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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 higher-level "Advanced Process Control (APC)" program (Ref. 6). Thus, it is critical that these facilities' technicians 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 as in the traditional definition. Loop checking is also an important component in any plant's continuous improvement planning program insofar as it helps define and reduce the variability of key process parameters on an ongoing basis.

The chapters of *Loop Checking: A Technician's Guide* are arranged to follow a typical automation project from design checkout at the factory acceptance test (FAT) through to an ongoing sustaining loop performance program. The steps of such projects is as follows:

- loop checking basics
- the factory acceptance test (FAT)
- start-up
- performance benchmarking
- sustaining the performance

This guide is intended to discuss general methods and practices that can be applied across many processes or industries. The technician will encounter different plans and programs in his or her own company for addressing loop performance. These will, of course, affect how loop checking is defined and accomplished for the technician's specific environment. However, the instrument technician typically has the best overall knowledge and skills for checking and maintaining control loop performance.

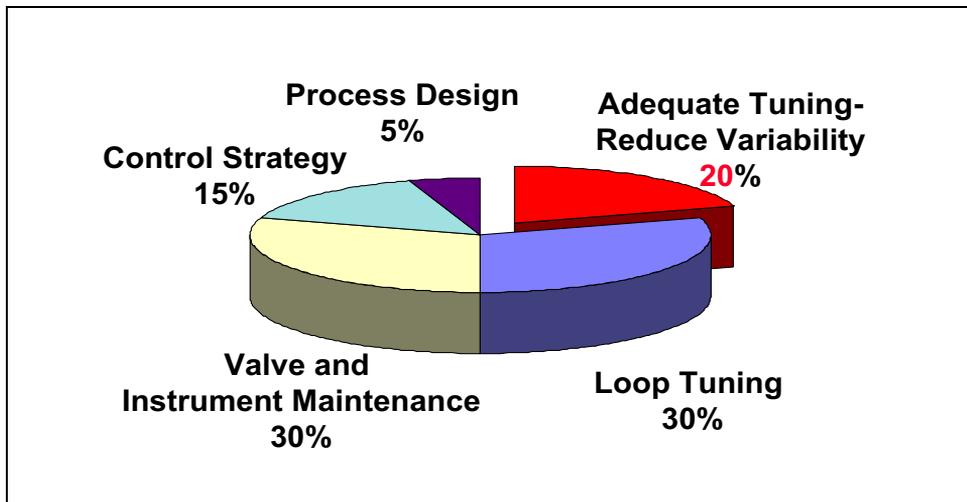
1.1 THE OPPORTUNITY

In today's intensely competitive markets, manufacturers are striving 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

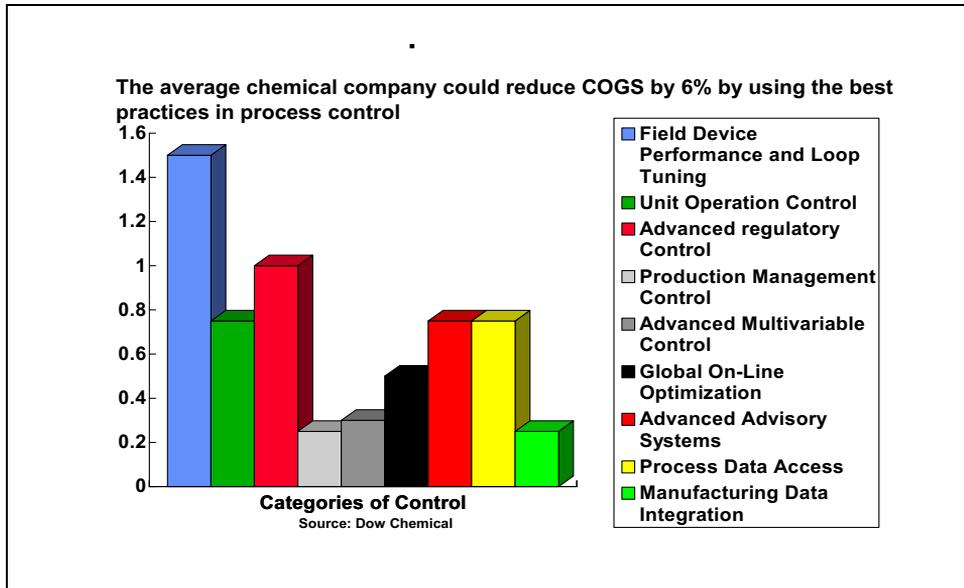
As we noted, the control loop (and the continual checking of performance) plays a vital role in the plant's financial performance. However, it has been observed that up to 80 percent of all loops are not performing their intended function of reducing the variability that results from the problems caused by the factors shown in Figure 1-1. Such issues as measurement placement and the dead time or process mixing it causes, undersized headers and valves, loop tuning, and control strategy, all affect the loop's ability to accomplish the desired objectives.

FIGURE 1-1
Control Loop Performance Issues



In addition, plant performance studies (such as those summarized in Figure 1-2) have shown that the largest opportunity for reducing costs (1.5%) is provided by field device performance and loop tuning, where loop checking methods can be applied.

FIGURE 1-2
Process Improvement Opportunities



The Control System Technician (CST) can become involved in the performance of the plant's control loops, from the control implementation stage through to the checkout phase and then continuing 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.

Defining the Loop

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

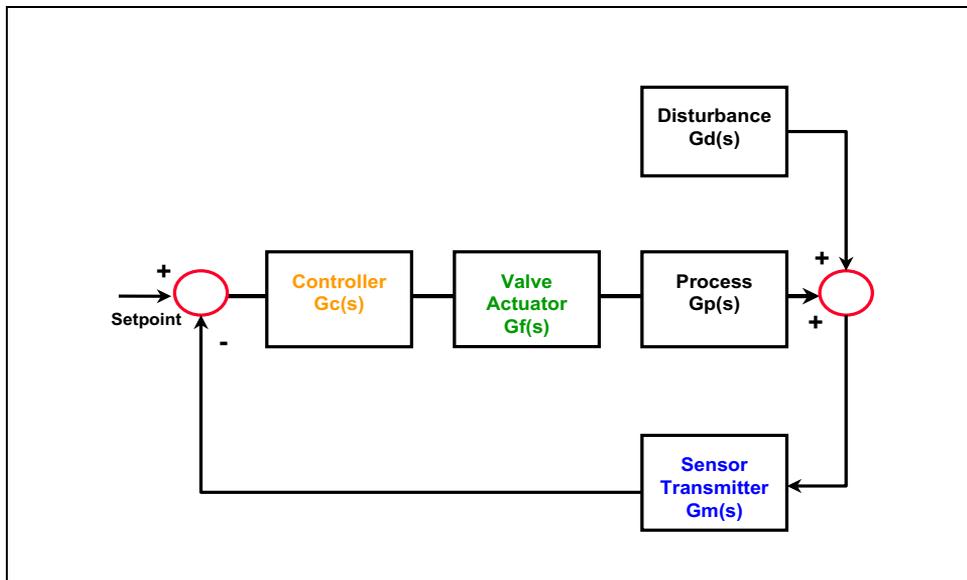
- to force the process to perform in a predetermined, desirable manner. The process may be a flow, pressure, temperature, level, or some other variable in the manufacturing plant (Ref. 3).
- to adapt automatic regulatory procedures to the more efficient manufacture of products or processing of material (Ref. 4).
- to ensure safety, environmental regulation, and profit (Ref. 5).

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, that is, the set point (SP), and acts on the difference between SP and PV (error) using a control algorithm (typically PID). The loop then outputs to the final control element. The diagrams below indicate that the main elements of the loop are:

- transmitter/sensor (for measuring the PV)
- process controller (with an operator-entered SP and control algorithm)
- final control element (valve/actuator and accessories)

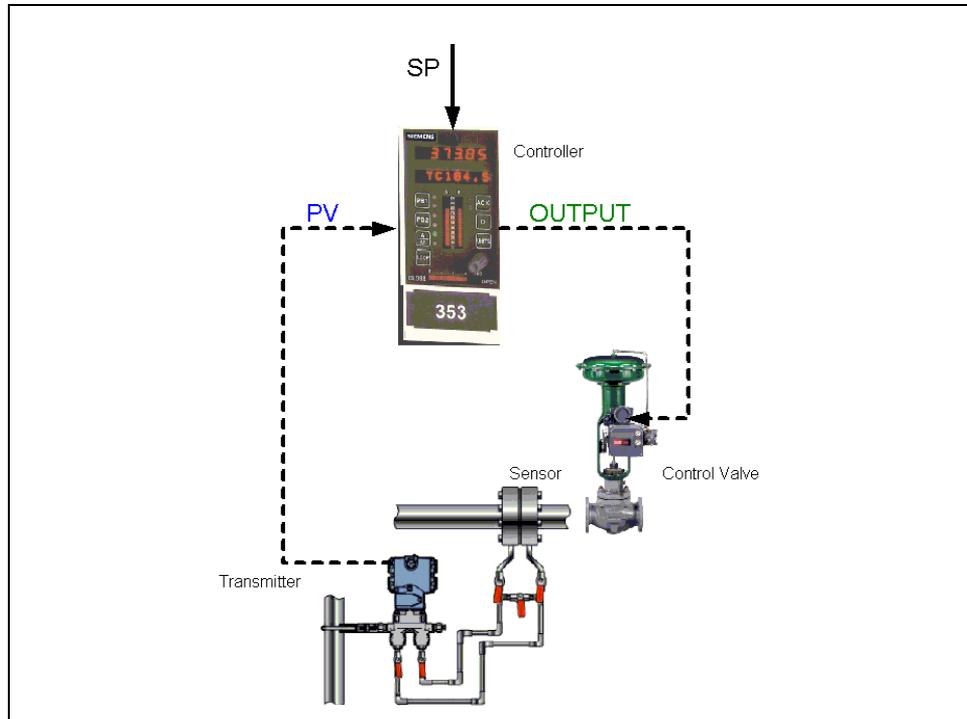
Control system engineers use the block diagram in Figure 1-3 to show the relationships of the control loop elements.

FIGURE 1-3
Feedback Loop Block Diagram



In a more practical view, the block diagram looks like Figure 1-4 below when depicted with hardware for measurement, controller and final control element functions.

FIGURE 1-4
Control Loop



For the purposes of this guide, we'll focus on the single input, single output control loop as depicted in Figures 1-3 and 1-4.

Elements of the Loop

Let's discuss each element in the loop. Although several chapters could be dedicated to each element of the loop (a good resource is Reference 1), we will try to keep the discussion brief and highlight important features for our expanded definition of loop checking, which includes performance.

Sensor / Transmitter

The loop starts here and cannot do a good job unless the measurement is accurate, reproducible (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 and is a better number for control and measurement evaluations – see Reference 6). Total Probable Error is another important performance specification that you may use for comparison purposes. Measurement resolution of the signal within the control system is usually not an issue with today's control

systems I/O design, but if you configure the loop for large spans (watch for temperature loops), then small changes can go undetected. Of course, proper selection and installation of the sensor and transmitter is critical based on service conditions, accuracy, reproducibility, stability, reliability, and other plant standards. Deadtime and noise introduced by measurement installation location can really hurt the loop performance (the typical controller, proportional, integral and derivative [PID] does not handle deadtime 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 deadtime, while a sensor installed near the valve outlet instead of upstream of the valve will have excessive noise.

Controller

The controller compares the transmitter measurement (PV) to the operator-entered set point (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 be aware of the type PID algorithm that your plant's control system manufacturer has implemented. The two (2) common types are called "classic" and "non-interacting" (Ref. 5). Others have called them "series" and "parallel". There is a difference in how you tune the loop with these two types of controllers. If your plant has just one control system, then your plant standard tuning methods can be used without worrying about this difference. However, as plant purchases come from different vendors/OEM's, different control system types are employed (e.g., programmable logic controller [PLC] vs. distributed control system [DCS]). You need to pay attention when tuning the different controllers to make sure the right tuning methods are applied. The microprocessor-based systems have also introduced us to configurable loop scan (execution) times, which can also be critical to loop performance. You'll want to make sure your controller is executing fast enough for the process dynamics. Table 1-1 suggests a starting point for some typical measurement types.

Final Control Element

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

TABLE 1-1.
Typical Scan Times

MEASUREMENT TYPE	SCAN RATE RANGE (SEC)
Pressure	0.25 – 2.0s
Flow	0.25 – 2.0s
Temperature	1.0 – 15.0s
Level	1.0 – 5.0s
Conductivity	0.5 – 2.0s
Consistency	1.0s
Analyzer (gas)	1.0s
pH	0.25 – 5.0s
Average Torque	0.5 – 1.0s
Speed	0.25 – 1.0s
Current and Other Electrical Measurements	1.0s
Analog Output	1.0s

controls, but the most 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), converts the electronic signal to a pneumatic signal that must then drive an actuating device to a precise location. We'll talk more about valve and loop performance in later chapters but you'll be hard pressed to beat a sliding stem valve with spring-and-diaphragm actuator and a two-stage positioner for performance. In addition to the controller performance enemies of deadtime and noise mentioned previously, the valve could also introduce non-linearities and deadband into the loop – neither of which is good for the PID controller. In receiving an electronic signal and converting it to a valve plug/ball/disk position in the pipe, various sources of non-linearity and deadband can build up. Friction from seals and packing, backlash of mechanical parts, relay dead zones, shaft windup can keep the valve from maintaining the signal required by the control system. Proper valve sizing and selection of valve characteristic can help linearize the flow response to controller output changes – again very important to how the PID can perform.

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 basics apply to verify the input/control and design/output of the loop.

In some plants, the term “loop” may also include other control system functions such as Analog Indicate Only, Motor Start/Stops, On-off Valves, Discrete Input/Output type control functions. A detailed discussion of these functions is not included in this guide although you could easily expand the methods and techniques to include them in your plant’s loop check plan.

There are several excellent resources that go into more depth on each of the elements of the loop. Vendor literature and application papers are good sources of information as are a variety of industry publications (e.g., ISA, TAPPI, etc. – Ref. 5 and 6).

Loop Checking

Some think of loop checking as a process to confirm that the components of the loop are wired correctly and is typically something done prior to start-up. However, due to factors described in the introduction above, the loop check’s scope has expanded to also include tests to confirm that it is “operating as designed” and then to ongoing programs for benchmarking and monitoring performance. The block diagram in Figure 1-5 illustrates the components of this expanded loop checking process.

This process starts when the instruments are received at the plant site. It continues through installation and start-up and into the ongoing plant operation. In addition, the control system should perform the intended function properly. This includes verifying the transmitter’s process variable (PV) for display to the operator, for use in the control strategy, and for historical trending. This verification testing prior to start-up is known as the factory acceptance test (FAT) which, as an option, can be duplicated at site with the actual hardware and software installed, termed site acceptance test (SAT). Further discussed in Chapter 2, the FAT can be performed prior to shipment of the hardware or in parallel with the hardware installation at site if the overall start-up schedule is compressed.

Once the technician checks the control strategy to verify that the expected output to the final control element is produced, the loop can then 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.