SECTION 1
INTRODUCTORY REVIEW

G. McMillan

From the mid-1970s to the mid-1990s, the hiring of engineers and technicians dwindled to new lows. Technical training was replaced with management training programs. Fast-track employees aspired to be managers rather than technical leaders. This, combined with the early retirement of most of the experienced engineers and technicians, led to a huge gap in age and experience in the area of process/industrial instrumentation and control. Companies have attempted to replenish their technical capability in the past few years, but the new hires are typically not given a mentor, access to a technical training program, and technical support. Nor are they given time to develop their skills on projects of incremental complexity. Often they are thrown immediately into some very difficult situations.

To help address this new need, the emphasis of the new material in the handbook has shifted from operating principles to application guidance. New features and process conditions that are important considerations for successful installations are discussed. Selection ratings, key points, and rules of thumb are offered. This update provides the reader with a perspective and appreciation for what is important for implementation from authors with decades of experience.

Plants have also suffered from neglect. In attempt to improve the return on equity, capital was not made available to replace old equipment. Meantime, the surge in the economy means plants are running at 200% or more of name-plate capacity. As a result, equipment is pushed beyond its normal operating region. This has increased the benefits from process control improvement to get the most out of a plant. Section 10 has been added to provide a comprehensive treatment of this important opportunity.

The biggest news, of course, is the move to smart instrumentation, the Windows NT platform, and Fieldbus. Distributed Control Systems and Field-Based Systems in Section 3, Knowledge-Based Operator Training in Section 8, Instrument Maintenance Cost Reduction in Section 10, and an Overview of the ISA/IEC Fieldbus Standard in Section 11 provide information essential to get the most out of these major shifts in technology.

Finally, standards have been recently developed to address safety, batch operation, and Fieldbus. Section 11 has been added to provide an overview of the important aspects of these new standards by authors who have played a key role in their development.

This handbook has been designed for the practitioner who needs to apply instrumentation and control systems in industry. The following is a walk-through of the technical articles.

SECTION 2: CONTROL SYSTEM FUNDAMENTALS

Control Principles

As was observed by readers of earlier editions, this has been one of the most widely used articles in this handbook. This article is intended not only for individual study, but also for use by groups of scholars in college, technical school, and in-plant training programs. The article commences with the nontheoretical analysis of a typical process or machine control system. Discussed are process reaction curves, transfer functions, control modes, and single-capacity and multicapacity processes—relating control characteristics with controller selection.

Techniques for Process Control

This article reviews from both the practical and the theoretical viewpoints the numerous advancements achieved in solving difficult control problems and in improving the performance of control systems where fractional gains in response and accuracy can be translated into major gains in yield and productivity. This article is the logical next step for the instrumentation and control engineer who understands the fundamentals of control, but who desires to approach this complex subject in a well-organized mathematical and theorectical manner. When astutely applied, this advanced knowledge translates into very practical solutions. The author proceeds in an orderly manner to describe state-space representation, transfer-operator representation, the mathematics of open-loop, feedback, feedforward, and multiple-loop control, followed by disturbance representation, modeling, the algebraics of PID (proportional-integral-derivative) design, adaptive control, pattern recognition, and expert systems. The techniques of least squares, batch parameters, the Kalman filter, recursive parameter identification, and projection also are described.

Basic Control Algorithms

Continuous process control and its counterpart in discrete-piece manufacturing control systems traditionally were developed on an analog base. Experience over the past few decades has shown that digital control provides many advantages over analog systems, including greater flexibility to create and change designs on line, a wider range of control functions, and newer functions, such as adaptation. But digital computation is not naturally continuous like the analog controller. The digital approach requires sophisticated support software.

This article addresses the basic issues of carrying out continuous control in the digital environment, emphasizing the characteristics that must be addressed in the design of operationally natural control algorithms. The author describes number systems and basic arithmetic approaches to algorithm design, including fixed-point and floating-point formats. Lag, lead/lag, and dead-time calculations required in the development of a basic control algorithm are presented. Also included are descriptions of quantization and saturation effects, the identification and matrix-oriented issues, and software and application issues. A closing appendix details the generalized floating-point normalization function.

Safety in Instrumentation and Control Systems

Never to be taken lightly are those features that must be engineered into control systems on behalf of protecting plant personnel and plant investment, and to meet legal and insurance standards. This is a major factor of concern to users and suppliers alike. Even with efforts made toward safety design perfection, accidents can happen.

The author of this article carefully defines the past actions and standards that have been set up by such organizations as the International Electrotechnical Commission (IEC). He gives descriptions of numerous techniques used to reduce explosion hazards, including design for intrinsic safety, the use of explosionproof housings, encapsulation, sealing, and pressurization systems. Obtaining certification approval by suppliers and users of intrinsically safe designs is discussed in some detail, along with factors pertaining to the installation of such equipment.

SECTION 3: CONTROLLERS

Distributed Control Systems

This article traces the evolution of the distributed control system (DCS). It provides an interesting perspective of how concerns and demands have been addressed. Of particular importance is the discussion of how the DCS is meeting the needs to be open and to take advantage of new market trends. The advantages of interfacing third-party software for advanced applications such as expert systems and production management control is highlighted. The effects of Fieldbus, Windows NT, and the Internet are analyzed. Finally, a comprehensive list of DCS selection criteria is offered to help the user make the most complex and far-reaching decisions in instrumentation and process control in that it sets the ease and degree of automation, maintenance, and operability of the plant.

Programmable Controllers

The author provides a perspective of the criteria for making the many choices of architecture, software, and hardware. The tables of the choices of networks and input/output (I/O) outline the essential issues. The discussion of controller size, modularity, and distribution addresses the key questions for any application. The article also provides a balanced view of alternatives such as PC-based soft control. Both the user and the supplier will benefit from this treatment of this important component of discrete manufacturing, safety interlock, and sequential control systems:

Stand-Alone Controllers

The continuing impressive role of these controllers, particularly in non-CIM environments, is emphasized. Descriptions include revamped and modernized versions of these decades-old workhorses. A potpourri of currently available stand-alone controllers is included, with emphasis on new features, such as self-tuning and diagnosis, in addition to design conformation with European DIN (Deutsche Industrie Norm) standards.

Hydraulic Controllers

The important niche for powerful hydraulic methods continues to exist in the industrial control field. The principles, which were established decades ago, are described, including jet pipe, flapper, spool, and two-stage valves. Contemporary servo valves are discussed. Hydraulic fluids, power considerations, and the selection criteria for servo or proportional valves are outlined. A tabular summary of the relative advantages and limitations of various hydraulic fluids, including the newer polyol esters, is included.

Batch Process Control

During the past few years much attention has been directed toward a better understanding of the dynamics of batch processes in an effort to achieve greater automation by applying advanced control knowledge gained from experience with continuous process controls and computers. This has proved to be more difficult and to require more time than had been anticipated. Standards organizations, such as the Instrument Society of America, continue to work up standards for a batch control model. In this article an attempt has been made to cut through some of the complexities and to concentrate on the basics rather than on the most complex model one can envision. Batching nomenclature is detailed, and definitions of the batch process are given in simplified, understandable terms. To distinguish among the many methods available for accomplishing batch control, a tabular summary of process types versus such factors as duration of process, size of lot or run, labor content, process efficiency, and the input/output system is given. Interfacing with distributed control system and overall networking are considered.

Automatic Blending Systems

Although the need to blend various ingredients in pots and crocks dates back to antiquity, contemporary blending systems are indeed quite sophisticated. The author contracts the control needs for batch versus continuous blending. A typical blend configuration is diagrammed in detail. Some of the detailed topical elements presented include liquid or powder blending, blending system sizing, blend controllers, stations, and master blend control systems. The application of automatic rate control, time control, and temperature compensation is delineated.

Distributed Numerical Control and Networking

An expert in the field redefines numerical control (NC) in the contemporary terms of distributed numerical control (DNC), tracing the developments that have occured since the days of paper-tape controlled machines. The elements of the basic DNC configuration are detailed in terms of application and functionality. Much stress is given to behind-the-tape readers (BTRs). The numerous additional features that have been brought to NC by sophisticated electronic and computer technology are described. The tactical advantages of the *new* NC are delineated. The manner in which numerical control can operate in a distributed personal computer (PC) network environment is outlined. UNIX-based networks, open architectures, and the Novell networks, for example, are described

Computers and Controls

This article, a compilation by several experts, commences by tracing the early developments of the main-frame computer, the 1960–1970 era of direct digital control (DDC), up to the contemporary period of personal computers (PCs) and distributed control system (DCs). Inasmuch as there is another article in this handbook on DCSs, primary attention in the article is on PCs. The basic PC is described in considerable detail, including its early acceptance, its major components (microprocessor, memory, power supply, keyboard, and I/O). The advantages and limitations of the PC's "connectability" in all directions, including networks, are discussed. Internal and external bus products are compared. PC software is discussed, with examples of specific languages and approaches. Software control techniques are presented in some detail. Progressive enhancement of the PC toward making it more applicable to process and factory floor needs is reviewed. In consideration of the fact that minicomputers and mainframe computers enter into some control situations, a few basic computer definitions are included in the form of an alphabetical glossary. This is not intended as a substitute for a basic text on computers, but is included as a convenient tutorial.

Manufacturing Message Specification

This article provides a detailed look into the structure and importance of an international standard for exchanging real-time data and supervisory control information among networked devices in a manner that is independent of the application function and the developer. The standard provides a rich set of services for peer-to-peer real-time communications over a network for many common control devices such as programmable logic controllers (PLCs), robots, remote terminal units (RTUs), energy management systems, intelligent electronic devices, and computers. The rigorous yet generic application services provide a level of interoperability, independence, and data access that minimizes the life-cycle cost (building, using, and maintaining) of automation systems.

Field-Based Systems

The concept and advantages of a field-based system are introduced. The importance of maximizing the utility of Fieldbus and the explosive trend of adding more and more intelligence in the field devices is emphasized by the citation of impressive benefits from the reduction in wiring, termination, calibration, configuration, commissioning, and maintenance costs. It is also apparent that since the field-based system uses the same graphical configuration and instruction set as foundation Fieldbus, the user can focus more on the application and make the location of functionality transparent. The embedding of more advanced functionality, such as self-tuning into the controller as a standard feature, promotes the integrity and use of these techniques. The process simulation links open up the possibility of knowledge-based training systems (see Section 8) and OPC connectivity enables value-added applications of third-party software.

SECTION 4: PROCESS VARIABLES—FIELD INSTRUMENTATION

Temperature Systems

Commencing with definitions of temperature and temperature scales and a very convenient chart of temperature equivalents, the article proceeds to review the important temperature measurement methodologies, such as thermocouples and resistance temperature detectors (RTDs), with a convenient tabular summary of each for selection purposes. Smart temperature transducers are illustrated and described. Other temperature measurement methods described include thermistors, solid-state temperature sensors, radiation thermometers, fiber-optic temperature sensors, acoustic pyrometers, and filled-system thermometers.

Pressure Systems

This article has been updated to reflect the use of ceramic differential-pressure transmitters and diaphragm seals. These are important topics since the proper application of these close-coupled ceramic d/ps, digital heads, or diaphragm seals can eliminate the installation of sensing lines, which are the source of most maintenance problems.

Flow Systems

The author provides an easy-to-read view of what is important to ensure the proper selection and installation of flow meters. The reader should appreciate the clear and concise comparison of the major types of in-line meters. The application matrix serves as a vital reference of performance parameters. From the discussion of how fluid conditions affect meters, the user realizes that the many supposed mass flow meters recently touted in the literature, such as temperature- and/or pressure-corrected pitot tubes, positive displacement (PD) pumps, vortex meters, magmeters, and thermal mass flow meters, are dependent on some stringent assumptions. These meters that compute mass flow from several measurements are based on a constant known composition, a user-defined equation between density, viscosity, and/or heat capacity and temperature and/or pressure, and a fixed velocity profile, except for the PD pump. Only the Coriolis mass flow meter is independent of the process fluid and velocity profile.

Level Systems

The author provides a good perspective of the effect of process conditions on the performance of level measurements. It becomes apparent that the only continuous level measurements essentially independent of the process fluid are radar measurements and floats since they detect the surface. Ultrasonic measurements also detect the surface but are affected by dust and the composition of the vapor. Hence a lot of discussion is devoted to the application and the installation of surface detection devices. Level measurements that use differential pressure or Nuclear devices are greatly affected by fluid density and hence on both fluid temperature and composition unless a second completely submersed measurement is used to compute density. Capacitance probes with coating rejection are affected by the dielectric constant unless a second completely submersed probe is used to measure the dielectric constant.

Industrial Weighing and Density Systems

Strain-gauge and pneumatic load cells for weighing various hopper and tank vessels as may be used in batching systems are described, as well as a microprocessor-based automatic drumfilling scale. Numerous fluid-density measuring systems are reviewed, including the photoelectric hydrometer and the inductance bridge hydrometer. Specific-gravity sensors described include the balanced-flow vessel, the displacement meter, and the chain-balanced float gauge. Several density and specific-gravity scales are defined.

Humidity and Moisture Systems

This is the most well-organized and comprehensive yet concise treatment of these measurements that can be found in any handbook or journal. This extensive discussion of features, advantages, and limitations of a wide variety of devices should eliminate much of the confusion about choices and help make these important measurements more commonly used. Diverse applications are summarized.

SECTION 5: GEOMETRIC AND MOTION SENSORS

Basic Metrology

Of fundamental interest to the discrete-piece manufacturing industries, this article includes the very basic instrumental tools used for the determination of dimension, such as the interferometer, optical gratings, clinometer, sine bar, optical comparator, and positioning tables.

Metrology, Position, Displacement, Thickness, and Surface Texture Measurement

Described are the fundamentals of metrology and rotary and linear motion and the instrumental means used to measure and control it, such as various kinds of encoders, resolvers, linear variable differential transformers, linear potentiometric, and the new magnetostrictive linear displacement transducers. Noncontacting thickness gauges, including the nuclear, x-ray, and ultrasonic types, are described. The importance and measurement of surface texture are described.

Quality Control and Production Gaging

The fundamentals of statistical quality control (SQC) are presented with definitions of common cause, control limits, histogram, kurtosis, median, normal distribution, paretochart, skewness, special cause, and standard deviation. The reader should see world class manufacturing in Section 10 to see how statistical indices are used for quantifying process control improvements. This article also illustrates typical installations of impedance-type dimension gauges and provides numerous examples of the applications.

Object Detectors and Machine Vision

This article starts with a description of the principles and features of inductive, capacitive, ultrasonic, and photoelectric proximity sensors. This is followed by an introduction to machine vision technology with an emphasis on data patterns and image processing. It concludes with a discussion of discrete-piece identification and bar coding.

Flat Web (Sheet) On-Line Measurement and Control

This article discusses important benefits and application considerations of on-line measurement and control of sheet thickness in both the cross direction (CD) and the machine direction (MD). The advantages of new modular, smarter, and more open Windows NT-based systems are discussed. Simple equations to predict the speed requirement and limits of CD and MD measurements are presented along with important application aspects of advanced profile control and constrained multivariable predictive control and real-time optimization of the sheet line.

Speed, Velocity, and Acceleration Instrumentation

Following definitions of terms, the many kinds of tachometers available are presented, including dc, ac, voltage-responsive, variable-reluctance, photoelectric, and eddy-current. The tachometerless regulation of servo speed is described as are governors. Air and gas velocity measurements, including air-speed indicators and anemometers, are delineated. Vibration measurement and numerous kinds of accelerometers, including piezoelectric, piezoresistive, and servoaccelerometers, are described. Velocity transducers for sensing relative motion are discussed.

Vibration Measurements

Vibration measurements and numerous kinds of accelerometers are described. The signal conditioning of piezoelectric and piezoresistive accelerometers are explored in greater detail. The effect of environmental conditions such as temperature, cable motion, mounting compliance, dynamic strain inputs, and electrostatic and electromagnetic fields are discussed along with the selection and the installation implications.

SECTION 6: REAL-TIME ANALYTICAL COMPOSITION MEASUREMENTS FOR INPUT TO PROCESS CONTROL

Introduction

The opening remarks to this section present a unique insightful viewpoint that can be gained only from decades of experience in designing and installing analyzers and sample systems. The list of common mistakes and then the steps that can lead to improved performance provide much-needed words of wisdom. This is followed by a discussion of practical considerations and trends.

Concentration Measurement Technology and Devices

This article starts with a description of the features of thermal conductivity and gas-density detectors. Next, the application options and considerations of conductivity analyzers are outlined. This is followed by an in-depth look at several different devices. A comprehensive look at pH measurement details the theory and reality, electrodes, problems and causes, and best practices for measurement, installation, and maintenance. An extensive list of key points summarizes the essential concepts and the rules of thumb summarize the important recommendations for pH measurement. The treatment of turbidity and refractive-index measurements is similarly complete in scope, addressing aspects of design, installation, calibration, problems and application data. Next, the features and capabilities of ultraviolet/visible absorption analysis and ionization concentration transducers are discussed. The article also provides a brief overview of a myriad of other techniques.

Sample Extraction, Conditioning, Preparation for On-Line Analysis

The success of a non-in-line analyzer depends on its sample system. The sample must present the right information in a form that maximizes analyzer reliability. This article provides a practical and extensive compilation of the principles of sample handling and transfer for continuous sampling and the advantages and sample preparation and multidimensional manipulation techniques for discrete sampling. It concludes with valve and device configurations and the benefits of trap and transfer techniques.

System Control and Managing Data

An analyzer system is often like a miniature chemical plant. This article addresses the many issues involving the control and programming of the system, digital signal processing, information display, storage, communication, and housing.

Calibration and Validation

This article discusses the aspects of calibration and validation necessary to ensure that the required performance is met and maintained. Details are provided on standards and methods and the decisions based on statistical process control (SPC) charts. Several examples are used to illustrate the use of SPC. Included are concept, maintenance cost evaluation, and performance monitoring.

Application Examples

Actual industry examples drive home the essential ideas and fill in the missing details needed for practical applications. This article lists informative successful analyzer applications. The system design is outlined and the results are plotted.

SECTION 7: CONTROL COMMUNICATIONS

Data Signal Handling in Computerized Systems

Networking, whether simple or complex, cannot succeed unless the raw data fed to the network are reliable, accurate, and free from competing signals. The author defines signal types, termination panels, field signals and transducers, sampled data systems, analog input systems, analog outputs, and digital inputs and outputs. Stressed are signal conditioning of common inputs, such as from the thermocouples, solid-state temperature sensors, and resistance temperature detectors (RTDs). Amplifiers, common-mode rejection, multiplexers, filtering, analog signal scaling, and analog-to-digital and digital-to-analog converters are among the numerous topics covered and profusely illustrated.

Noise and Wiring in Data Signal Handling

The basic problems that a control engineer must seek to correct or avoid in the first place, including grounding and shielding, are delineated. Troubleshooting for noise is highlighted. A tabular troubleshooting guide is included.

Industrial Control Networks

Early networking and data highway concepts are described as a basis for understanding the many more recent concepts. Network protocols, including CSMA/CD, token bus, and token ring, are defined. Communication models and layers are defined as well as open systems and Fieldbus. The important more recent roles of fiber-optic cables and networks are described, including the characteristics of optical fibers or cables and light sources and detectors. Note that this topic appears also in several other articles of the handbook.

SECTION 8: OPERATOR INTERFACE

Operator Interface—Design Rationale

The basics of good design are brought to the process and machine operator interface. There are discussions of the fundamental factors that determine good interface design, including human, environmental, and aesthetic considerations. Graphics used in panels are described as well as visual displays. The role of color is included. The article ends with a discussion of interface standards and regulations, maintainability, and miniaturization.

Cognitive Skills and Process Control

The author reports on special studies of the operator interface from an industrial engineering standpoint and explores in particular the cognitive skills required of an operator.

Distributed Display Architecture

This article essentially zeros in on the CRT and equivalent interfaces that do not enjoy the attributes of larger panels. Interactive graphics are described in some detail.

Operator Training

The need for these operator training systems has dramatically increased because of the decrease in resources, the push for more capacity from stressed equipment, and the advent of more complex automation strategies. This article describes the concept of a graphical Windows NT operator training system that uses a dynamic model and field-based system configuration as the knowledge bases for the plant and the control system, respectively. The incremental improvements and performance requirements are detailed.

Smart Alarms

The distributed control system (DCS) has increased the number of alarms by an order of magnitude. The operator becomes insensitive to frequent alarms and is subjected to a barrage of alarms during a crisis or a shutdown. This article describes how the alarm, instead of triggering alarms off of a high or a low measurement, should be built up to show the actual operating condition from information from diverse sources such as sensors, tasks, modes, outputs, and other alarms. When done properly, a single alarm is generated that identifies the root cause.

SECTION 9: VALVES, SERVOS, MOTORS, AND ROBOTS

Process Control Valves

This article describes not only both general and special types of control valves, actuators, and accessories in terms of features needed in a large variety of applications, it also describes the issues to be addressed for the best valve and material selection. Also offered are helpful hints on storage and protection and installation techniques. A new topic on control valve performance highlights the choices and the benefits associated with minimizing the dead band and the nonlinearity of the control valve characteristic. The new opportunity of using smart digital positioners to monitor and improve valve performance is outlined. Finally, an extensive troubleshooting chart lists the causes and the solutions for major problems and symptoms of erosion, leakage, and poor response.

Control Valve Cavitation

The author provides knowledge from years of study of the fundamentals of cavitation, emphasizing cavity behavior and its negative effects on valve and system performance. The importance of valve sizing and selection toward the avoidance of cavitation problems is stressed.

Control Valve Noise

This research specialist addresses the serious problem of valve noise. Noise terminology is defined. The kinds of noise encountered—mechanical, hydrodynamic, and aerodynamic—are delineated. Suggestions for reducing noise are given.

Servomotor Technology in Motion Control Systems

This rather exhaustive article, directed mainly to engineers in the discrete-piece manufacturing industries, also finds generous application in the process industries. It embraces factors in selecting a servomotor, describing the basic kinds of dc motors, hybrid servos, stepper motors, linear steppers, power transmission drives, stepper motor drives, emergency stop measures, machine motion control systems, and a potpourri of motion control systems.

Solid-State Variable-Speed Drives

There has been a profusion of solid-state variable-speed motor drives ranging from subfractional to multithousand horsepower rating. Semiconductor switching devices and their impact on the development of ac variable-frequency drives is described. There is an extensive review of the various types of medium-voltage variable-frequency drives such as the load commuted inverter, filter commuted thyristor inverter, current-fed GTO inverter, neutral-point-clamped inverter, multilevel series cell VFD, and the cycloconverter. The comparison table provides a useful aid for selecting the right drive.

Robots

The technology of robotics, after an amazing surge of activity, now has reached a reasonable stage of maturity and acceptance. In this article the basic format of the robot is described, that is, its characteristics, including axes of motion, degrees of freedom, load capacity, and power requirements, as well as its dynamic properties, including stability, resolution and repeatability, and compliance among other characteristics. End effectors or grippers are presented. Workplace configurations are analyzed. Robot programming and control are explained and numerous styles of robots are illustrated.

Current-to-Pressure Transducers for Control Valve Actuation

Diaphragm-motor valves (pneumatically operated) remain the principal choice as final controlling elements for fluid flow. Although the demand for pneumatic control generally has diminished over the past few decades, the process control valve is operated by pneumatic force. Thus modern electronic controllers with digital outputs must utilize some form of current-to-pressure (air) transducer at the valve site. Several forms are available, including the older flapper-nozzle principles. This article also describes the combination of the newer pressure sensors with electronic feedback control.

SECTION 10: PROCESS CONTROL IMPROVEMENT

World Class Manufacturing

This article documents the methodology for finding and quantifying the benefits of process control improvement that has proven successful in one of the largest chemical companies. The methodology is extremely powerful yet relatively simple. Indices are developed that quantify the performance of the process and the control system for key process variables. The difference between these two indices can be used to estimate the benefits from improved process control. These indices along with utilization numbers can also be put on line to monitor the health of new control systems implemented and document the benefits achieved, which is critical for operations motivation and justification for future improvements.

Plant Analysis, Design, and Tuning for Uniform Manufacturing

This article provides a technical overview of a comprehensive suite of concepts, tools, and techniques that have become the standard for process control improvement in the pulp and paper industry. These include plant analysis to measure process and product variability by use of time-series analysis techniques, plant auditing procedures designed to identify the causes of process variability, an interpretation of the results in both the time and the frequency domain, the use of spectral analysis for both diagnostics and design, the use of model-based controller tuning such as internal model control (IMC) concepts and lambda tuning for both plant design and controller tuning, the use of a tuning strategy to achieve coordinated dynamics of a process area by preselection of the closed-loop time constants for each control loop, and understanding the performance-robustness envelop of a control loop, the impact of actuator nonlinearities on control performance, and the variability propagation pathways through a complex process. These methods are applicable to all process industries, especially process control loops on liquid plug flow or unit operations involving gas and solid streams. For unit operations involving backmixed volumes, there is often a significant process time constant that attenuates the amplitude of the variability introduced by fast loops (pressure and flow) to the degree to which the effect on the uniformity of the final product is within the on-line or the lab measurement resolution and repeatability limits.

Control Valve Response

The author of this article is the technical leader in understanding how the shaft length and connections, packing, actuator construction, and positioner design affect the ability of the control valve to respond.

The article correctly focuses on the essential need of the control valve to move within a reasonably short time to a small change in controller output. The best way to determine this capability is to review the change in a low-noise highly sensitive flow measurement for a change in controller output of 0.5%. In many rotary control valves, the actuator shaft will respond, but because of loose connections and twisting of the shaft, the actual disk or ball will not move. Also, the common practice of making changes of 10% or more in controller output reveal few, if any, of the problems and make every control valve look alike.

Process Impact

This article provides definitive examples of how improvements in the regulatory control system can significantly reduce the variability in processes. These examples show how tuning and decoupling loops, adding feedforward, and reducing valve dead band can yield impressive results. A case is developed for dedicating the resources to analyze each loop methodically for process control improvement. Most truly successful constrained multivariable predictive control systems and real-time optimizations demand the improvement of the regulatory control system as a necessary prerequisite. The benefits from these critical basic improvements are a major part of the total benefits reported for the advanced control system.

Best Practices, Tools, and Techniques to Reduce the Maintenance Costs of Field Instrumentation

This article focuses on the source of maintenance problems and how to do predictive as opposed to preventative maintenance. Good engineering practices are itemized that can greatly reduce the magnitude of the problems to the point to which most problems originate not in the application but in the manufacturing of the instrument or in the wear-out phase of the instrument. The article discusses the practical value of specific types of instrument knowledge and process knowledge-based diagnostics. An important point is made that frequent calibration is counterproductive and that good practices and smart instrumentation combined with diagnostics provides the confidence needed to leave the instruments alone. Rules of thumb summarize the overall recommendations.

New Developments in Analytical Measurements

Advanced control systems need concentration measurements in order to truly optimize the process. This article is a compilation of new industrial methods, such as Near Infared, Fourier Transform Infrared, Mass Spectrometer, Raman Scattering, Nuclear Magnetic Resonance, X-Ray Fluorescence, Microwave, and Neutron Activation. Many offer the hope of less sample conditioning and recalibration and therefore less on-site support. They also open up the opportunity to measure new components reliably on-line. This article tempers the enthusiasm with a word of caution that newer analyzers use technologies that are sophisticated and require extensive engineering and setup. The discussion of application considerations reinforces a practical view of the opportunity.

The Improvement of Advanced Regulatory Control Systems

This article starts with an extensive summary of the problems and causes of poor loop performance. One of the key discoveries is that measurement and control valve resolution are the largest undocumented sources of loop dead time. The concepts presented help the user track down the cause of a control problem. It then summarizes good practices for implementing the solutions including instrumentation and control valve upgrades, a variety of strategies, such as feedforward, dead time compensation, and override control, and controller tuning techniques, such as the closed loop, open loop short cut, and simplified Lambda methods.

Multivariable Predictive Control and Real-time Optimization

The addition of constrained multivariable predictive control is becoming recognized as the largest proven general opportunity in process control. Unlike other advanced control systems, it has a recognized track record in increasing production capability on the average by 3%–5%. While improvements in yield have not been as consistently high because of a greater dependence on application specifics, they are still considerable. This article provides a concise yet thorough treatment of CMPC from the practitioner's viewpoint. It provides an understanding of the concepts and the implementation techniques. The rules of thumb and guidelines on corrections to the regulatory system, plant testing, controller construction and tuning, and the outlining of maintenance issues are the types of information that are greatly needed but not available in the open literature. The article concludes with a discussion of real-time optimization and future directions.

Neural Networks

The hype of being able to just dump and crank (mine) historical data has distracted users from the real benefits of neural networks. Neural networks can find nonlinear effects that cannot be computed based on first principles or even seen because of the number of variables and the complexity of the relationships. This article provides both a theoretical and a practical understanding of this potential. Applications as virtual analyzers and in supervisory control are discussed. Perhaps the most underrated opportunity is the one of knowledge discovery in which the neural network identifies previously unrecognized key relationships. The guidelines presented on building neural networks are based on years of industrial application experience.

SECTION 11: STANDARDS OVERVIEW

Safety-Instrumented (Interlock) Systems

This article provides an overview of ISA S84 and IEC 1508/1511 standards that define a detailed, systematic, methodical, well-documented design *process* for the design of safety-instrumented systems. It starts with a safety review of the process, implementation of other safety layers, systematic analysis, as well as detailed documentation and procedures. The steps are described as a safety-design life cycle. The intent is to leave a documented, auditable trail and make sure that nothing is neglected. While these procedures are time consuming, the improvements pay off in not only a safer but a better performing process (an in-depth study has shown that as safety increased, production also increased). The implications in terms of logic system, sensor, redundancy, final elements, and solenoid design and installation are discussed. Key points and rules of thumb summarize the recommendations.

An Overview of the ISA/IEC Fieldbus

Fieldbus promises to revolutionize instrument installations. This article documents the savings from reduced terminations, home run wiring, I/O cards, and control-room panel space and faster configuration, engineering, documentation, checkout, and commissioning. It also discusses the installation options, such as cable types, devices per spur, topology, and junction box details, and the execution and status of the basic and advanced function blocks. These function blocks are comprehensive enough to become the common control language that leads to standardization and a seamless transition between functionality in the control room and in the field. Rules of thumb for proper implementation are also offered.

Batch Control: Applying the S88.01 Standard

In this article, the S88.01 standard is discussed and a methodology is presented for applying the standard to the definition of control system requirements for batch processes. This methodology uses an object-oriented approach that fits well with batch control and the S88.01 standard, including the development of objects that can be reused from project to project. Significant savings from applying the S88.01 standard have been demonstrated in all phases of batch control projects. The separation of the recipe procedure from the equipment logic is emphasized. This separation is one of the major reasons that the S88.01 standard has been so successful. Recommendations for dealing with exception handling and detailed equipment logic, which are the major portions of a batch control project, is provided.