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Introduction to Loop Checking

Process control loops have a major impact on the financial performance of today's manufacturing facilities. It is also recognized that a good foundation of the basic regulatory control loop is essential to the success of intermediate and advanced process control (APC) [1]. Thus, it is critical that the technicians in these facilities focus on loop checking and performance. For this reason, this guide defines *loop checking* broadly to include control loop performance rather than merely in terms of plant start-up situations, such as in the traditional definition. Loop checking is also an important component in the continuous improvement planning program at any facility, insofar as it helps define and reduce the variability of key process parameters on an ongoing basis. It is also critical for maintaining regulatory compliance as dictated by local, state, and federal agencies.

The chapters in this book are arranged to follow a typical automation project from design check-out at the factory acceptance test (FAT) through to an ongoing sustaining loop performance program. The steps of such projects are as follows:

- Loop checking basics
- FAT
- Start-up
- Performance benchmarking
- Sustaining the performance

This guide discusses general methods and practices that can be applied across many processes or industries. The technician will encounter different plans and programs in their own company for addressing loop performance. These will affect how loop checking is defined and accomplished for the technician's environment. Some companies may designate a set or subset of employees to accomplish this task; however, the instrument technician typically has the best overall knowledge and skills for checking and maintaining control loop performance.

A recommended resource for more information on loop checking is ANSI/ISA-62382-2026/IEC 62382:2024, *Automation Systems in the Process Industry – Electrical and Instrumentation Loop Check* (IEC 62382:2024 IDT) [2], which defines procedures and specifications for executing a loop check.

1.1 The Opportunity

In today's intensely competitive markets, manufacturers strive to continually improve manufacturing performance to meet their business needs and goals. Typical business drivers are as follows:

- Increased throughput
- Increased yield

- Increased quality
- Minimized waste and off-spec

As we noted, the control loop (and the continual checking of loop performance) plays a vital role in the plant's financial performance. However, it has been observed that up to 80% of all loops are not performing their intended function of reducing the variability that results from the problems caused by the factors shown in Figure 1.1 [3]. Issues such as measurement placement and the resultant dead time or the noise it causes, undersized headers and valves, loop tuning, and control strategy all affect the loop's ability to accomplish the desired objectives.

In addition, plant performance studies (such as those summarized in Figure 1.2) have shown that field device performance and loop tuning provide the greatest opportunity for reducing costs (1.5%) when loop checking methods can be applied.

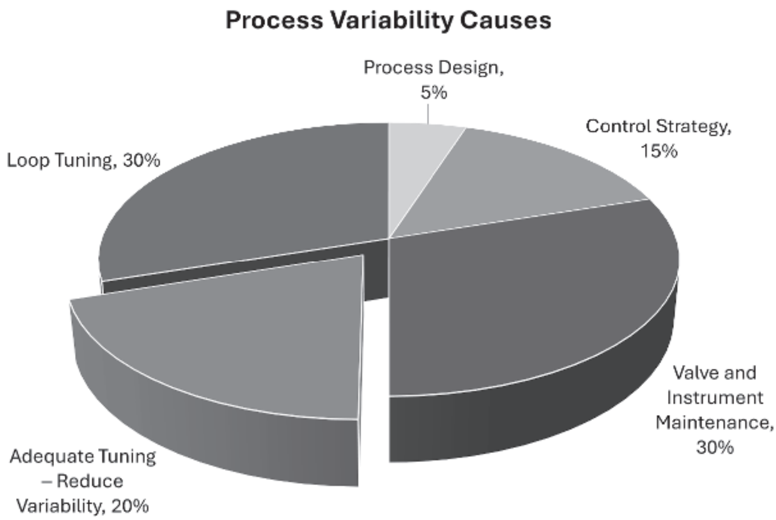

Figure 1.1 Control loop performance issues.

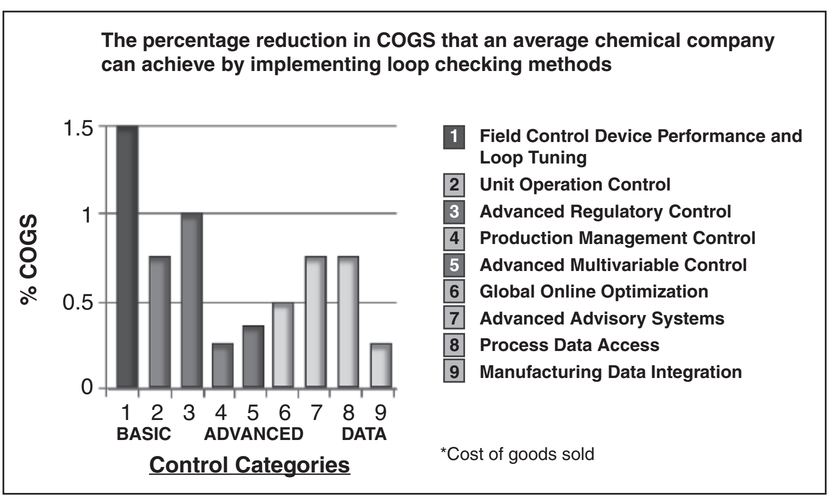

Figure 1.2 Process improvement opportunities.

The control system technician (CST) can become involved in monitoring and increasing the performance of the plant control loops, from the control implementation stage to the checkout phase and then through start-up, commissioning, and ongoing operations.

1.2 Loop Checking: Introduction

The following section reviews the components of the control loop and the scope of loop checking.

1.2.1 Defining the Loop

The purpose of control loops has been defined in various ways:

- To force the process to perform in a predetermined, desirable manner. The process may be a flow, pressure, temperature, level, or other variable in the manufacturing plant [4].
- To adapt automatic regulatory procedures to manufacture products or process material more efficiently [5].
- To ensure safety, environmental regulation, and profit [6].

Basic to any discussion of control loops is feedback control. In this control, the loop starts by measuring the process variable (PV). It then compares the PV to the desired value, the set point (SP), and acts on the difference between the SP and PV (error) using a control algorithm (typically proportional-integral-derivative [PID]). The loop then outputs to the final control element. Figures 1.3 and 1.4 indicate that the main elements of the control loop are as follows:

- Transmitter and sensor (for measuring the PV)
- Process controller (with an operator-entered or calculated SP and control algorithm)
- Final control element (valve actuator and accessories, dampers, variable speed drives, etc.)

Control system engineers use the block diagram in Figure 1.3 to show the relationships of the control loop elements. In Figure 1.3, the “G-(s)” symbols represent transfer functions, which are

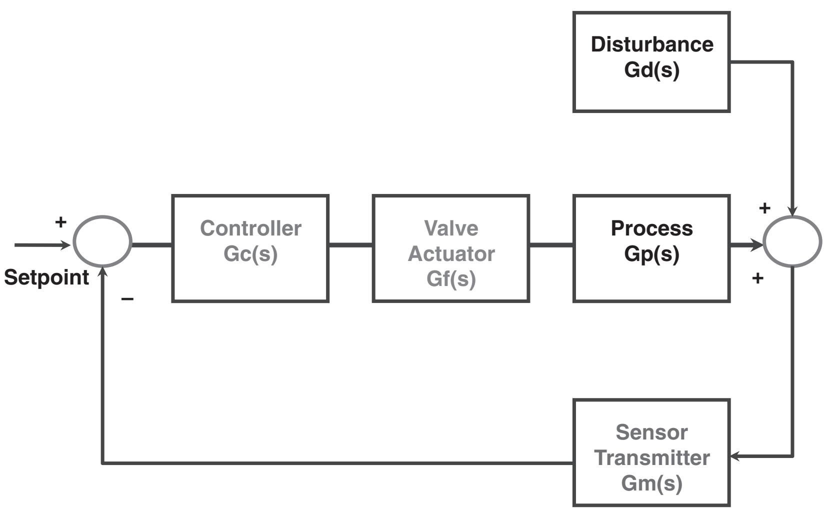

Figure 1.3 Feedback loop block diagram.

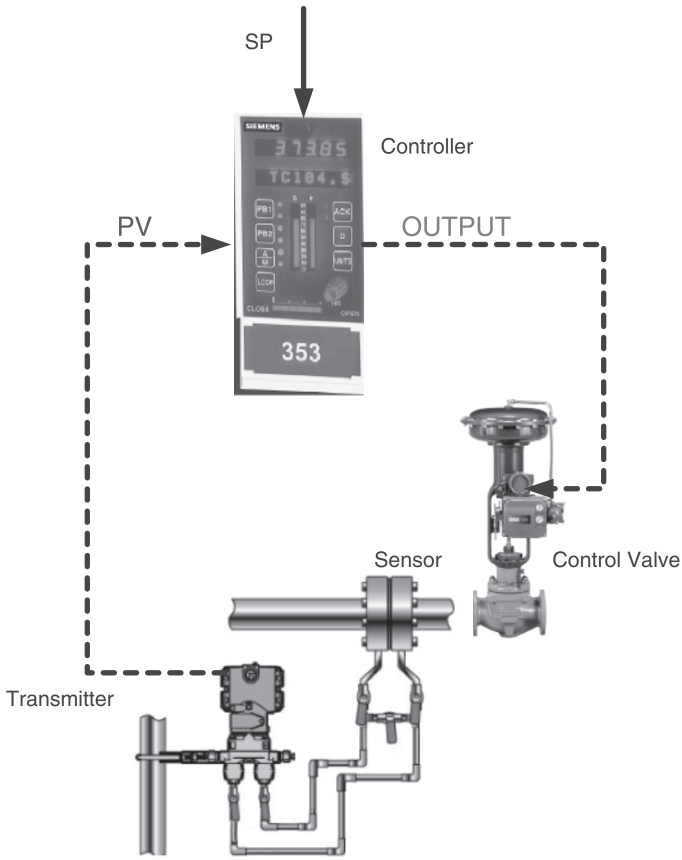

Figure 1.4 Control loop hardware.

the ratio of the output to the input for each component of the diagram. That is, G(p)s is the transfer function for the process (flow, pressure, level, etc.) controlled by the loop.

In a more practical view, the block diagram looks like Figure 1.4 when depicted with hardware for measurement, controller, and final control element functions.

For the purposes of this guide, we'll focus on the single-input, single-output control loop depicted in Figures 1.3 and 1.4.

1.2.2 Elements of the Loop

Let's discuss each element in the loop. Although several chapters could be dedicated to each element (Béla Lipták's *Instrument Engineers' Handbook*, Vol. 2: *Process Control*, third edition, is a good resource [7]), we will keep the discussion brief and highlight important features for our expanded definition of loop checking, which includes performance.

1.2.3 Sensor/Transmitter

The loop starts here and cannot work well unless the measurement is accurate and reproducible. Accuracy refers to *the largest allowable error that occurs under specific operating conditions.*

Accuracy is expressed as a percentage and indicates how close the displayed measurement is to the actual (standard) value of the signal measured. Reproducibility is the closeness of agreement of an output for an input approaching from either direction at the same operating conditions over a period of time.

Control and measurement evaluations are enhanced with strong accuracy and reproducibility specifications [1]. Signal measurement within the control system is usually not an issue with the input/output (I/O) design of today's control systems utilizing 16-bit analog-to-digital conversion, but if you configure the loop for large spans (e.g., temperature loops), small changes can go undetected.

Of course, properly selecting and installing the sensor and transmitter are critical, based on service conditions, accuracy, reproducibility, stability, reliability, and other plant standards. Dead time (the amount of time it takes for the PV to begin to respond after a change in output from the controller) and noise introduced by the measurement installation location can hurt the loop performance. The typical feedback PID controller does not handle dead time very well. For example, mounting a consistency transmitter so that it is convenient to work on versus placing it near the dilution source can introduce unwanted dead time. Conversely, a sensor installed near the valve outlet instead of upstream of the valve will have excessive noise. Additional sources of dead time may be incorrect piping, diplegs of pH chemical additions, poor mixing, the pH transmitter mounted too far downstream or on a slow recycle loop, slow-moving sample streams, and big sample pipes on analyzers.

1.2.4 Controller

The controller compares the transmitter measurement (PV) to the operator-entered SP, calculates the difference (error), acts on the error with a PID algorithm, and outputs a signal to the valve. Today's control systems all have very capable controllers, but you need to know which type of PID algorithm the control system manufacturer has implemented at your plant. The three most common versions are *standard*, *parallel*, and *series*. The controller type makes a difference in how you tune the loop. If your plant has just one control system, then the plant's standard tuning methods can be used without worrying about the differences. However, because plants purchase from different vendors/original equipment manufacturers (OEMs), different control system types can be employed (e.g., programmable logic controllers [PLCs] and distributed control systems [DCSs]). You must pay attention when tuning the different controllers to make sure the right tuning methods are applied. There are many configurable controller options that affect loop performance. These can include set point filtering, rate of change, reverse- or direct-acting, set point tracking, and derivative action on process variable only (D-on-PV). You must check to ensure that all of the controller settings provide the desired results. Microprocessor-based systems have introduced configurable loop scan (execution) times, which can be critical to loop performance. The controller (and I/O) must execute fast enough for the process dynamics. Table 1.1 suggests a starting point for the scan rates for some typical measurements.

1.2.5 Final Control Element

The final control element takes the signal from the controller and attempts to position the flow-controlling mechanism according to this signal [4]. There are various types of final control elements, and some have better performance in positioning the device. Final control elements can be variable speed drives for pumps or fans, dampers or louvers, or heater controls, but the most

Table 1.1 Typical scan times.

Measurement Type	Scan Rate Range (secs)
Pressure	0.25–2.0
Flow	0.25–2.0
Temperature	1.0–15.0
Level	1.0–5.0
Conductivity	0.5–2.0
Consistency	1.0
Analyzer (gas)	1.0
pH	0.25–5.0
Average torque	0.5–1.0
Speed	0.25–1.0
Current and other electrical measurements	1.0
Analog output	1.0

common is the control valve. The valve receives the most attention in the loop check because it receives an electrical signal from the controller (i.e., 4–20 mA current or digital value on a bus) and converts the electronic signal to a pneumatic signal that must then drive an actuating device to a precise location. We talk more about valve and loop performance in later chapters, but you will be hard-pressed to beat a sliding stem valve with a spring-and-diaphragm actuator and a two-stage positioner for performance.

In addition to dead time and noise affecting controller performance, the valve could introduce nonlinearities and dead band into the loop—neither of which is good for the PID controller. When receiving an electronic signal and converting it to a valve plug, ball, or disk position in the pipe, various sources of nonlinearity and dead band can build up. Friction from seals and packing, the backlash of mechanical parts, relay dead zones, and shaft windup can keep the valve from matching the signal required by the control system. Proper valve sizing and valve characteristic selection can help linearize the flow response to controller output changes, which is very important to PID performance.

1.2.6 Other Loop Types

In addition to feedback control, technicians will encounter several other control strategies when performing loop checking, such as cascade, ratio, and feedforward control. The process control example in this chapter briefly discusses these techniques, but the same basic methods apply to verifying the loop input or control and design or output.

In some plants, the term *loop* may include other control system functions such as analog indicate-only, motor starts and stops, on-off valves, and discrete input or output control functions. This guide does not include a detailed discussion of these functions, although you could easily expand the methods and techniques to include them in the loop check plan for your plant.

For more in-depth information on loop elements, refer to the vendor literature and application papers, publications from the Technical Association of the Pulp and Paper Industry (TAPPI) and the International Society of Automation (ISA), and books by Nancy Sell [8] and Terrence Blevins et al. [1].

1.2.7 Loop Checking

Some think loop checking is a process to confirm that the loop components are wired correctly and is typically performed before start-up. However, due to the factors described in the previous sections, the loop check scope begins when the instruments are received. It has expanded to include tests to confirm that it is operating as designed and that ongoing programs exist for benchmarking and monitoring performance. The block diagram in Figure 1.5 illustrates the components of this expanded loop checking process.

1.2.7.1 Process Overview

Loop checking starts when the instruments are received at the plant site and continues through installation and start-up and into the ongoing plant operation. Because of the scope of this manual, we will not cover the receiving, calibration, or installation aspects of the loop check [9]. Instead, we will focus more on the verification, start-up, and monitoring phases.

The verification process is intended to ensure the control system performs the intended function properly. The testing process, known as the FAT, can be performed before shipping the hardware or in parallel with the hardware installation at the site if the start-up schedule is compressed. It includes verifying the transmitter PV for the operator display, use in the control strategy, and historical trending. The valve position response should also be checked to ensure it matches the 0–100% controller output signal. The FAT can be duplicated at the site with the actual hardware and software installed, where it is known as the site acceptance test (SAT).

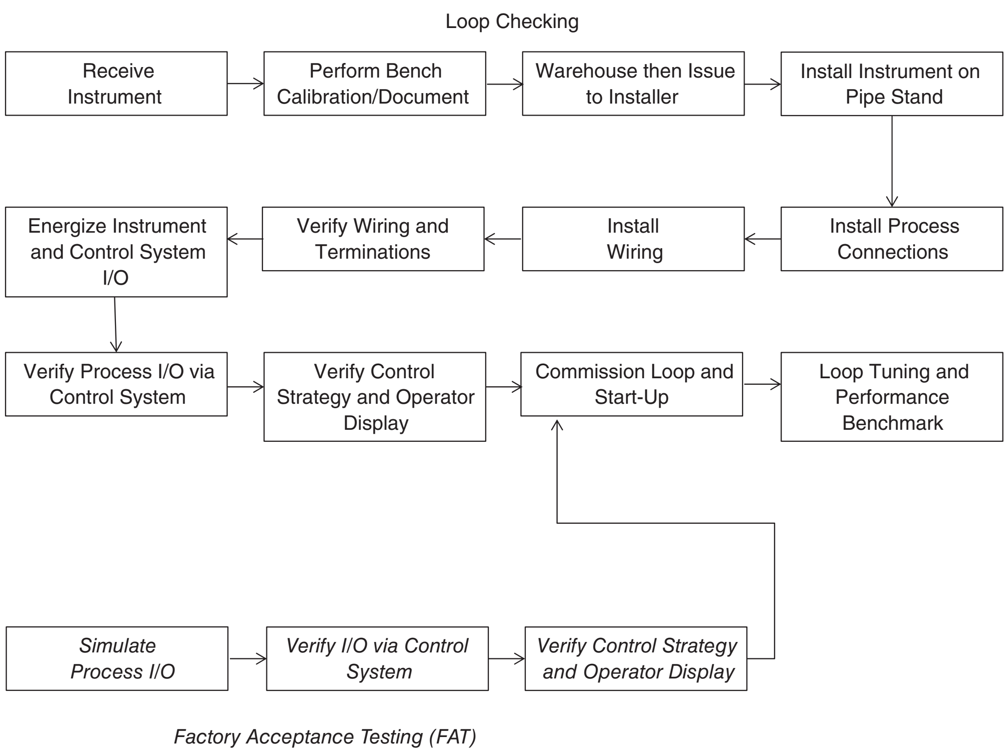

Figure 1.5 Loop checking process.

Once the technician checks the control strategy to verify that the expected output to the final control element is produced, the loop can be commissioned, and start-up can proceed.

Finally, the loop check can include defining the loop performance benchmark and providing a method for monitoring the performance over time.

1.2.7.2 Technology Improvements

Recent developments in smart instruments, I/O buses, and software products have made increased flexibility and productivity possible in the loop checking process. Such smart digital technology makes it possible to access and use new types of information that were not available from the analog 4–20 mA transmitter and valve. For example, HART® and FOUNDATION™ Fieldbus[1] devices give the technician access to significant amounts of diagnostic, calibration, and performance information, not only about the device but about the process as well. Software packages store this extensive data for analysis, future reference, regulatory agency documentation, and sophisticated troubleshooting assistance. As a result, fewer people and less time are required to perform the conventional tasks involved in the checkout process. However, along with the new technology, new tool and training requirements must be followed for plants to capitalize on the advertised benefits. Subsequent chapters of this guide discuss the impact of smart technology on the various phases of loop checking.

1.3 Process Control Example

The following example of boiler drum level, feedwater, and steam flow (three-element control) is used throughout this guide to illustrate the loop check (see Figure 1.6). By combining feedback, cascade, and feedforward control techniques, we can cover several aspects of loop checking simultaneously.

The control objective in this example is to maintain the drum level at an operator-entered set point within close tolerances throughout the boiler's operating range. This is achieved by controlling the feedwater inlet flow, with assistance from steam flow, to compensate for load disturbances.

Close control of the level set point is desired because of process equipment safety issues. These include concerns about water carryover into steam lines resulting from high drum levels and the potential for boiler tube damage due to low water levels.

1.3.1 Measurement

For this example, the flow and level measurements are accomplished using differential pressure devices. The feedwater and steam flows utilize orifice plates to develop a differential pressure that is proportional to the square of the flow. The drum level transmitter reads a differential pressure signal between the water and steam in the drum and an ambient water column. Boiler drum pressure, water temperature, and corrections for steam and water densities are used to calculate the boiler water level.

1.3.2 Control System

We assume either a DCS or PLC control system is being used. All controller algorithms are PID. The control strategy involves the following loop types:

- **Feedback control:** The output of the feedwater flow loop controls the feedwater valve according to a set point cascaded from the drum level loop and compared to the feedwater flow

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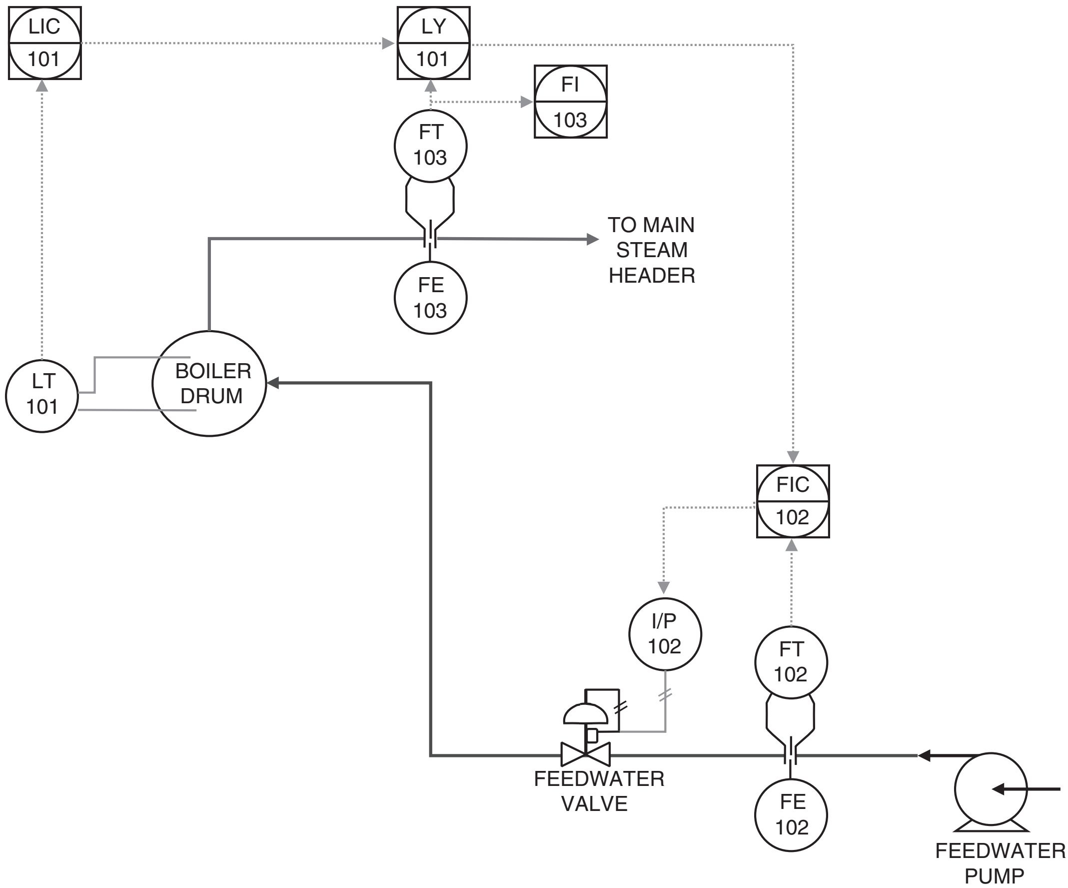

Figure 1.6 Example of boiler drum process control loops.

measurement. This closed-loop control of the feedwater flow in a cascade system allows the feedwater flow loop to correct any disturbances in the feedwater flow before those disturbances affect the drum level.

- **Cascade control:** The drum level controller (primary loop) compares the drum level measurement to the operator set point, and its output becomes the set point of the feedwater flow controller (secondary loop).
- **Feedforward control:** The feedforward action is accomplished by summing the steam flow measurement with the corrective output from the drum level controller. The control intent is for the feedwater flow into the boiler to match the steam flow out of the boiler, then the level controller is used to fine-tune the feedwater flow to keep the level near the set point. Additional consideration and tuning may be required to mitigate shrink and swell, delays in steam flow readings, leads and lags in the process, and variations in drum pressure. This summed signal is then used as the set point for the feedwater flow loop.

1.3.3 Final Control Element

This example assumes a pneumatic-operated, sliding stem control valve with a digital valve controller for manipulating the feedwater.

1.4 Other Loop Checking Considerations

Summarized below are other considerations for designing, implementing, checking, and benchmarking control loops. These guidelines are based on the philosophy that control systems should minimize product variability and improve the overall efficiency of an operation. Instrument and control system manufacturer's installation and maintenance guidelines should also be followed.

1.4.1 Keeping Score

How do we know when a loop is performing well? We need a quantitative measure that will identify the loop performance. As we discuss further in Chapters 4 and 5, many different methods are used to measure loop performance. The performance team must determine the best approach for the plant.

Some people have mentioned the following as performance measurements [10]:

- The plant didn't blow up.
- The process measurements stay close enough to the set point.
- They say it is fine, and you can go home now.

However, there are a host of mathematical techniques for measuring loop performance that are better choices. This section briefly discusses a few of these measurements that have been used in process control applications.

1.4.1.1 Loop Variability

One method is to calculate the loop variability to get an idea of the relative performance compared to other loops. Variability can be defined as two times the standard deviation divided by the mean. Let's look at each of these terms. Figure 1.7 illustrates that as the PV changes, there will be a band of values that typically forms a distribution or spread (2 σ) around some mean (average) value.

1.4.1.2 Standard Deviation

Standard deviation, σ (sigma), is a statistically derived parameter that describes the spread of data about the mean value; the larger the value of σ, the greater the spread. The mean is simply the average of the values, and in loop analysis, this typically calculates closely to the set point.

Statistics again tell us that the spread of data represented by 1 σ will encompass about 68% of the total data values, while 3 σ will get 99.73%. See Figure 1.8 for a representation. As a sort of

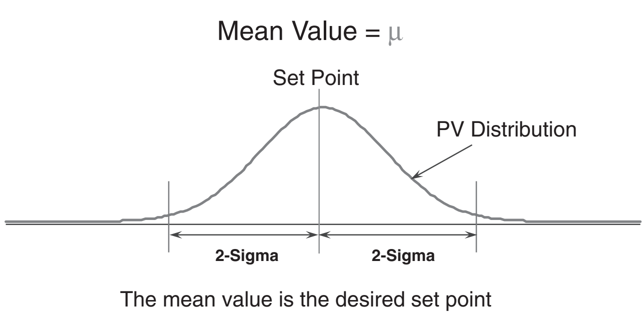

Figure 1.7 Loop variability.

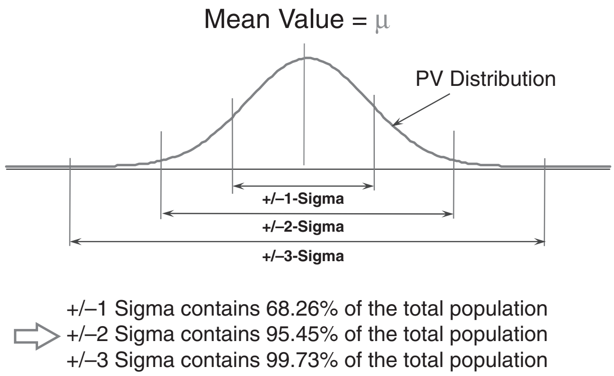

Figure 1.8 Picking the data spread.

an industry benchmark, we've settled on the 2 σ value to use for our process control variability calculation.

Thus, when you divide 2 σ by the mean (and multiply by 100), you will have a value in percent that will then enable you to compare loops that, for example, control flow (perhaps measured in gallons per minute or GPM) with level loops (engineering units in feet). Of course, some loops, such as secondary cascade loops or certain level loops, are designed to absorb some process variability; thus, a higher variability is fine.

Consider the following example: Figure 1.9 shows data on a recorder from a flow loop transmitter; the loop is in manual, and random disturbances are causing the flow to vary. By using commercially available spreadsheet tools or loop analysis software, the statistics of two times standard deviations

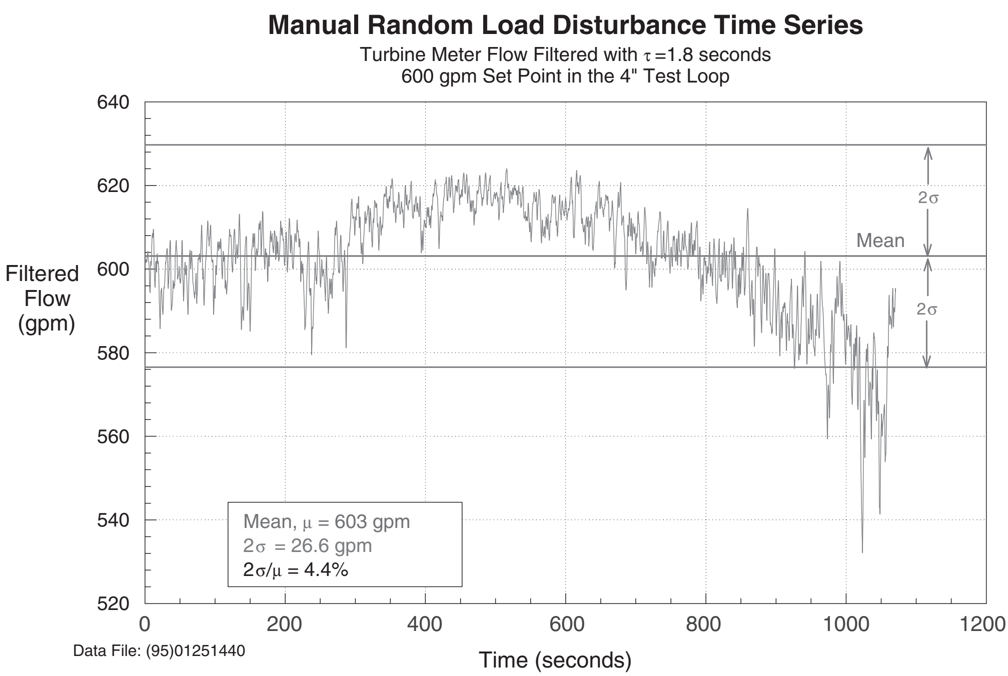

Figure 1.9 Flow example with statistics.

Table 1.2 Variability rating.

Variability (%)	Rating
Less than 0.5	Excellent
Less than 1.0	Very good
Less than 2.0	Good
Less than 5.0	Fair
Less than 10	Unacceptable

($2\,\sigma$) of 26.6 GPM, mean (μ, average) of 603 GPM, and resulting variability ($2\,\sigma/\mu$) of 4.4% can be calculated.

Placing the loop in automatic and repeating the test in Figure 1.9 should reduce the calculated variability. If it doesn't, read Chapters 4 and 5 for loop troubleshooting techniques that can help.

1.4.1.3 Heading Variability

So, what is good variability for a loop? Table 1.2 suggests a variability range for key loops in your process as a rule of thumb.

In addition, many software packages on the market can evaluate control loop performance. The following examples are from vendor information describing their evaluation techniques:

- **Variability Index:** A comparison of current loop operation to minimum variance control. For example, the control loop performance cannot be improved if the variability index is zero (0). If the variability index is 100, the loop is not reducing process variation (i.e., its performance isn't any better than if it were in manual). The variability index is not fooled by noise or load disturbances (i.e., it is a true indication of how far off the current performance is).
- **Harris Index:** A performance measure typically discussed by academics. The Harris Index looks at the error signal, which is the process variable or measurement minus the set point. The index measures the ratio between the error variance and the variance achievable by a minimum variance controller. The larger the value, the poorer the loop performance. The Harris Index calculation results in a number between 1 and infinity. A value of 1 is perfection or minimum variance control.

$$\frac{\textit{Current Variance}}{\textit{Minimum Variance}}$$

  where

$$\begin{aligned} 1 &= \text{perfect} \\ \text{Larger than } 1 &= \text{poorer performance} \end{aligned}$$

Another form of the Harris Index is the closed-loop performance assessment (CLPA). It is simply the Harris Index, normalized to be between 0 and 1:

$$\text{CLPA} = 1 - 1/(\text{Harris Index})$$

With the CLPA:

0 = perfect control
1 = poorest control

- **ExperTune Index:** Measures how well a control loop responds to process upsets. The index uses a process model combined with current and optimal PID tuning values. It can be calculated by simulating the response of the control loop to a load upset with both sets of tuning values. The simulation provides the data to calculate the integrated absolute error (IAE) between the SP and PV for each case. With the IAE for each case, a comparison can be made. The ExperTune Index is:

$$100 \times \frac{Current\ IAE - Optimal\ IAE}{Current\ IAE}$$

With the ExperTune Index:

0 = Perfect control
Larger than 0 = Percentage of performance improvement possible

The metric is unitless and provides a meaningful comparison between loops. This metric will catch loops that have been detuned (Neles ExperTune/Plant Triage software) [11].

1.4.2 Loop Nonlinearities and Dead Time: The Bad Guys

PID control is the most widely used control algorithm in process control loops. Although there are many techniques for tuning the PID settings (which are beyond the scope of this guide), the best response to process upsets is a basic underlying assumption that the process response is approximately linear with little change in installed or process gain and minimal dead time. The more nonlinearities and dead time that creep into a loop, the more the loop must be detuned and thus may not be able to meet your objectives.

Nonlinearities and dead time can even cause a loop to amplify the disturbances so that control is worse in automatic than it would be in manual! Being able to identify and fix or minimize nonlinearities and dead time is paramount to loop performance.

From a design standpoint, minimizing nonlinearities and dead time is desired prior to the loop checking process, but you should also be aware of other sources. For example, control valves introduce friction, backlash, shaft windup, and relay dead zones; transmitters can have damping filter and sample time issues; and the control system can introduce filter and control strategy nonlinearities. To help minimize these problems, purchase high-performance valves, positioners, and transmitters, and then utilize maintenance programs to sustain the performance over time.

Control valve sizing and selection can also greatly affect the overall loop linearity. As mentioned previously, we want the overall response of the process—that is, when the valve moves and the process responds—to be as linear and as constant a gain as possible over the operating range. This overall process response is called the *installed characteristic* of the loop. The importance of installed gain is illustrated in the pump and system A curve in Figure 1.10. As the flow through the system increases, the pump outlet pressure, or head, drops off, and the system losses through pipe

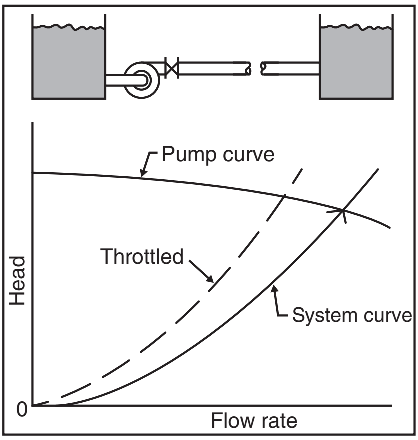

Figure 1.10 Pump and system A curve.

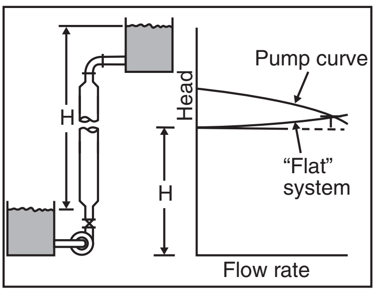

Figure 1.11 Pump and system B curve.

tees, elbows, check valves, and so on increase [12]. The throttling control valve absorbs the difference between the two pressures. Notice the difference in the pump and system B curve shown in Figure 1.11. The pressure drop does not change as much as it does in system A.

So, how do you select valves to handle these varying pump and system applications and still provide a linear response for the PID loop? The control valve trim (the internal parts of the valve that control the flow passage—e.g., the plug, seat ring, and cage) is engineered to fit the application by shaping the plug or cage windows to provide the *inherent characteristic*. It is important to select the trim with the inherent characteristic that best linearizes the pump and system curve. Most valve vendors develop a table or curve by testing each valve that shows the flow resulting from valve movement with a constant pressure drop. The three most common inherent characteristics are equal percentage, linear, and quick opening (see Figure 1.12).

Let's see how this works. For the pump and system A curve, where the throttling pressure drop across the valve decreases as flow increases, selecting an equal percentage inherent characteristic would be best because the increasing flow area of the valve cancels out the reduction in pressure drop. The net result is that the installed characteristic becomes more of a linear response for the range of flow conditions—good news for the PID loop and the chance to tune for tight control. Similarly, for a header pressure control example, the inlet and outlet pressures do not change much over the flowing range. Therefore, a linear inherent characteristic would be the best choice.

You're not out of the woods yet. Even though you know the inherent valve characteristic, you must also consider valve type (e.g., rotary and sliding stem) to get the true picture of what you're up against for loop checking.

For example, in Figure 1.13, a butterfly-style valve is tested in a flow loop for the installed gain the loop will experience. Notice that only a small opening (from about 20–40°) provides a linear

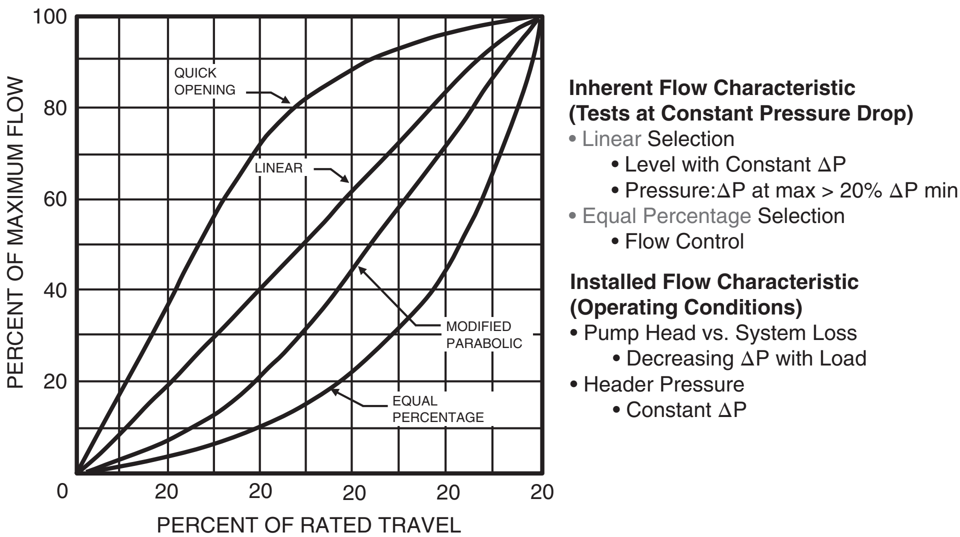

Figure 1.12 Control valve inherent characteristics.

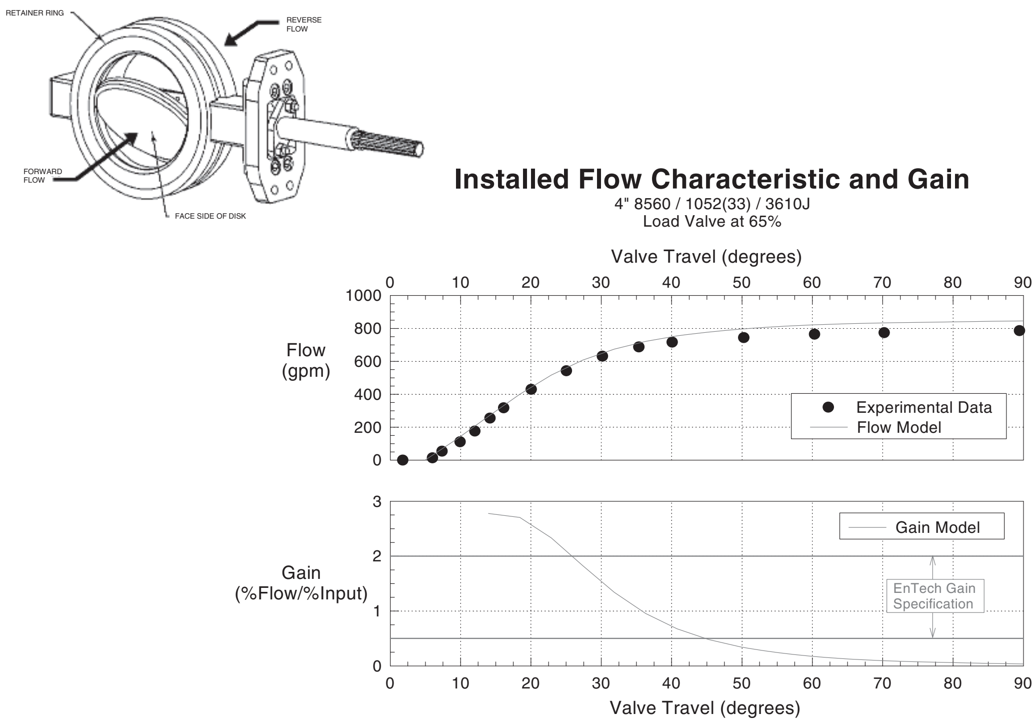

Figure 1.13 Butterfly valve installed gain.

response with a process gain within a desired range (called the *EnTech Gain Specification*). Compare this to Figure 1.14 for a sliding stem control valve, which shows that the gain is within spec over a wider operating range. Looking at the valve constructions and flow paths, you can see why the butterfly valve has the narrower range.

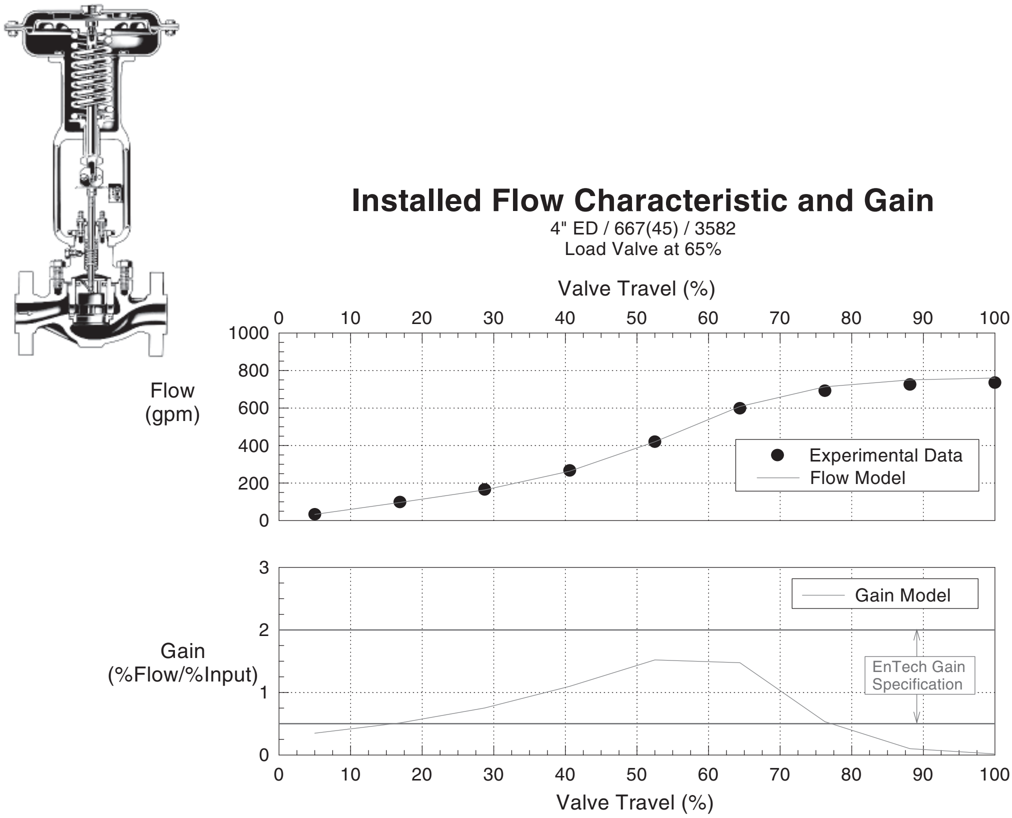

Figure 1.14 Sliding stem valve installed gain.

Now you can see why an oversized valve (either the butterfly or sliding stem) trying to throttle at low valve travel will not perform very well. Also, you can see why there is a significant difference in what the top-end control point should be. Imagine trying to tune the loop with a butterfly valve that must operate near 70° open for one product and 30° open for another—probably job security for those who tune loops. Table 1.3 summarizes the different styles of control valves and approximate control ranges for the standardized test conditions shown in Figures 1.13 and 1.14. Note that many things impact the control range (e.g., pressure drop across the valve versus line drop, the hydraulic configuration of the process, and the amount of static pressure in the system), but the examples in Figures 1.13 and 1.14 are included to emphasize valve style considerations. Workarounds such as output signal characterization can ease some of the installed curve

Table 1.3 Valve type—control range summary.

Style	Control Range (% of Travel)
Globe/Sliding Stem	60
Vee-ball/Rotary	55
Eccentric Ball/Rotary	38
Butterfly	22

nonlinearities or gain scheduling in the controller. However, spending the time and money to install the correct size and style valve will provide the best solution for loop checking performance.

1.5 Control Loop Design Guidelines

This section summarizes 11 guidelines engineers and technicians should consider when designing, implementing, checking, and benchmarking control loops [3]. These guidelines are based on the philosophy that control systems should minimize product variability and improve the overall efficiency of an operation. Engineers and technicians should also follow instrument and control system manufacturers' installation and maintenance guidelines. We recommend the following guidelines from Bialkowski [3]:

1) Dead time or time delay seen by the control loop should be minimized wherever possible. This means that (a) measurement devices should be located as close as practically possible to the final control element without affecting their measurement characteristics; (b) long instrument tubing runs should be avoided; (c) transmitters with long processing delays should be avoided, and so on.
2) Process transport delay should be minimized.
3) Control devices (valves, air motors, damper drives, etc.) should exhibit repeatable dynamics with minimal nonlinearities over the process's complete operating range. Their speed of response should be reasonable for the application.
4) The control loop's installed process gain from the control device to the measurement device should nominally be about 1% span/% output over the process's complete operating range. Process gains in the range of 0.5–2.0% span/% output are acceptable.
5) Filtering the control loop measurement should be kept to a minimum. A first-order filter should be at least 5–10 times less than the closed-loop time constant of the loop.
6) Generally, linear control algorithms (and possibly loop output characterizers for installed linear response) should be used. Control loop nonlinearity correction functions, such as control dead bands, error dead bands, nonlinear gains, error characterization, and the like, should be considered in special cases.
7) In applications where several processes or loops can interact, the control loop should be tuned using non-oscillatory tuning techniques.
8) Process areas should be tuned in a coordinated manner to minimize loop interaction and disturbances to processes that rely on ratioing ingredients or raw materials.
9) The control loop should be stable over the process's complete operating range.
10) The outer primary loop of a cascaded loop structure should be tuned 5–10 times slower than the inner secondary loop.
11) The less critical loop of a set of interacting loops should be tuned 5–10 times slower than the more critical loop.

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Review Questions

1.1 Why would a loop checking program be important to the plant manager/profit center manager? The project manager/engineer? The control system technician? The process engineer?

1.2 The typical plant can realize the best return on investment by implementing which of the following programs?
a) Advanced control packages
b) Process design improvements
c) Field device performance and loop tuning
d) Process data access and trending

1.3 What are the basic elements of the control loop? Which loop element would be most susceptible to long-term performance degradation and thus a candidate for specific device monitoring?

1.4 When does the loop checking process start? When does it end?