PI controllers or an outboard integral-relay is available from most manufacturers.

REPORT

Each student will individually prepare a laboratory report, using the format prescribed in the hand out furnished at the beginning of this manual. The report will contain the following:

(a) A statement in the student's own words of what he or she understands to have been the purpose of the experimental study.

(b) A completed copy of the "ANALYSIS SHEET."

(c) A written statement, in the student's own words, of whether or not the results of the analysis phase were indeed confirmed by the experimental demonstration.

(d) The student's conclusion from the study, in the form of statements of what the student believes he or she learned from the study. Include as many specific conclusions as possible. Avoid broad general statements of the form: "It was an interesting experiment and I learned a lot."

RECEIVER-CONTROLLER STUDY

LIST OF CASES TO BE ANALYZED

SINGLE INPUT CONTROLLER SETUP

Case No. 1 (Pneumatic)

System to control the dry-bulb temperature in a room by acting on the volumetric flow rate of heated air into the room.

Room Temperature Transmitter 40 – 85 ^{o}F
Set point: 65 ^{o}F
Throttling range: 5 ^{o}F
Damper Actuator 5 psi to 12 psi

Case No. 2 (Pneumatic)

System to control the dry-bulb temperature of the air in a room by acting on the volumetric flow rate of water through a hot-water heating coil in a duct supplying air to the room.

Room Temperature Transmitter 55 – 95 ^{o}F
Set point: 75 ^{o}F
Throttling range: 8 ^{o}F
Control Valve with actuator range of 4 psi to 11 psi

Case No. 3 (Pneumatic)

System to control the static pressure of the air being applied to a series of variable air volume (VAV) boxes by action on an upstream damper in a main duct.

Static Pressure Transmitter 0 in w.g. to 3 in w.g.
Set point: 1.5 in. w.g.
Throttling range: 0.3 in. w.g.
Damper Actuator 5 psi to 12 psi

Case No. 4 (Pneumatic)

System to control the static pressure in a pressurized clean room by action of a damper in a duct discharging air from the room.

Static Pressure Transmitter 0 in w.g. to 2 in w.g.
Set point: 0.9 in w.g.
Throttling range: 0.3 in w.g.
Damper Actuator 4 psi to 11 psi

Case No. 1 (Electronic)

System to control the dry-bulb temperature in a room by acting on the volumetric flow rate of heated air into the room.

Room Temperature Transmitter 40 – 85 ^oF
Set point: 65 ^oF
Throttling range: 5 ^oF
Damper Actuator 4 ma to 20 ma

Case No. 2 (Electronic)

System to control the dry-bulb temperature of the air in a room by acting on the volumetric flow rate of water through a hot-water heating coil in a duct supplying air to the room.

Room Temperature Transmitter 55 – 95 ^oF
Set point: 75 ^oF
Throttling range: 8 ^oF
Control Valve with actuator range of 4 ma to 20 ma

Case No. 3 (Electronic)

System to control the static pressure of the air being applied to a series of variable air volume (VAV) boxes by action on an upstream damper in a main duct.

Static Pressure Transmitter 0 in w.g. to 3 in w.g.
Set point: 1.5 in. w.g.
Throttling range: 0.3 in. w.g.
Damper Actuator 4 ma to 20 ma

Case No. 4 (Electronic)

System to control the static pressure in a pressurized clean room by action of a damper in a duct discharging air from the room.

Static Pressure Transmitter 0 in w.g. to 2 in w.g.
Set point: 0.9 in w.g.
Throttling range: 0.3 in w.g.
Damper Actuator 4 ma to 20 ma

RECEIVER-CONTROLLER STUDY

LIST OF CASES TO BE ANALYZED

DUAL INPUT CONTROLLER SETUP (RESET)

Case No. 5

System to control hot air discharge temperature by acting on the volumetric flow rate of water through a coil. Hot air discharge setpoint shall reset from 70 ^{o}F to 120 ^{o}F based on variation in outdoor air between 10 ^{o}F and 70 ^{o}F. The throttling range is 10 ^{o}F. Discharge sensor is 50^{o} to 150 ^{o}F. Outdoor air sensor is 0^{o} to 100 ^{o}F. Actuator spring range is 4-8 Psi.

Case No. 6

System to control air discharge temperature by mixing air from a hot and cold deck of a dual duct system. Discharge air setpoint shall reset from 55 ^{o}F to 65 ^{o}F based on variation in room air between 72 ^{o}F and 76 ^{o}F. The throttling range is 10 ^{o}F. Duct sensor is 35^{o} to 135^{o}. Room sensor is 50^{o} to 150^{o}F. Actuator spring range is 3-7 psi.

Case No. 7

System to control hot water temperature by acting on the volumetric flow rate of steam entering a hot water generator. Hot water setpoint shall reset from 100 ^{o}F to 180 ^{o}F based on outdoor air between -10 ^{o}F and 65 ^{o}F. The throttling range is 8 ^{o}F. Hot water sensor is 80^{o} to 240 ^{o}F. Outdoor air sensor is -20^{o} to 80 ^{o}F. Actuator spring range is 5-10 psi.

Case No. 8

System to control hot water temperature by acting on the volumetric flow rate of steam entering a hot water generator. Hot water setpoint shall reset from 120 ^{o}F to 180 ^{o}F based on variation in room air between 65 ^{o}F and 75 ^{o}F. The throttling range is 8 ^{o}F. Hot water sensor is 80^{o} to 240 ^{o}F. Room air sensor is 50^{o} to 100 ^{o}F. Actuator spring range is 4-8 psi.

Case No. 9

System to control space relative humidity by acting on the volumetric flow rate of steam entering a steam grid humidifier. Room relative humidity shall reset from 50% to 35% based on outdoor air between 35 ^{o}F and 0 ^{o}F. The throttling range is 10%. Relative humidity sensor is 10% to 60%. Outdoor air sensor is -20^{o} to 80 ^{o}F. Actuator spring range is 4-12 psi.

RECEIVER-CONTROLLER STUDY

LIST OF CASES TO BE ANALYZED

SINGLE INPUT CONTROLLER SETUP WITH REMOTE RESET (CPA)

Case No 10

Space temperature is controlled by varying the flow rate of hot water through a coil. The control system must provide automatic night setback. The throttling range is 4 ^oF. Occupied setpoint is 74 ^oF, unoccupied setpoint is 60 ^oF. The room sensor is 50^o to 100 ^oF. Actuator spring range is 5-10 psi.

Case No. 11

Space temperature is controlled by varying the flow rate of chilled water through a coil. The control system must provide automatic night setup. The throttling range is 4 ^oF. Occupied setpoint is 74 ^oF, unoccupied setpoint is 90 ^oF. The room sensor is 50^o to 100 ^oF. Actuator spring range is 3-9 psi.

Case No. 12

Space temperature is controlled by varying the flow rate of hot/chilled water through their respective coils. Refer to the figure on the next page. The valves are sequenced as shown. The control system is required to provide automatic seasonal changeover of room setpoint. The throttling range is 4 ^oF. Summer setpoint is 76 ^oF, winter setpoint is 70 ^oF.

Case No. 13

Space temperature is controlled by mixing air from the hot and cold deck of a multizone unit. Refer to the figure on the next page. The control system is required to provide automatic seasonal setpoint change with night setback/setup. The throttling range is 4 ^oF. The following setpoints apply:

	Summer	Winter
Day	72	76
Night	85	65

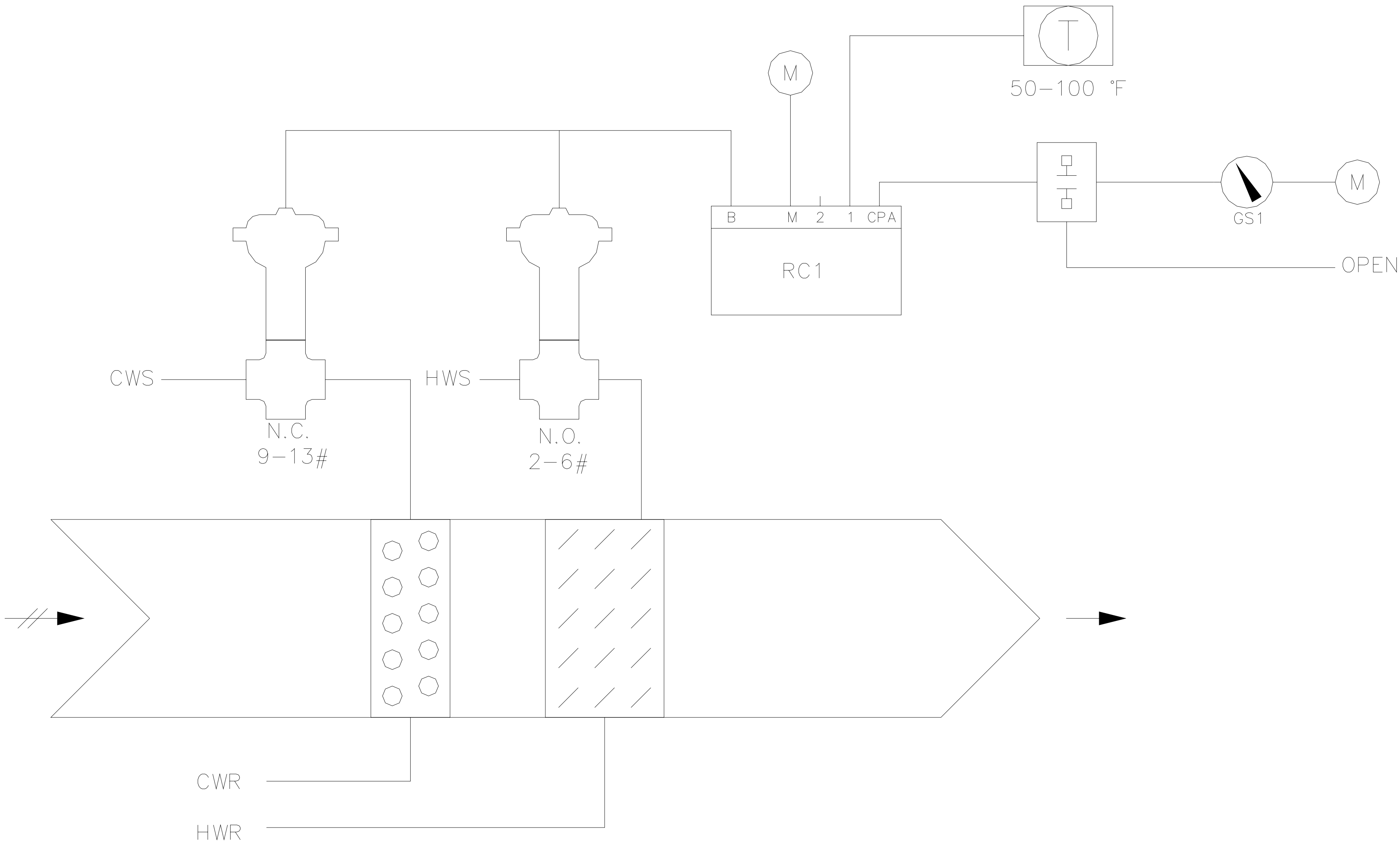
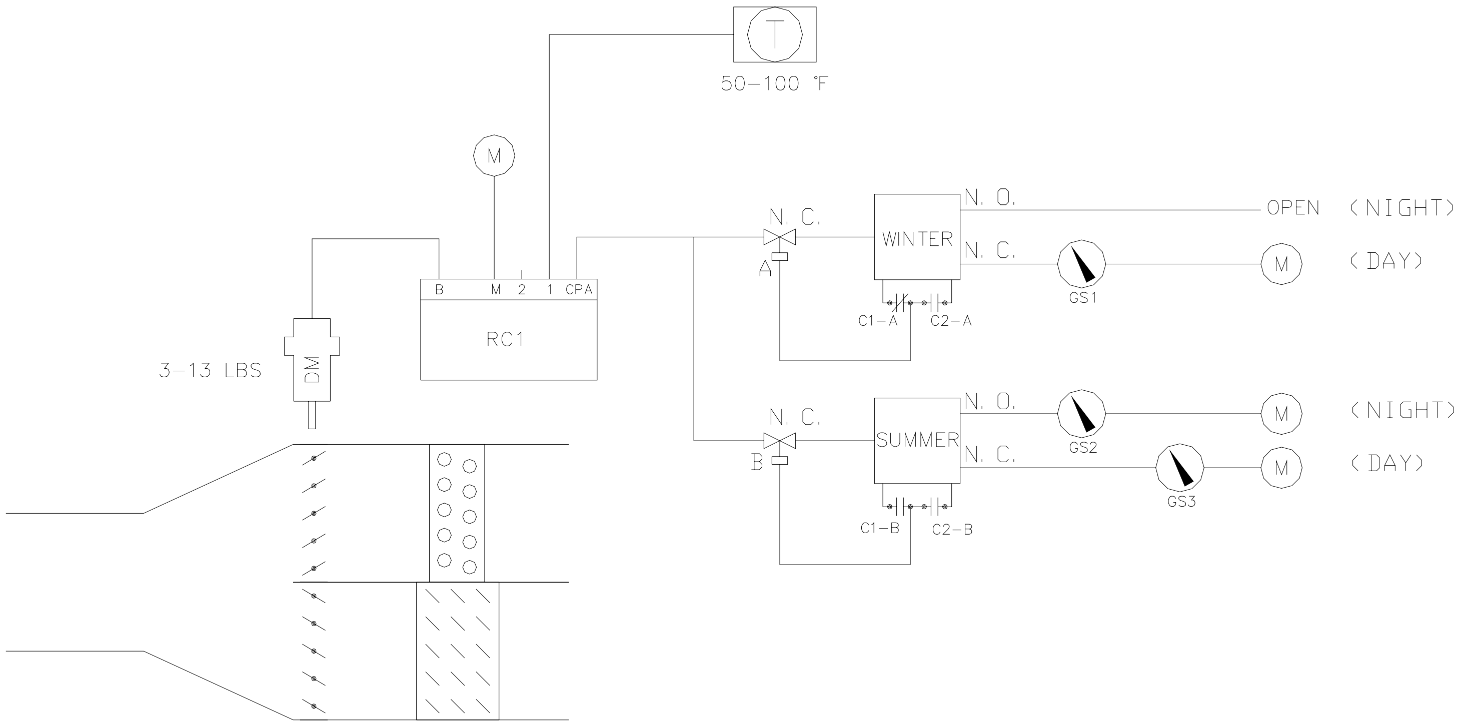
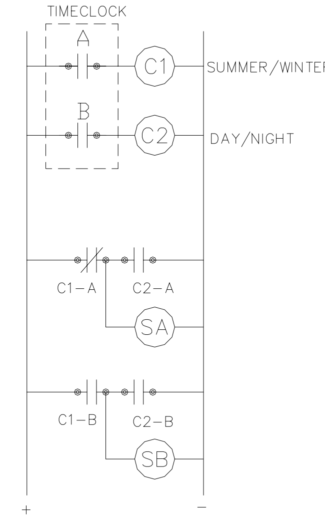


Figure 9 Schematic Diagram for Case 12





LADDER DIAGRAM
FOR RELAY CONTROL

1. SUMMER / DAY
TIMECLOCK CONTACTS 'A' AND 'B' CLOSE
COILS C1 AND C2 ARE ENERGIZED
CONTACT C1-A OPENS
CONTACT C2-A CLOSES
OPEN CIRCUIT TO WINTER AIR SOLENOID AND
VALVE 'A'. NO AIR PASSES. VALVE 'A' PREVENTS
FLOW THROUGH N. O. PORT OF AIR SOLENOID
CONTACTS C1-B AND C2-B CLOSE
SUMMER SOLENOID ENERGIZES
VALVE 'B' OPENS
CPA PRESSURE THROUGH GS3 APPLIED

2. SUMMER / NIGHT
TIMECLOCK CONTACT 'A' CLOSED, COIL C1 ENERGIZED
TIMECLOCK CONTACT 'B' OPEN, COIL C2 DEENERGIZED
CONTACTS C1-A AND C2-A OPEN
OPEN CIRCUIT TO WINTER AIR SOLENOID AND
VALVE 'A'. NO AIR PASSES. VALVE 'A' PREVENTS
FLOW THROUGH N. O. PORT OF AIR SOLENOID
CONTACT C1-B CLOSED
CONTACT C2-B OPEN
SUMMER SOLENOID DEENERGIZES
VALVE 'B' OPENS
CPA PRESSURE THROUGH GS2 APPLIED

3. WINTER / DAY
TIMECLOCK CONTACT 'A' OPENS, COIL C1 DEENERGIZED
TIMECLOCK CONTACT 'B' CLOSES, COIL C2 ENERGIZED
CONTACT C1-B OPENS
CONTACT C2-B CLOSES
OPEN CIRCUIT TO SUMMER AIR SOLENOID AND
VALVE 'B'. NO AIR PASSES. VALVE 'B' PREVENTS
FLOW THROUGH N. O. PORT OF AIR SOLENOID
CONTACTS C1-A AND C2-A CLOSE
WINTER SOLENOID ENERGIZES
VALVE 'A' OPENS
CPA PRESSURE THROUGH GS1 APPLIED

4. WINTER / NIGHT
TIMECLOCK CONTACTS 'A' AND 'B' OPEN
COILS C1 AND C2 ARE DEENERGIZED
CONTACTS C1-B AND C2-B OPEN
OPEN CIRCUIT TO SUMMER AIR SOLENOID AND
VALVE 'B'. NO AIR PASSES. VALVE 'B' PREVENTS
FLOW THROUGH N. O. PORT OF AIR SOLENOID
CONTACT C1-A CLOSED
CONTACT C2-A OPEN
WINTER SOLENOID DEENERGIZES
VALVE 'A' OPENS
ZERO CPA PRESSURE

Figure 10 Schematic Diagrams for Case 13

NOTES

1. ALL GAUGES ARE ASHCROFT 4-1/2" ASHCROFT #45 1279AS 04L 30 PSI RANGE WITH 0.2 PSI DIVISIONS

2. SW2 IS BARBER-COLMAN 2393-504 ALL OTHER SWITCHES ARE BARBER-COLMAN #2392-504 WITH PORT A BLOCKED.

3. ALL GRADUAL SWITCHES ARE BARBER-COLMAN 2390-501 WITH 0-20 PSI OUTPUT SET FOR 0-15 PSI OUTPUT

4. ALL RESTRICTORS ARE JOHNSON CONTROLS R-3710-2007 AQUA RESTRICTORS (0.007 IN.)

5. PROVIDE SUPPLY AIR TO BOX THROUGH SUPPLY AIR TAP. MAIN AIR TO CONTROLLER PROVIDED THROUGH SW1.

6. USE SW2 TO CHECK EITHER CPA PRESSURE OR CONTROLLER OUTPUT

7. SW4 AND GS2 MAY BE USED AS AN ADDITIONAL CPA PRESSURE IF RESET IS NOT USED

8. SW3 AND GS1 USED FOR PRIMARY SENSOR INPUT TO CONTROLLER

9. SW5 AND GS3 USED TO SELECT DESIRED CPA PRESSURE

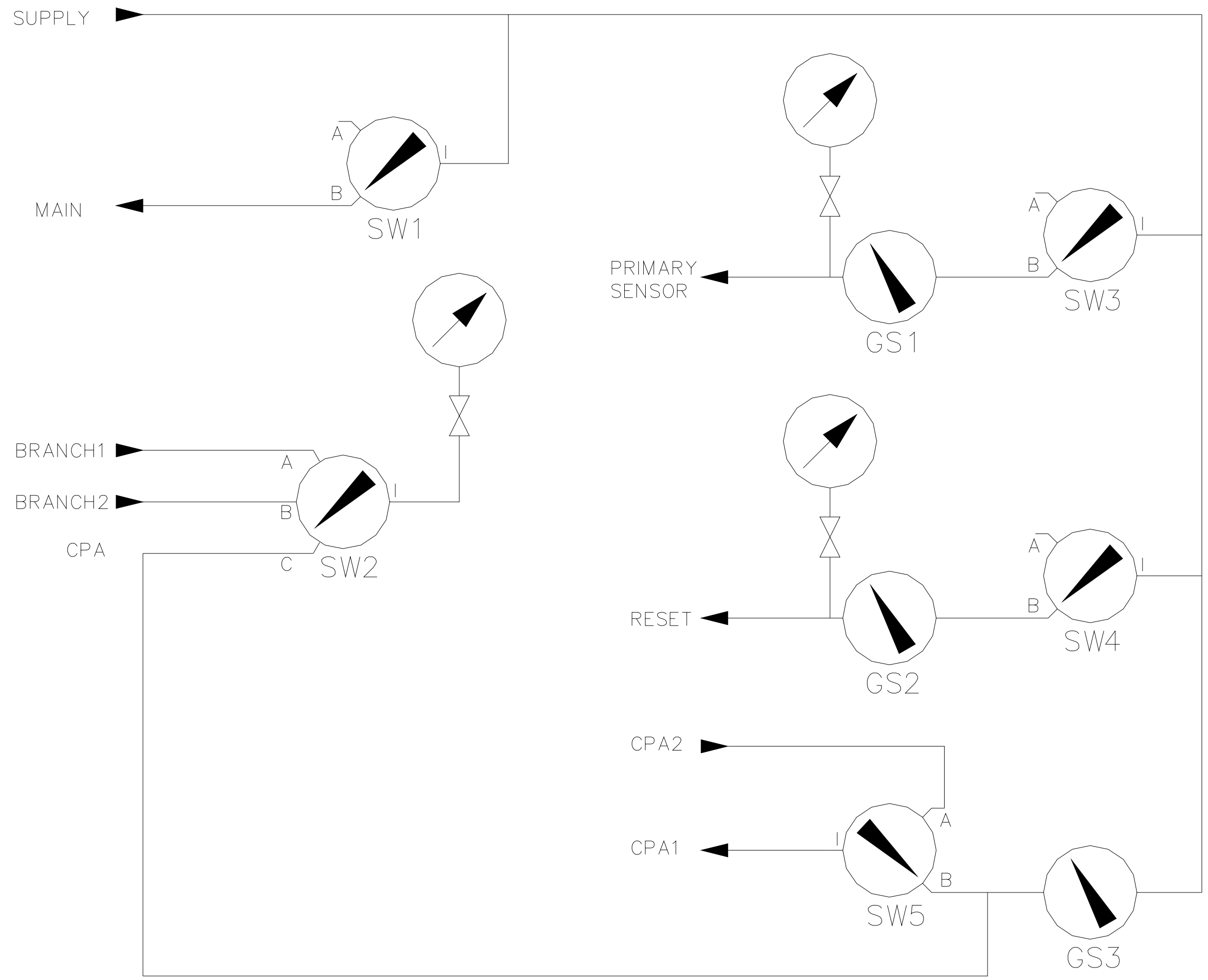


Figure 11 Schematic of Calibrator-Simulator

INSTRUCTIONS FOR USE OF CALIBRATOR SIMULATOR

1. CONNECT 20 PSIG SUPPLY AIR TO SUPPLY PORT. CONNECT MAIN AIR TO CONTROLLER FROM PORT MARKED 'MAIN'. SW1 OPERATES AS ON/OFF SWITCH FOR CONTROLLER MAIN AIR.

2. CONNECT CONTROLLER OUTPUT TO PORT MARKED 'BRANCH1'. IF USING MASTER/SUBMASTER SETUP, CONNECT MASTER TO 'BRANCH2' AND SUBMASTER TO 'BRANCH1'. USE SW2 TO DISPLAY DESIRED PRESSURE ON GAUGE 1.

3. CONNECT PRIMARY SENSOR INPUT OF CONTROLLER TO PORT MARKED SENSOR. TRANSMITTER INPUT WILL DISPLAY ON GAUGE 2. TRANSMITTER INPUT PRESSURE IS VARIED WITH GS1.

4. FOR RESET, CONNECT PORT MARKED 'RESET' TO CONTROLLER RESET PORT. RESET PRESSURE WILL DISPLAY ON GAUGE 3. RESET PRESSURE IS VARIED WITH GS2.

5. FOR CPA, CONNECT PORT MARKED 'CPA' TO CONNTROLLER CPA INPUT. SET SW2 TO 'CPA' TO READ CPA PRESSURE ON GAUGE 1. USE GS3 TO SET HIGH CPA PRESSURE. USE SW5 TO SWITCH BETWEEN LOW CPA PRESSURE OF 0 PSIG TO HIGH CPA PRESSURE AS CALCULATED.

6. RESET PORT ON BOX MAY ALSO BE USED AS A CPA PORT. CONNECT 'CPA2' TO RESET PORT WITH EXTERNAL LINE. BY SETTING FIRST CPA PRESSURE ON STANDARD CPA PORT AND SECOND CPA PRESSURE ON RESET PORT, USE SW5 TO SWITCH BETWEEN TWO CPA PRESSURES.

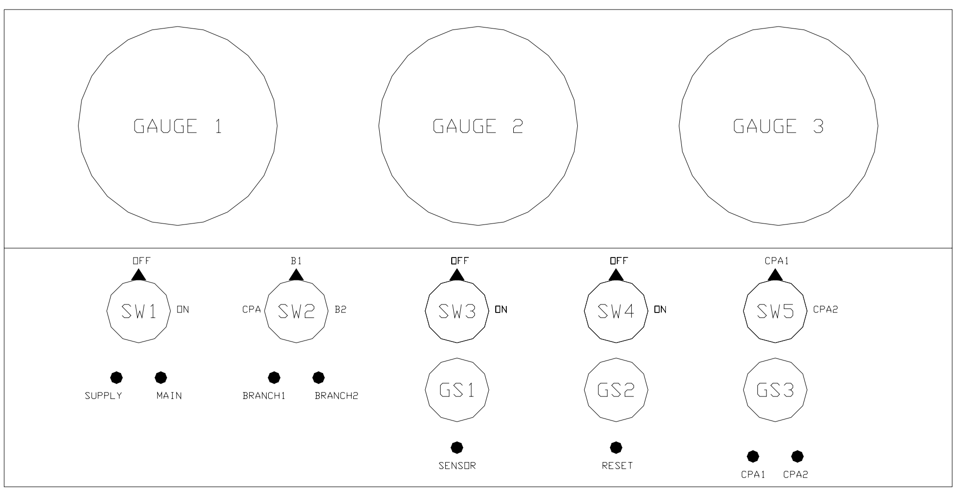


Figure 12 Calibrator Simulator Layout and Instructions

CONTROLLER IS (Check One)

- ☐ SINGLE INPUT
- ☐ DUAL INPUT
- ☐ CPA

SPRING RANGE	
SENSOR RANGE	
SENSOR SPAN	
SENSOR SESITIVITY	
SETPOINT	
CAL. PRESSURE	
TR	
CS	
%PB	
GAIN	
AUTHORTY/RATIO	

CPA CONDITION		SETPOINT	CPA	CONDITION GRAPHED
SUMMER	**DAY**			
	NITE			
WINTER	**DAY**			
	NITE			

RESET SENSOR		RESET PARAMETERS	
RANGE		**CONDITION GRAPHED**	
SPAN		**RESET SETPOINT**	
SENSITIVITY		**RESET PRESSURE**	

ACTION TABLE

SENSOR INPUT	DEVICE POS.	OUTPUT PRESS.

RESET SCHEDULE

RESET COND.	SETPOINT	RESET VAR
A		
B		

CONTROLLER OUTPUT

50%

DEVICE POSITION

Sensor Input

Sensor Pressure

CONTROLLER ACTION DIAGRAM

BASIS OF RESET

(CONDITION BEING RESET)

RESET GRAPH

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF SINGLE INPUT CONTROL

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(4) Proportional Band ("PB") Setting: ______ %

(5) Set Point Pressure: ______ psig

(6) With input pressure set to low end of throttling range:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(7) With input pressure set to high end of throttling range:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With output pressure set to low end of spring range:

(a) What should input pressure be: ______ psig
(b) What is input pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With output pressure set to high end of spring range:

(a) What should input pressure be: ______ psig
(b) What is input pressure observed: ______ psig
(c) What is the percent error: ______ %

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF RESET CONTROL

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(4) Proportional Band ("PB") Setting: ______ %

(5) Authority/Ratio Setting: ______ %

(6) Controller Calibration Conditions:

(a) Value of primary sensor input: ______ psig
(Engineering Units) ______ ___

(b) Value of reset sensor input: ______ psig
(Engineering Units) ______ ___

(7) With primary sensor input pressure set to low end of throttling range and reset sensor at high end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With primary sensor input pressure set to high end of throttling range and reset sensor at high end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With primary sensor input pressure set to low end of throttling range and reset sensor at low end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(10) With primary sensor input pressure set to high end of throttling range and reset sensor at low end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF REMOTE SETPOINT ADJUSTMENT (CPA)

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(3) Proportional Band ("PB") Setting: ______ %

(4) What are your CPA pressures and under what conditions will they be applied?
____
____
____

(5) Controller Calibration Conditions:

(a) Value of primary sensor input: ______ psig
(Engineering Units) ______ __

(b) Value of CPA pressure: ______ psig

(6) With primary sensor input pressure set to low end of throttling range and low CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(7) With primary sensor input pressure set to high end of throttling range and low CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With primary sensor input pressure set to low end of throttling range and high CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With primary sensor input pressure set to high end of throttling range and high CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: %

CONTROLLER IS (Check One)

- ☐ SINGLE INPUT
- ☐ DUAL INPUT
- ☐ CPA

SPRING RANGE	
SENSOR RANGE	
SENSOR SPAN	
SENSOR SESITIVITY	
SETPOINT	
CAL. PRESSURE	
TR	
CS	
%PB	
GAIN	
AUTHORTY/RATIO	

CPA CONDITION		SETPOINT	CPA	CONDITION GRAPHED
SUMMER	**DAY**			
	NITE			
WINTER	**DAY**			
	NITE			

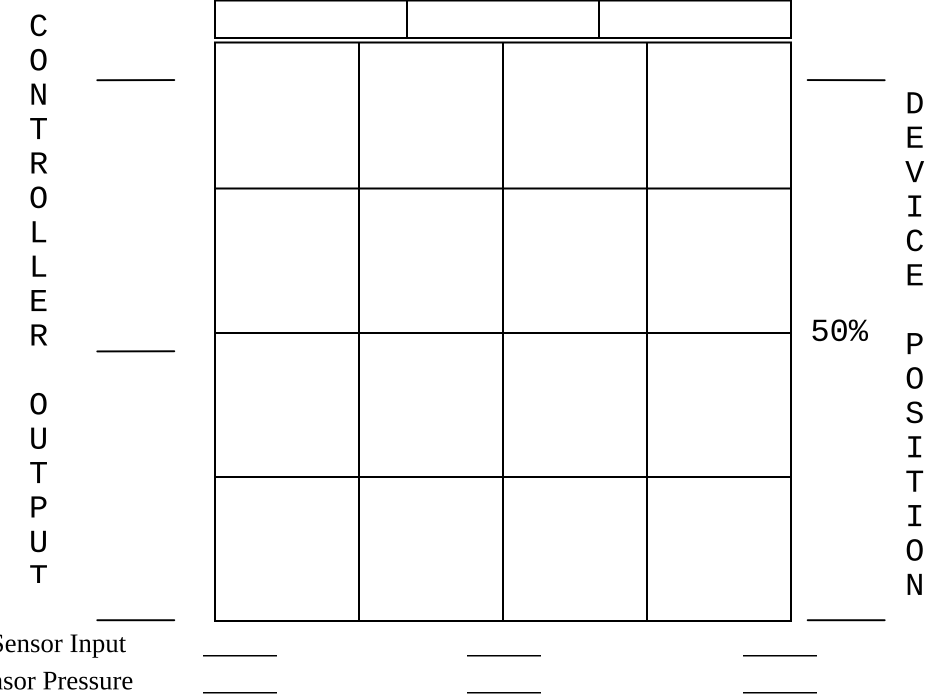
RESET SENSOR		RESET PARAMETERS	
RANGE		**CONDITION GRAPHED**	
SPAN		**RESET SETPOINT**	
SENSITIVITY		**RESET PRESSURE**	

ACTION TABLE

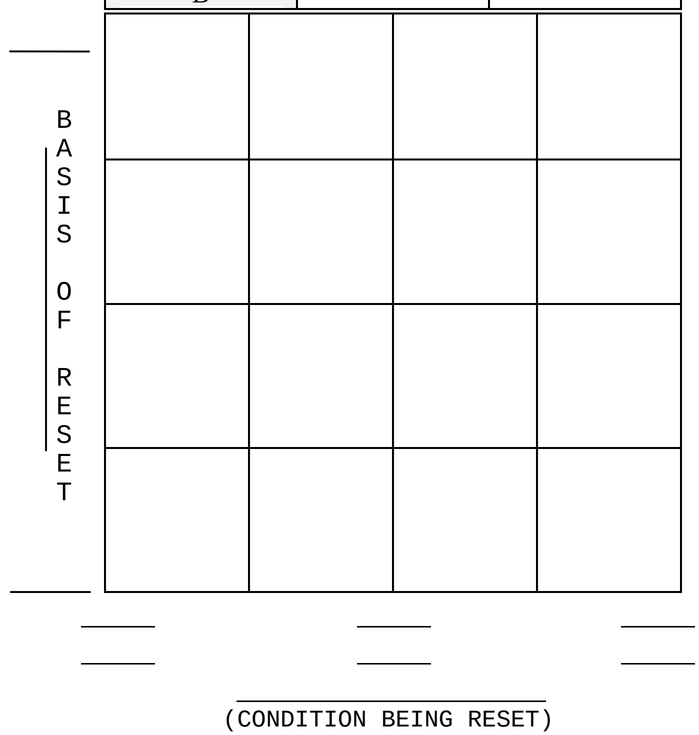
SENSOR INPUT	DEVICE POS.	OUTPUT PRESS.

RESET SCHEDULE

RESET COND.	SETPOINT	RESET VAR
A		
B		



CONTROLLER ACTION DIAGRAM



RESET GRAPH

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF SINGLE INPUT CONTROL

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(4) Proportional Band ("PB") Setting: ______ %

(5) Set Point Pressure: ______ psig

(6) With input pressure set to low end of throttling range:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(7) With input pressure set to high end of throttling range:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With output pressure set to low end of spring range:

(a) What should input pressure be: ______ psig
(b) What is input pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With output pressure set to high end of spring range:

(a) What should input pressure be: ______ psig
(b) What is input pressure observed: ______ psig
(c) What is the percent error: ______ %

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF RESET CONTROL

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(4) Proportional Band ("PB") Setting: ______ %

(5) Authority/Ratio Setting: ______ %

(6) Controller Calibration Conditions:

(a) Value of primary sensor input: ______ psig
(Engineering Units) ______ ___

(b) Value of reset sensor input: ______ psig
(Engineering Units) ______ ___

(7) With primary sensor input pressure set to low end of throttling range and reset sensor at high end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With primary sensor input pressure set to high end of throttling range and reset sensor at high end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With primary sensor input pressure set to low end of throttling range and reset sensor at low end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(10) With primary sensor input pressure set to high end of throttling range and reset sensor at low end:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

RECEIVER-CONTROLLER STUDY
ANALYSIS SHEET
DATA FOR EXPERIMENTAL CHECK OF REMOTE SETPOINT ADJUSTMENT (CPA)

(1) System Definition: ____
____
____
____
____

(2) Component Selection: ____
____
____
____
____

(3) Proportional Band ("PB") Setting: ______ %

(4) What are your CPA pressures and under what conditions will they be applied?
____
____
____

(5) Controller Calibration Conditions:

(a) Value of primary sensor input: ______ psig
(Engineering Units) ______ ___

(b) Value of CPA pressure: ______ psig

(6) With primary sensor input pressure set to low end of throttling range and low CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %?

(7) With primary sensor input pressure set to high end of throttling range and low CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(8) With primary sensor input pressure set to low end of throttling range and high CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %

(9) With primary sensor input pressure set to high end of throttling range and high CPA pressure:

(a) What should output pressure be: ______ psig
(b) What is output pressure observed: ______ psig
(c) What is the percent error: ______ %