

# Preface

This book gave me a chance to get back to my instrumentation roots. I spent the first seven years of my career in the field as an instrument design and construction engineer. I was responsible for the calibration, installation, and commissioning of instruments for a half-dozen plants, where I became painfully aware that the actual performance of the process measurements and control valves (the most prevalent type of final element) was largely unknown. These were the days before the advent of smart instrumentation. We didn't know the effects of stiction and backlash on control valves or the effects of impulse line, process, and ambient conditions on measurements. We didn't know the performance of measurements and control valves that were installed in industrial plants greatly differed from catalog information. We shifted set points and just shook our heads when the material and energy balances did not close. At the time the plants could sell everything produced. Since we were mostly interested in capacity we just pushed on to make more product. Operating efficiency and turndown were not a primary concern, which was fortunate because we didn't have the speed of response and accuracy of "today's" instrumentation needed for measuring and improving process performance and tracking down valve problems.

I then moved into engineering technology where I had the chance to develop an expertise in solving difficult problems in particularly challenging loops. I spent most of the 1980s working on pH, furnace pressure, and compressor surge loops, which were the ultimate test of measurement and valve performance.

My perspective on the importance of field devices was solidified in the 1990s, when I was part of a corporate-wide process control improvement program. Most of the opportunities involved tuning control loops and adding feedforward control for continuous processes and feedback loops for fed-batch operations. However, a lot of great ideas "fell by the wayside" because of missing or imprecise measurements and inadequately responsive valves.

An important point in process control improvement is that if you don't have a way to determine the capability and benefits of a proposed automation system, projects will tend toward the lowest-cost alternatives. The biggest mistakes I made as lead engineer in the 1970s were traced back to misguided attempts for

project cost savings suggested by a super experienced instrument engineer at the contract design firm, who otherwise did a great job. My most memorable mistake was not putting positioners (valve position controllers) on all control valves to save about \$500 per valve. Many of the valves without positioners didn't move until the controller output was greater than 25%. A more insidious example of capital cost taking priority over performance was the proliferation from the 1970s to the 1990s of relatively inexpensive rotary piping valves that were promoted and used as throttling valves by the addition of spool-type valve positioners on actuators, linkages, and shaft connections that had been designed for on-off service, not for throttling. The complete assembly including the high friction valve design was fundamentally wrong for regulating a flow. The leakage specs and price were attractive. Deadband (backlash) and resolution (stiction) were not considered. Since the valve specification didn't require the valve to actually move in response to the small changes in signal commonly typically incurred in a control loop, there was no valve shaft position feedback measurement, and field tests typically involved visual observation of valve shaft movement for changes in output of 25% or larger, the user did not know the real price paid for the use of this type of valve. Aggravated by noisy flow measurements with poor turndown, increased process variability was attributed to mysterious sources. Without online loop metrics, there was little recognition of the deterioration in loop performance resulting from the use of these piping valves.

Putting a smart positioner on a rotary piping valve with the feedback measurement at the actuator shaft rather than sensing ball or disk stem position only added to the confusion. The actuator shaft would move in response to the positioner but the ball or disk would not respond in proportion due to extensive seal friction, twisting (windup) of the ball or disk shaft, and backlash in the connections and linkages. It was only after actual tests in the flow labs of control valve manufacturers was the true cost of using piping valves recognized. The publication of the lab test results and the subsequent ISA standards developed on valve step testing, the availability of position feedback as a secondary process variable on digital signals, and the analysis of resolution and deadband led to increased awareness of valve response and dramatic improvement in valve dynamics.

The awareness of the importance of measurement and valve performance gained during these career experiences as a user in a major chemical and life science company led to a greater appreciation of recent advances.

Today we have smart transmitters and true control valves with rangeability, resolution, and sensitivity that are an order of magnitude better than the typical fare of the last century. A combination of embedded intelligence and new sensor,

transmitter, valve, and positioner technology has resulted in dramatic improvements to measurements and valves. Combined with the ability to have additional process variables, diagnostics, and alerts reported to the control room by digital signals and the mobility afforded by wireless communication, we can increase the spectrum of applications and the utility of the field automation system including finding the optimum locations for process measurement and control. Doors are opening for online data analytics, process performance metrics (e.g., energy, quality, and yield) and new opportunities for basic and advanced control improvements to address the increasing need for greater efficiency, flexibility, and rangeability of processes.

It was recently realized that research and development could also greatly benefit from the advanced performance, intelligence, and historization capabilities of smart industrial automation systems. The future is best exemplified by the lab-optimized industrial distributed control systems with pH, dissolved oxygen, pressure, temperature, and mass flow measurements for benchtop and pilot plant bioreactors described in Chapter 1 that were pioneered by Broadley-James Corporation. The addition of wireless instrumentation to these systems increases the already significant advantages of moving advanced industrial automation capability upstream in the commercialization process.

This book makes no assumptions about prior knowledge beyond that the reader has some technical background. In Chapter 1, Modern Measurement Fundamentals, special care has been taken to explain technical terms and concepts relating to the use and performance of measurements in the process industry. There is special emphasis on the advances in smart instrumentation and wireless communication. Chapters 2 through 6 focus on the details needed for the best implementation of the specific types of measurements that would be used today on automation upgrade and new plant projects in the process industry. Chapter 7 on Final Element Fundamentals follows an approach similar to that of Chapter 1 in assuming no industrial experience; the material on control valves, dampers, guide vanes, and variable speed drives will be beneficial to students and new employees. Chapter 8 gets into the details of the types of control valves that are used in 95% of the applications in the chemical and petrochemical industry. The book concludes with the latest details on WirelessHART automation systems in Chapter 9. The questions at the end of each chapter are designed to stimulate the thought processes needed for a successful application.

The foundation of a process automation system is the measurements and final elements. If you don't get this right, not much else matters. Measurements provide the only window into the process and final elements provide the only means of

affecting the process. The degree of process control improvement from increasingly advanced layers of process analysis and control depends upon the integrity and breadth of the foundation. The goal of this book is to create a foundation where imagination is the limit for automation.