Abu Dhabi National Oil Co.

ADNOC Technical Institute

INSTRUMENTATION

ADVANCED PROCESS CONTROL FUNDAMENTALS

UNIT 8

RATIO CONTROL LOOP TUNING

UNITS IN THIS COURSE

TABLE OF CONTENTS

8.0 TERMINAL OBJECTIVE:

Given a process simulator with an operating ratio control loop that needs tuning, Ziegler-Nichols formulas, and the necessary tools, the trainee will be able to tune the loop for stable loop performance. The flow rate in two loops must be in the correct ratio to each other. After a step set point change of 5% is made in the automatic mode, the tuned control loop must produce a one-quarter decay ratio curve and control at the set point within ± 2% of the chart scale.

8.1 ENABLING OBJECTIVES:

8.1.1 Unaided, the trainee will be able to correctly describe operating principles and applications of ratio control.

8.1.2 Unaided, the trainee will be able to correctly describe the procedure for tuning a ratio control loop.

MATERIALS:

P&ID A027 XA-H98049 Sheet 1.
P&ID R69 XA-822002 Sheet 23.

8.2 INTRODUCTION:

The quality of most products depends upon the amount of each ingredient mixed into the products. It can be bread, or it can be a prescription medicine, or fuel for a jet aircraft. The real secret is to be able to make that same quality product over and over again. To do that, the right proportion of each ingredient must be added every time.

Many of the products that are used are mixtures of several ingredients. Many of the plant processes depend on the use of several different products in the process.

RATIO CONTROL is used in processes where exact amounts of certain products must be maintained. Ratio is another word for proportion. Ratio is expressed as 2 to 1, or 8 to 5, or 1000 to 1, and so on. It means for a given amount of one product, use so much of the other product.

Instrument systems called RATIO CONTROL LOOPS control the amounts of products used in certain processes automatically. This module will teach you:

- The principles of operation of a ratio loop.
- Some applications of ratio control.
- How to adjust a ratio controller.
- How to tune a ratio control loop.

8.3 PART 1: DESCRIBE THE PRINCIPLES AND APPLICATIONS OF RATIO CONTROL.

In plant processes, ratio control is almost always concerned with the mixing of two fluids. It may be fuel gas and air in a furnace. It may be acid and water, or gas to steam. In each process, the flow of fluids must be controlled in strict proportions.

You know how a flow control loop works, and you know how a cascade loop works.

A ratio control loop uses some of the principles of each type of loop. In a ratio control loop, the flow rate of one loop controls the flow rate of another loop. You saw examples of one loop controller setting the set point of another controller when you studied cascade control.

In a ratio loop, the output signal from a transmitter of a variable in one loop is used to establish the set point of the controller of a variable in another. But it is not a straight one-for-one setting. This is where RATIO comes in. We will look at the question of setting a ratio set point in a moment. First, let’s use some illustrations to get the idea of what ratio is. (See Figure 8.01).

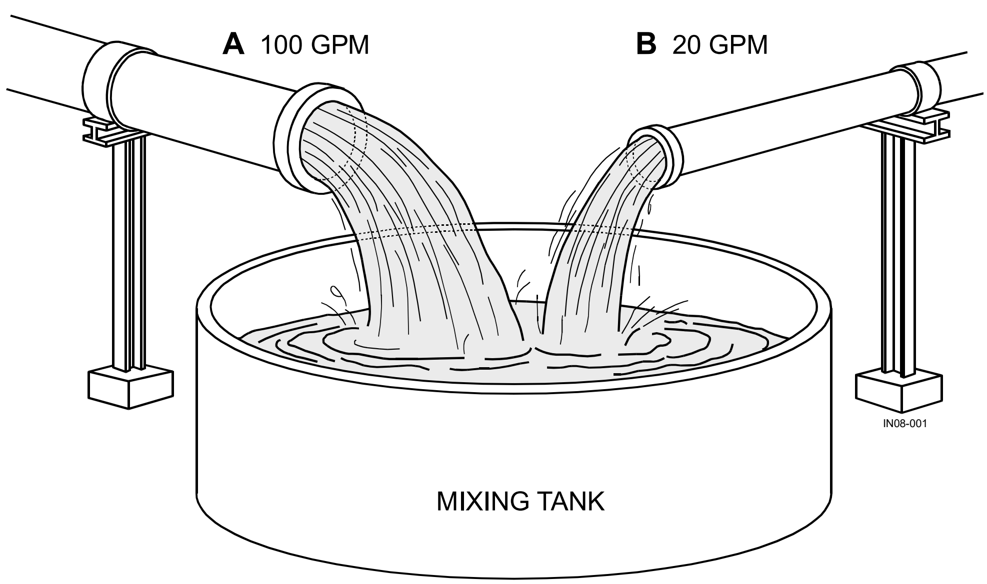

Figure 8.01 – Flow mixing (OT 3.6.2)

Figure 8.01 shows a very simple ratio control system. The maximum flow is 100 gallons per minute through one pipe and 20 gallons per minute through the other. This is a ratio of 1 to 5, comparing the flow of the secondary fluid with the flow of the primary fluid. As long as the flow rate in each pipe remains at the maximum, the liquid in the mixing tank will always have a 5 to 1 ratio of the two liquids.

Suppose we could only use one size of pipe for both flows but we wanted the 1 to 5 ratio of the mixture to stay the same? We would have to control one of the flows (see Figure 8.02)

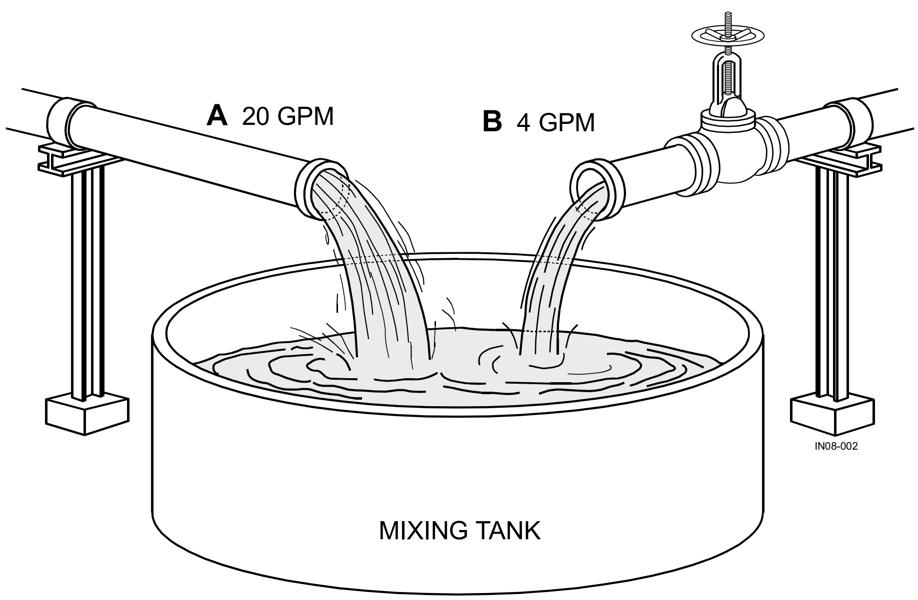

Figure 8.02 – Ratio Flow

This looks good so far. But we are interested in automatic ratio control. The valve in Figure 8.02 is a hand-operated valve. What will happen if, for some reason, the flow rate in pipe A will not stay constant at 20 gpm? Sometimes the flow rate is 16 gpm, 18 gpm, 20 gpm, and so on. Every time the rate drops below 20 gpm, the ratio between the two flows changes and the mixture in the tank changes. The **quality** of the mixture is not up to standard.

Think about flow control, flow loops, and flow instruments. How would you control the quality of the mixture?

The first thing we need to decide is which flow we want to be our standard. Let's use Flow A. We will call A the **Primary Flow**. What that means is regardless of what the actual flow in pipe A is, we want the flow in pipe B to be 1/5 of A's flow. Let's call B the **Secondary Flow**.

Here is something to fix in your mind about ratio loops. Whenever the ratio is expressed in numbers, such as 2 to 1 or 1 to 5, the first number given refers to the secondary flow.

We will install an orifice plate and differential pressure transmitter in pipe A. We will need a valve that can be controlled in pipe B. Now, we'll add a controller that will use the DP transmitter signals to open and close the valve in pipe B. (See Figure 8.03)

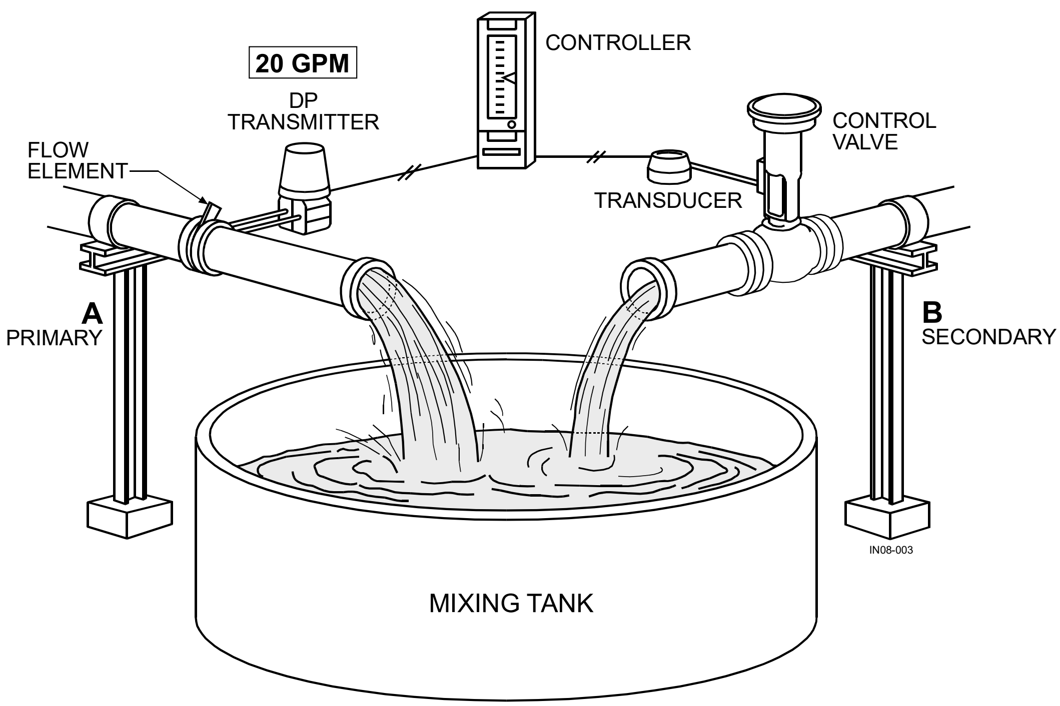

Figure 8.03 – Ratio Loop (Open Loop)

Can you see what is missing in this system? How does the controller know that the flow rate in pipe B is 4 gpm? The system in Figure 8.3 is an open loop, without feedback from the controlled variable.

To close the loop, we need a sensing element and a transmitter in pipe B to tell the controller what the flow rate is.

We also need something else. We need a special kind of controller, a **Ratio Controller**.

Let's complete our ratio control loop. Then we will look at how ratio controllers work. (See Figure 8.04)

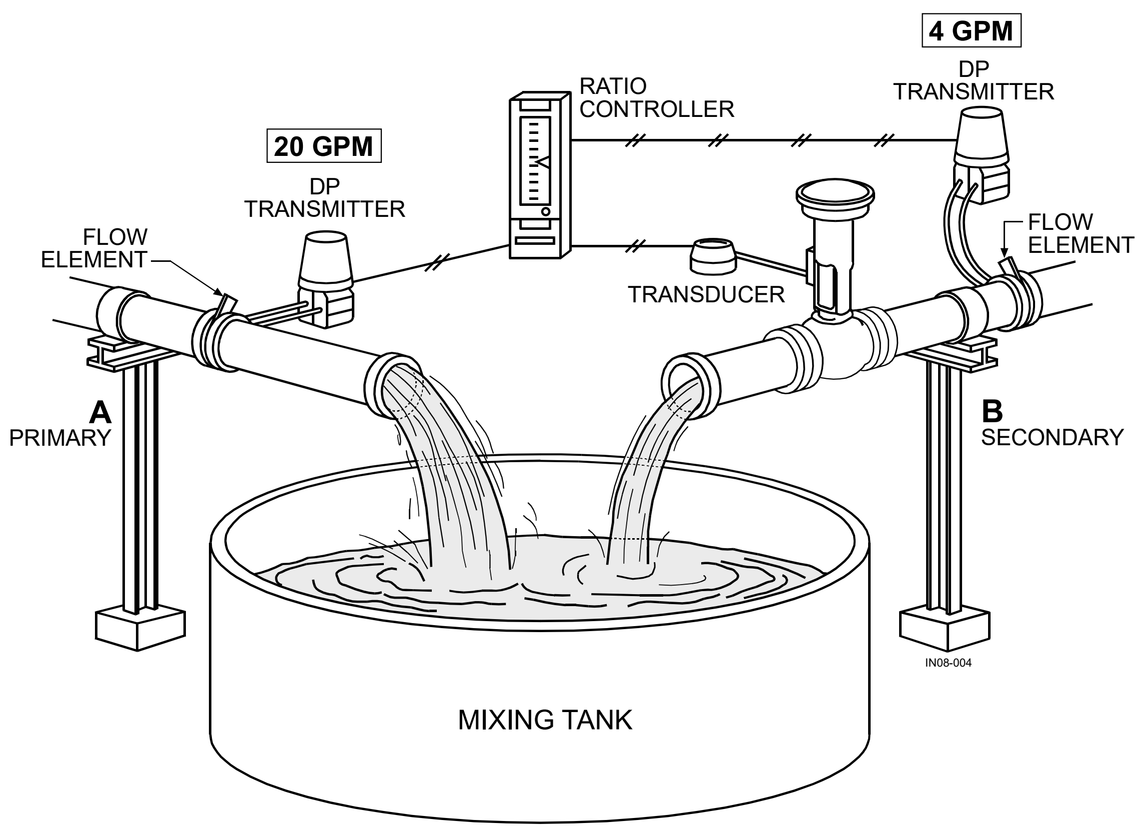

Figure 8.04 – Ratio Control Loop

We now have a complete ratio control loop. What is the ratio in this loop? Right! 1 to 5. Remember: 1 = **Secondary Flow Rate** and 5 = **Primary Flow Rate**. The first digit refers to the secondary controller.

In our sample ratio control loop, two transmitters send signals to one controller. The controller will multiply the primary loop transmitter signal by the ratio factor (1/5). The resultant signal becomes the set point for the secondary loop.

The signal from the secondary loop transmitter is the variable measurement, (the correct flow in pipe B). The output signal from t he ratio controller corrects the position of the control valve to make the measurement and the set point equal.

Ratio loops may also consist of two separate controllers. One controller in the primary loop will keep the primary variable at a controlled set point. The primary controller will also transmit its measurement signal to the ratio controller in the secondary loop. The measurement signal from the primary controller will determine the set point of the ratio controller.

Look at Figure 8.04 again. There is only one control valve in our ratio system. The flow through pipe A is not controlled. To control the flow through pipe A, a second controller and control valve must be added to the system. The controller will act as the master controller in the primary loop, controlling the flow through pipe A. The secondary ratio controller receives the same measurement signal as the primary controller. The ratio controller uses this signal to adjust its set point in proportion to flow changes in pipe A.

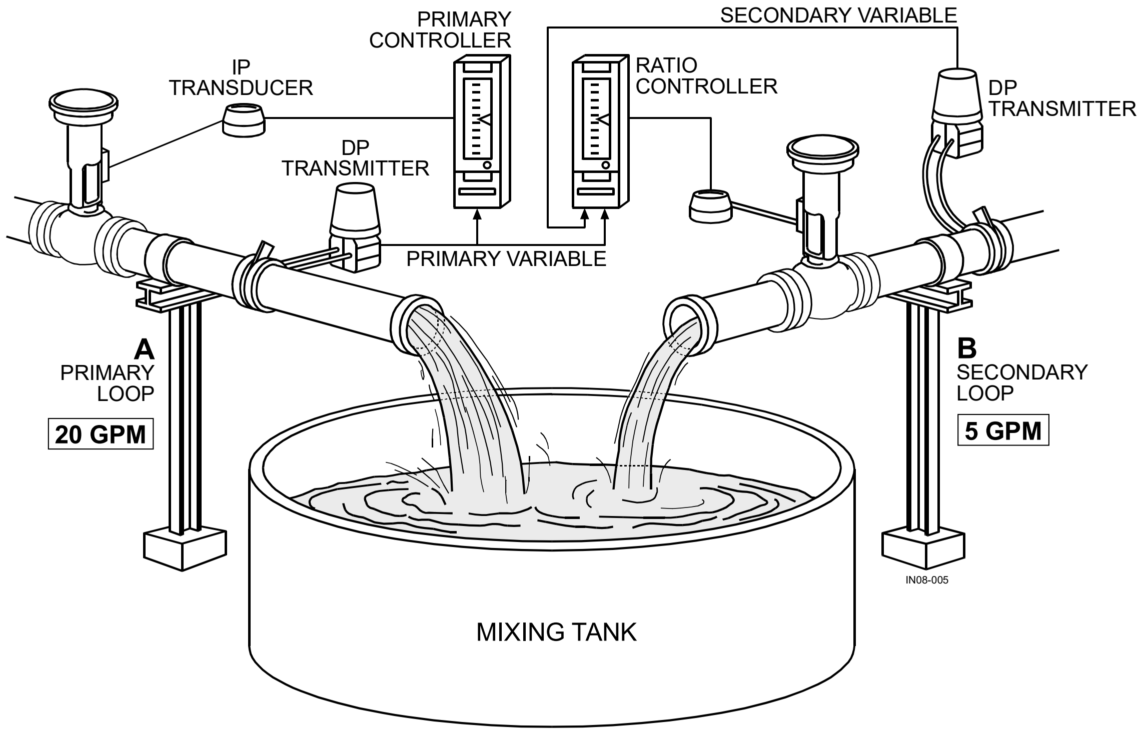

Figure 8.05 – Two-Controller Ratio Control Loop

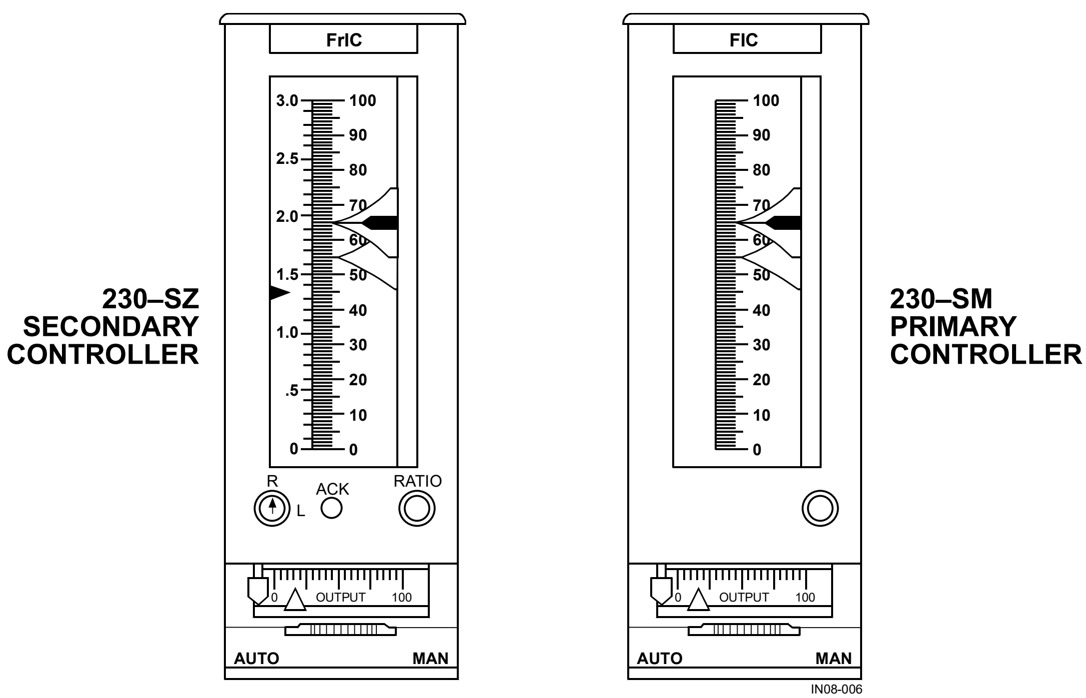

Figure 8.06 – Foxboro Ratio Controllers

The Foxboro Controllers in Figure 8.06 are the controllers you will work within this module. In ratio loops with only one controller, the Foxboro 230 SZ is usually used.

Look at the indicator scale on the 230SZ controller. The right side of the scale is for the controller set point and the variable measurement. It is a linear scale like others you have seen before.

Notice the scale on the left side. It is the ratio scale. The scale is graduated from zero to 3.0.

Foxboro indicator scales can be changed by removing the plastic scale and replacing it with another scale that is graduated differently. Scales with different ratio values can be installed. The scale on the 230-SZ controller is changed if the range of the ratio controller is changed. There is an internally mounted jumper on the controller circuit board that is used to change the ratio range.

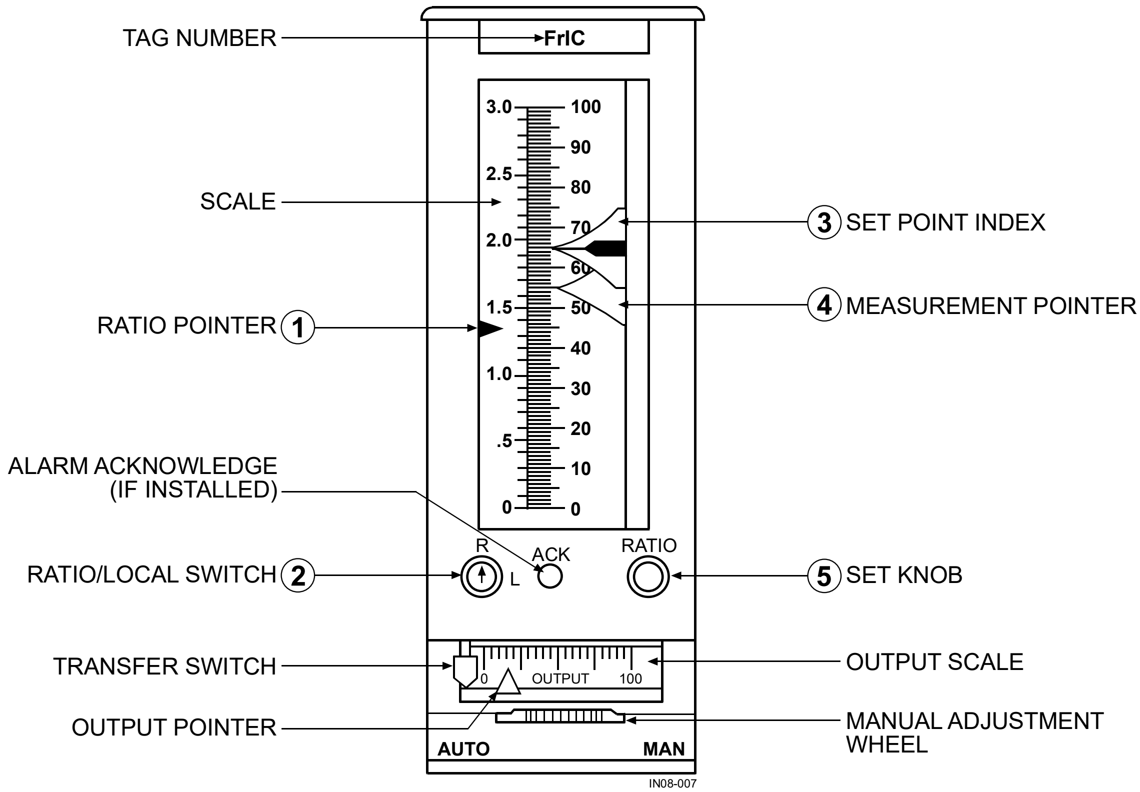

Figure 8.07 – Foxboro 230-SZ Controller

Notice the Tag Number in the illustration. The small letter 'r' following the variable identifier is used by ADNOC to identify this as a **Ratio Controller**. The small 'r' is also used on P&IDs to identify a ratio controller.

The Ratio Pointer is a movable pointer that indicates the ratio the controller is set for. The ratio pointer is moved using the **Set Knob** when the **Ratio/Local Switch** is turned to the R position.

The **Set Point Index** moves up and down the scale in response to signals from the primary controller. The set point reading will be the result of multiplying the primary controller measurement signal by the ratio value shown by the ratio pointer. From the pointer indications in the illustration, can you figure out what the primary controller signal is? 48.15%. Ratio set point (65%) **Divided By** ratio pointer (1.35%)

$$\frac{6.5\%}{1.35} = 48.15\%$$

The **Measurement Pointer** shows the measurement of the variable, which the ratio controller is controlling.

The ratio controller is the secondary controller.
When the ratio/local switch is set in the 'L' position, the ratio loop is broken. The controller is then controlling an ordinary flow loop. The controller set point index is moved by the set point know. Now the set point index will not move about as it does in the ratio loop mode.

The **Transfer Switch**, **Output Pointer**, **Output Scale** and the **Manual Adjustment Wheel** are the same as you have seen before. They are used in exactly the same way as with a cascade loop or an ordinary loop.

$PRI = \frac{RSP}{RP}$	$RSP = RP \times PRI$	$RP = \frac{RSP}{PRI}$
$PRI = \frac{45\%}{1.45}$	$RSP = 1.45 \times 44.82\%$	$RP = \frac{45\%}{44.82\%}$
$PRI = 44.82\%$	$RSP = 65\%$	$RP = 1.45$

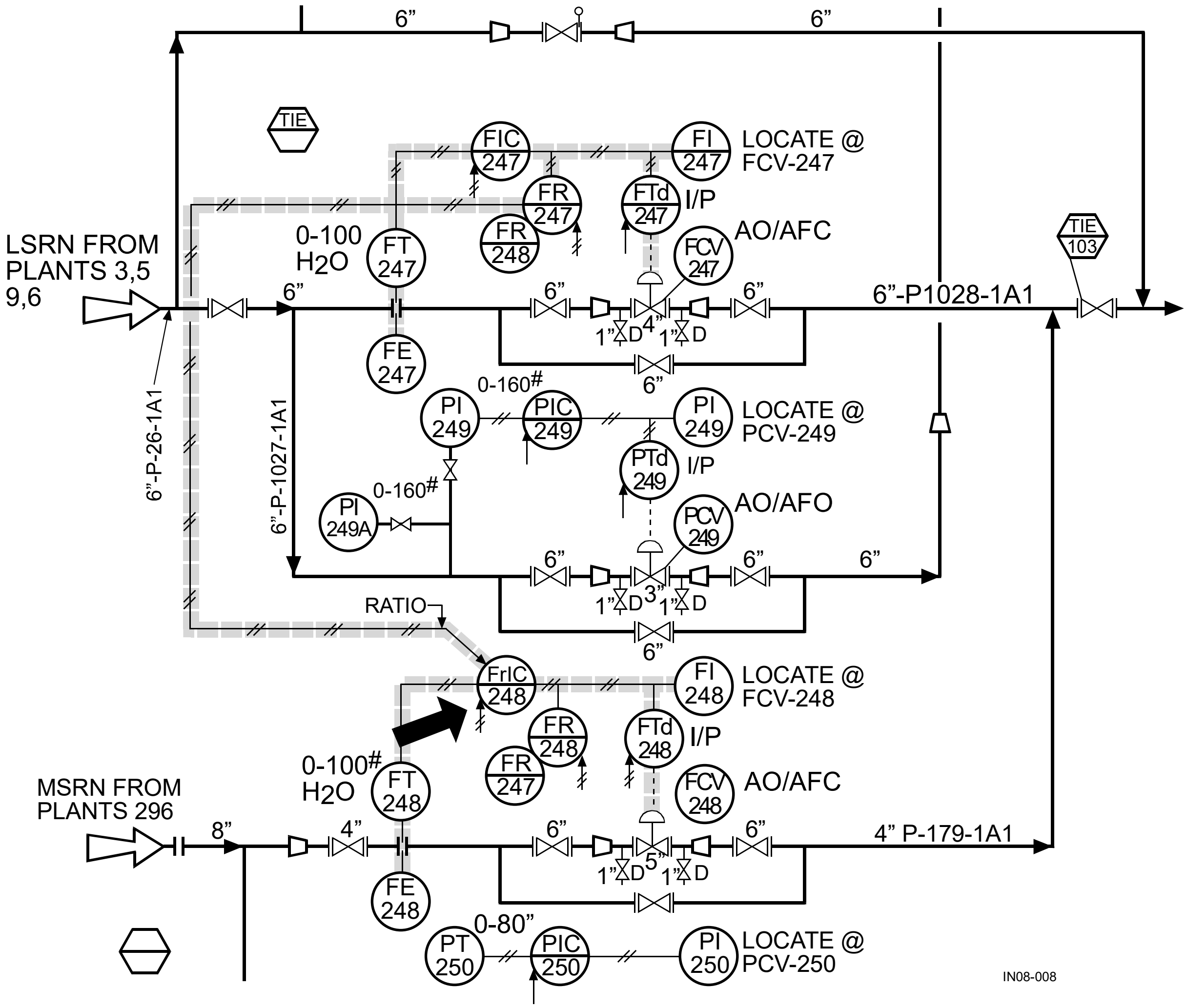

Figure 8.08 – Ratio Control Loop (F-247/F-248 (OT 3.6.10)

Study the P&ID in Figure 8.08 and you will see that flow loop F-247 and flow loop F-248 are almost identical. One difference is the pipeline sizes. The only other difference is the flow controllers. Flow Loop F-248 has a flow ratio-indicating controller, FrIC-248.

Which loop is the primary loop and which is the secondary loop?

Right! The one with the ratio controller is the secondary loop.

Why?

Because the secondary loop flow is controlled in ratio to the primary loop flow. Wherever the ratio controller is, that is the secondary loop.

8.4 PART II: DESCRIBE THE PROCEDURES FOR TUNING A RATIO CONTROL LOOP:

In a ratio control loop, the primary and secondary loops can be isolated from each other. Each can be tuned as if the other did not exist. When you take the ratio loop out of the ratio mode, the primary and secondary loops become ordinary flow control loops.

To isolate the two loops in a Foxboro ratio control loop, you need only turn the RATIO/LOCAL switch to LOCAL.

To isolate the two loops in a Honeywell ratio control loop, you need only move the mode selector switch from C to A. The C position is used if the controller is in either a cascade or a ratio loop. With the switch set in A position, the loop is in the AUTOMATIC mode and acts as an ordinary loop.

You will start the tuning task with the loop operating in the ratio control mode. The loop will have a two-pen recorder. One pen will be recording the primary loop variable. The second pen will be recording the secondary loop variable. Be sure you use the correct pen for the loop you are tuning.

Your instructor will demonstrate how to check the jumper on the Foxboro controller. You will not have to remove the controller from the panel or check the jumper when you perform the tuning task. Remember how and where the jumper is checked in case you have to check it in the future.

You will tune the primary and secondary controllers for proportional plus integral action only. Derivative action will be switched off.

In tuning a cascade loop you use the Ziegler-Nichols formulas and procedure to produce a ¼ decay reaction curve only when you tune the Foxboro and the Honeywell SLAVE controllers. For the MASTER controller, you used a trial and error method. In this section, you will use the ¼ decay reaction curve method to tune both the secondary and the primary controllers. You can tune the primary controller using the ¼ decay procedure because the controller does not depend on the secondary controller response as it did with the cascade loop you tuned previously.

In a ratio loop, it does not matter which loop you tune first. For our purposes in this module, you will tune the primary loop first.

Using the Ziegler-Nichols ¼ decay tuning method, a process measurement will not return to its set point immediately if there is a set point change. In most instances, the ¼ decay method will return the variable to its set point fast enough for the process being controller. In the future, you may have to tune a ratio control loop where it is essential that the variable return to its set point as quickly as possible. You can speed up the controller action by adjusting the secondary controller integral function. Your instructor will explain and demonstrate how this is done. Make those adjustments after you have produced a ¼ decay reaction curve for the secondary controller.

A Task Sheet containing the Ziegler-Nichols formulas you need will be found in the module Task Aid. You will also be given the formulas you need for the module Performance Test.

Your instructor will assign a specific ratio to which you will adjust the ratio control loop. After you have tuned the primary and secondary loops, you will place the ratio con troll loop into operation using the ratio factor you were assigned. When the loop is operating and is stable, you will have to verify that flow rates in the loop are correct.

If the flow rate in the primary loop is 100 gpm,
And
If the ratio for the loop is 1.5 to 1,
Then
The total flow should be 250 gpm.

Primary flow plus secondary flow equals total flow. When the ratio loop is stable, the controller indicators should also agree with each other.

If the primary controller measurement pointer indicates 30% and the ratio is set at 1.5 (1.5 to 1), then the set point for the secondary controller should read 45%. That is the SET POINT, not the measurement pointer on the secondary controller.

8.5 TROUBLESHOOTING AND REPAIRING ADVANCED CONTROL LOOPS:

TUNE RATIO CONTROL LOOPS

Given a process simulator with an operating ratio control loop that needs tuning, Ziegler-Nichols formulas, and the necessary tools, the trainee will be able to adjust and tune the loop for stable loop performance. The flow rate in two loops must be in the correct ratio to each other. After a step set point change of 5% is made in the automatic mode, the tuned control loop must produce a one-quarter decay ratio curve and control at the set point within ±2% of the chart scale.

Tools and Equipment:

Small Flat Blade Screwdriver

Materials:

P&ID for process simulator

ILDs for process simulator

Special Instructions:

Practice this task with the Foxboro ratio control loop in the Lab-Volt system. Use the same procedures to tune the Foxboro Controllers for the Performance Test.

8.6 TASK STEPS:

1. Switch the primary controller to MANUAL.
2. Switch the secondary controller to LOCAL and MANUAL. (Foxboro)
    - Switch both controllers to MANUAL (Honeywell)
3. Set both controller set points at 50% of indicator scale.

TUNE THE PRIMARY CONTROLLER

1. Stabilize the process measurement at the set point.
2. Set the integral for minimum action.
3. Set the derivative dial to OFF.
4. Set proportional band to its maximum setting.
5. Switch the controller to the AUTOMATIC mode.
6. Move the set point 2% to cause a process disturbance.
7. Return the set point to 50% as soon as the measurement pointer begins to move.
8. Check the recorder for cycling. Look for an Ultimate PB curve.
9. Reduce the PB setting by half.
10. Repeat steps 8 through 11 until Ultimate PB is achieved.
11. Determine the Ultimate Period.
12. Calculate the PB and integral settings for a ¼ decay reaction curve. (See Task Sheet 1 for formulas.)
13. Switch the controller to MANUAL mode.
14. Set PB and integral for values calculated in Step 14.
15. Stabilize the process measurement pointer at the set point.
16. Switch the controller to AUTOMATIC mode.

17. Cause a process disturbance. Return set point to 50%
18. Check the recorder for a ¼ decay reaction curve.
19. Make small adjustments in PB and/or integral settings to achieve the ideal ¼ decay reaction curve.
20. Repeat this entire procedure if the reaction curve is not satisfactory. Do not start the master controller tuning procedure until the slave controller is correctly tuned.
21. Adjust the set point to 40% of scale.

TUNE THE SECONDARY CONTROLLER

1. Repeat steps 1 to 20 for tuning the primary controller.
2. Adjust integral for a fast return to set point.

CHECK THE RATIO LOOP

1. Adjust the ratio set point to the ratio assigned by the Instructor.
2. Set both controllers in the AUTOMATIC mode.
3. Switch the secondary controller to RATIO mode (Foxboro).
    - Switch the secondary controller to C (Honeywell).
4. Verify that the secondary controller set point equals the primary controller measurement times the ratio.
5. Verify total flow in the ratio control loop.
    - Add the primary flow and the secondary flow together.
    - Check the total flow recorder. The recorded flow should equal calculated total flow within ±1%.