

A DIFFERENT PERSPECTIVE ON PLANT RELIABILITY

Improve Reliability by Improving Process Control

Neal F. Rinehart
Emerson Process Management
Marshalltown, IA

ABSTRACT

Reliability is always at the top of the list of priorities and concerns for a process plant. Today's competitive marketplace demands high process availability and predictable output. Overall, a process that is efficient in terms of output (yield) versus input (costs) is a requirement to be financially successful.

Although many factors can impact reliability, the prime responsibility to manage it is often given to the maintenance department or reliability engineering group. Focusing on reliability from only an equipment or mechanical perspective, however, can lead to thinking in terms of hardware performance (mean time between failures) and can minimize the understanding of the impact process control has on reliability.

This article examines how adding a "process" perspective to reliability is an essential step in achieving improved reliability performance. In addition to reviewing the findings from several key studies, results from specific process control equipment optimizations will be explored. Indeed, both process and maintenance considerations are important elements that must be addressed to achieve world-class process plant performance.

INTRODUCTION

Reliability is a top priority for operating process plants. Ask any plant manager or production supervisor if reliability is important and you will always receive a resounding “yes”. It is also apparent that reliability is more important today than ever before. In industries like oil refining, where virtually all North American facilities are operating at or near theoretical capacity, any slowdown or shutdown would be devastating to a refinery’s profitability. Likewise, the extremely high input costs seen in chemical plants today require higher performance processes to be successful in returning an acceptable profit.

Reliable processes are critical for today’s plants for other reasons as well. In 2004, the cost of non-standard/non-compliance products in the U.S. process industry exceeded \$20 billion.¹ In addition to the resulting scrap, any rework performed resulted in lost plant capacity. Average losses in capacity across the process industries are estimated to be between 3% and 7%.² Because of the importance of good reliability, a significant amount of plant resource is focused there. In 2002, over \$200 billion was spent in the United States to maintain existing process equipment and facilities.³ For every \$1 spent in the U.S. on building new plants, \$5 is spent on maintaining existing plants. In heavy industries like pulp & paper or iron & steel, plant maintenance costs can be as high as 60% of the costs of goods sold.³

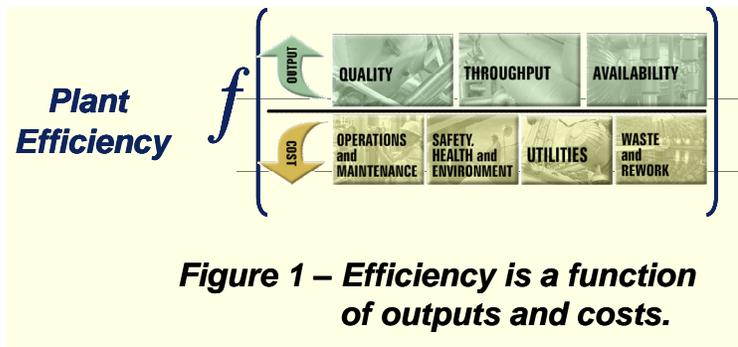
Historically, the prime responsibility for reliability in process plants is often focused within the maintenance function. More recently, some organizations have established separate reliability engineering groups with specific skills sets to further address important reliability issues. In either case, this approach to reliability has required significant financial investment in tools, techniques, and manpower to properly resource the effort. Numerous new maintenance planning/scheduling systems have been introduced in the past decade to support reliability efforts. Additional training related to mechanical skills have been undertaken. Many investments have been made in information and data gathering systems to support reliability/maintenance functions.

At the same time work was underway on reliability initiatives, operations and production have been investing in efficiency improvement technologies. Advanced control, real time optimization, new control systems, and business systems like SAP are just a few of the things that have received attention over the past 10 years. Specific productivity methodologies such as JIT, CIM, Six Sigma, and lean methods have also been incorporated into many operations. The investment on these efficiency initiatives is even larger than that for reliability initiatives.

The desired result from all these activities is the improvement in both reliability and efficiency of the process plant. Although reliability is difficult to measure, there are several attributes that everyone looks for in a reliable process. A reliable process should be operationally ready at all times. Reliable processes are predictable in terms of output quantity and quality. A reliable process will perform without failure when operated correctly. Reliability really measures the capacity/capability of both equipment and processes. Finally, reliable process plants need to conform to applicable environmental regulations.

Overall, a reliable process should be an efficient process. By measuring process efficiency (or efficiency improvements) a good understanding of process reliability (or reliability improvements) can be developed. The efficiency of any process can be measured by examining process variables related to outputs (quality, yield, uptime) compared to cost

inputs (maintenance, utilities, safety, waste, rework). Figure 1 shows that plant efficiency is a function of reliable and predictable performance in a number of key measurable areas. Optimizing plant performance involves maximizing process outputs while minimizing process inputs.



HOW ARE WE DOING WITH RELIABILITY AND EFFICIENCY?

With all the attention and investment that has been placed on reliability and efficiency how much has overall process performance been improved? As a point of reference, Ender⁴ reported in 1993 that more than 30% of installed controllers he studied were in manual mode and that 65% of control loops operating in automatic mode actually produced less variance when placed in manual mode. EnTech Control Engineering examined over 5,000 control loops in the early 1990’s and found that nearly 80% of the audited control loops failed to reduce process variability to an acceptable degree.⁵ Several other studies from this time frame show similar results. Indeed, a decade ago the reliable performance of process plants was severely impacted by the inability of the process to actually be controlled.

It turns out that not a great deal of improvement in process performance has been seen in the last 10 years. In an extensive process study first reported on in 2001, Desborough and Miller⁶ found that 68% of the process loops surveyed had performance that was rated fair or worse. Control in 42% of the 26,000 loops they studied was either oscillatory or open-loop (manual).

Figure 2 graphically shows the results from this study. Many of the loops in this study were in units that had been “optimized” with process efficiency investments like advanced control or supervisory control. In an extension of this study reported on in late 2003 that included more than 100,000 loops at 350 different manufacturing locations, the same distribution of loop performance demographics was seen. With all the investment being made in reliability and process optimization, not much real progress has been realized over the last decade.

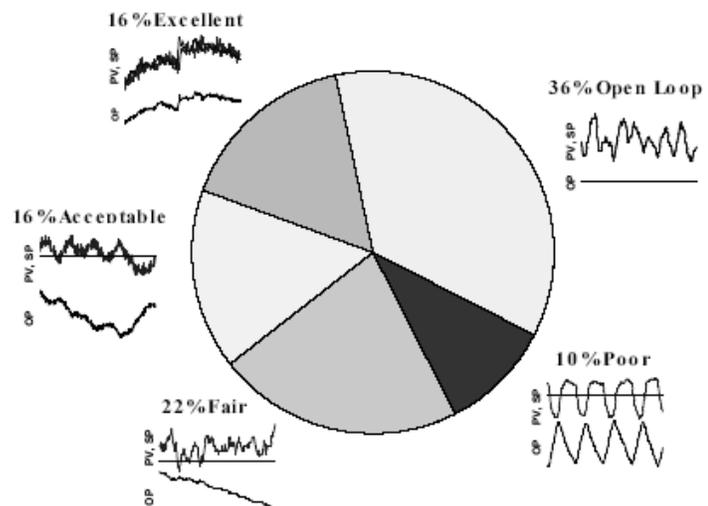


Figure 2 – Global multi-industry performance demographics.⁶

SOME INTERESTING STUDY DATA

It is obvious from these results that a different approach to process efficiency and reliability might be in order. A review of several key industry benchmarking studies provides a good place to start. The first of these studies was performed by Solomon Associates on over 100 olefin plants in North America. With respect to overall plant reliability, this study demonstrated that the economic impact of reliability can be enormous. Key findings of this study were reported on by Birchfield.⁷

Because reliability is difficult to measure, Birchfield proposed the use of a measurement called Reliability Index (RI). As figure 3 shows, RI (sometimes referred to as unplanned capacity loss) is the percent of total plant capacity that is lost to events such as slowdowns, shutdowns, turnarounds, and other process losses such as flaring.

$$\text{Reliability Index} = \frac{(\text{slowdowns} + \text{downtime} + \text{turnarounds} + \text{flaring})}{\text{total capacity}} \times 100$$

(Unplanned Capacity Loss)

Figure 3 – A “process-focused” measurement of process reliability.

Using RI to measure reliability introduces a much different perspective. While it is the tendency to think of reliability as a maintenance function, the RI suggests that process people need to play a key role in solving reliability issues in the plant. Each of these variables is a measure of process effectiveness and not just equipment performance. Instead of approaching reliability from a maintenance perspective focused on equipment reliability, RI introduces the idea that good process control is a requirement for good reliability.

Other findings from this study also show a very clear relationship between process control and process reliability. The most reliable olefin plant was 800% more reliable than the plant at the bottom of the list. The loss of production due to reliability issues ranged from 2 percent of plant capacity in the best facility to about 16 percent of plant capacity in the worst plants. Furthermore, it was found that overall plant reliability was best in plants that had the highest level of working, effective process control. Increased levels of process control correlated positively with better plant reliability. Plants that had the best process control had fewer slowdowns and shutdowns.

One of the most important findings from the study related to the nature of reliability issues observed. Approximately 70% of reliability issues were process (control) induced with the other 30% being mechanically induced. The need for an expanded approach to improving reliability, that includes asset utilization and process performance, is apparent from this Solomon study.

Another study that provides a different perspective on reliability was from a Business Driven Reliability (BDR) Initiative at the ExxonMobil Refinery in Beaumont, Texas.⁸ Although this refinery was top quartile in Solomon studies, work was initiated in the 1990's to significantly reduce the cost of unreliability (CoUR) at the refinery. A study done at the refinery indicated that the opportunity existed to reduce CoUR by more than \$100 million dollars. Because of this refinery management identified reliability as the top priority.

The BDR study team examined past reliability efforts to learn from both the successes and failures experienced. The team concluded that in order to be successful, several changes in

the refinery's approach to reliability needed to be made. The first change related to where the primary reliability focus should be directed. Since the largest source of work orders came from rotational equipment, the biggest group in maintenance was naturally focused on those problems. Data from CoUR study showed most of the dollars lost from unreliability came from fixed process equipment like piping, valves, vessels, and heaters and not from rotational equipment. By looking at overall costs it was apparent that reliability efforts needed to focus on additional 'process critical' equipment.

The second important change identified was the need to broaden organizational responsibility for reliability. Traditionally, the reliability function in the refinery had been driven within the maintenance department. The study data showed that reducing CoUR required an approach broader than just maintenance since most of the cost of unreliability was found on the process side of the business. Operations needed to be part of a cross-functional reliability process with the maintenance department.

Other process loop studies have determined that process control equipment has a huge impact on the reliability and profitability of a process plant. In the EnTech Control Engineering study⁵ cited earlier, Bialkowski reported that "the undesirable behavior of control valves is the biggest contributor to poor loop performance and the destabilization of product uniformity."

In another benchmarking study⁹ by Monsanto and 11 other chemical companies it was determined that the largest positive impact on the cost of goods sold (COGS) would come from control valve performance improvements coupled with proper loop tuning.

Improvements realized from final control element optimizations were as high as 1.5% of the COGS, easily exceeding the benefits that could be gained from other process and reliability optimization efforts. In the average plant studied, the potential improvements from final control optimization alone approached \$15 million annually. Results from this benchmarking study are shown in figure 4.

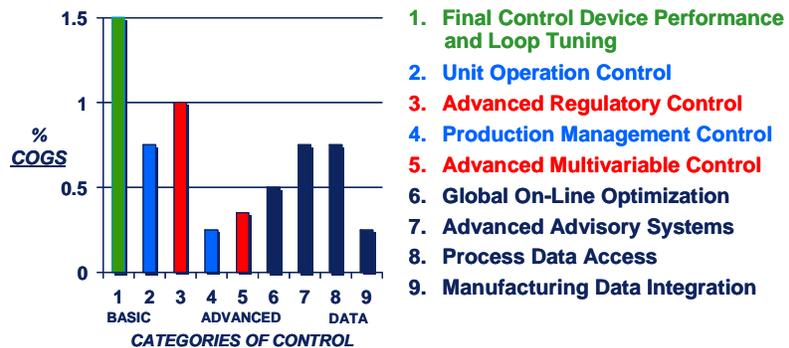


Figure 4 – Results from a benchmarking study in the chemical industries. The Cost of Goods Sold (COGS) can be significantly impacted by changing to best practices in final control.

Additional loop performance audits performed by Emerson Process Management in the hydrocarbon and chemical industries have yielded similar findings. In more than 7,000 loops audited in refining and petrochemical plants, over half the loops needed valve and/or valve instrumentation improvements to achieve optimal performance (most failed to respond to a 2% change in setpoint). All of the loops studied were profit critical loops and many were part of units that had advanced control strategies already applied. Subsequent control valve performance optimization initiatives on these loops that focused on reduced process control variability resulted in significant efficiency and reliability improvements in the entire process unit. It was common to see overall unit efficiency improvements of 2-5% after control valve performance optimization projects.

WHAT CAN BE DONE?

Good process control performance is an essential element in achieving world-class reliability performance as well as optimizing overall process efficiency. By adding a process control perspective to maintenance-based reliability programs significant improvements can be realized. Instead of addressing mechanical or device reliability as has traditionally been done, the organization that broadens its approach will truly act (and react) in response to plant process reliability.

One of the best ways to initiate a process-focused approach to reliability efforts is to improve and then maintain the performance of existing process control assets. As noted in some of the earlier studies, the performance of control valves is one of the most critical parts of the process control system. By improving the behavior of control valves considerable improvement in process efficiency and reliability can be achieved. This is best shown in the following examples that are from specific efficiency/reliability improvements in actual process units. By “*getting the gain*” in final control performance, significant process improvements were realized in process reliability.

- A new, higher activity catalyst was charged into a first-stage hydrocracking reactor. After commissioning, reactor temperature variations of +/- 4°F at the catalyst bed were observed with the existing control loop equipment. An audit revealed that the existing hydrogen feed valve was not capable of responding fast enough to process changes demanded by the new catalyst. Changing the control valve instrumentation on the main hydrogen control valve reduced the temperature variation to +/- 0.5°F. As a result, unit production was increased by over 1,000 barrels per day. In addition, the excellent temperature control has resulted in improved catalyst life and has allowed an extension in the time between turnarounds. Both process output and reliability were improved.
- In a synthetic lube-oil blending facility “off specification” blends (blends requiring rework) totaled 11% of the production. An audit revealed that control valve and measurement equipment changes were needed to improve process control. After implementation of these improvements, the number of “off spec” blends was reduced to 2% of the total production. Based on rework costs alone, this optimization was worth over \$1.3 million. Even more important, this reduction in rework increased available production time by 10%. Control valve optimization provided significant improvement in the facility’s efficiency and reliability.
- A naphtha cracker in Brazil re-instrumented 350 control valves to improve the plant’s performance. Operational benefits that were realized included a 25% reduction in furnace alignment time, reduced maintenance as a result of more uniform coke formation on furnace tube walls, and greater operational stability. In addition to the reliability improvements, the resulting reductions in process variability allowed process changes that improved the yield of cracking products (more “good” product, less “bad” product). Annualized process impact was over \$4 million.¹⁰

- Because of excessive fuel consumption, the fired heaters on a 160,000 BPD crude unit were evaluated. Before valve performance optimization, the ΔT across the passes was +/- 9°F. Fuel gas consumption was averaging 18.7MMSCFD. After valve optimization, ΔT was only +/- 2°F and fuel gas consumption was reduced to 17.5MMSCFD. At a conservative fuel gas price of \$6 MMBTU, the annualized savings were approximately \$1.5 million. In addition, the better control of temperature within the heater resulted in better control of coke formation on the heater tubes. This allowed for extending the time between required heater maintenance activities.

These examples are just a sample of the evidence showing the profound impact that the selection of the right final control equipment has on the bottom line performance of process plants. Establishing proper control valve performance is the foundation of establishing process loop performance. The resulting gain in loop performance not only improves process efficiency but also impacts the overall reliability of the process. Optimum control valve performance is vital for achieving efficient, reliable processes and is a sound first step for real improvement in process reliability.

SUSTAINING THE GAIN

Sustaining good valve performance is essential for the on-going reliable performance of process plants. In the past, reactive maintenance was the most prevalent practice used for control valves. With increased awareness of how valve performance drives process reliability, many companies began using preventative maintenance practices. Control valve maintenance was scheduled according to the valves criticality (safety and/or operational) in the process plant. Although this was an important change in maintenance practice and improved over plant performance, many control valves are removed from service for unnecessary repair. As reported by Rodda at DuPont¹¹, unnecessary repair accounted for as many as 30% of the valves actually worked on. In an ARC study¹² it was estimated that "...as much as 60 percent of scheduled preventative maintenance checks on process valves are unnecessary."

A bigger concern with scheduled maintenance is that control valve problems can not be found until the maintenance is actually performed. With annual maintenance shutdowns, ample opportunity existed to use preventative maintenance practices supplemented with off-line diagnostic technologies. Now that the time between turnarounds is being extended to 2, 3, or 4 years and more, less time is available to perform off-line diagnostics. Unless control valves are equipped with bypass valves, off-line diagnostic tests must be done during the actual turnaround/shutdown. Because of time demands during the turnaround, control valve maintenance was often compromised to meet other schedule demands.

With the advent of microprocessor-based valve instrumentation and sensor technology, the health of a control valve assembly can easily be evaluated while the valve remains in service. Data is collected without intruding on normal process operations and can be analyzed in real-time to provide maintenance recommendations specific to the problem at hand. The development of in-service, predictive control valve diagnostics has been driven by the requirement to maximize process up-time with fewer resources to support the operation. The ability to evaluate valve performance in-service also allows for better turnaround

planning as the information gathered can be used to effectively plan necessary maintenance actions without working on valves that are healthy.

The value of predictive control valve maintenance is large in terms of both on-going maintenance spend and overall process plant reliability. With predictive, in-service diagnostics the cost of unnecessary valve repair can be avoided and turnaround planning is much more effective. With fewer and fewer maintenance man-hours available to maintain field instrumentation, predictive maintenance should be strongly considered as a best practice.

An ARC¹² study also reported that “the cost of performing predictive maintenance on valves can be up to 5 times less expensive than preventative maintenance and ten times less expensive than corrective maintenance, even before the costs of downtime are figured in”. Incorporating predictive control valve diagnostics into maintenance practices will have a significant impact on plant maintenance costs and operating efficiency of process plants.

The integration of smart control valve diagnostics into today’s plant control systems allows the implementation of a true reliability and operations management (R/OM) program. Traditional DCS environments often lack data concerning the health and well-being of critical process equipment. The only measure of process health comes from mining information from the process data historian. Unfortunately, historian data by itself does not allow for the identification of process problems until they become severe. With smart field instrumentation, the health of the process control equipment can be evaluated on a real-time basis. Because of the wealth of data coming from today’s smart field instruments, the root cause of process problems related to process control equipment can be analyzed and clearly identified much earlier than in traditional DCS environments.¹³

Today’s predictive valve hardware and software automatically convert the diagnostic data into specific work action information. Integration of this equipment with the control system allows for alerts to be directed to the appropriate work group, whether operations or maintenance, well in advance of severe process impact. This early identification of problems facilitates corrective action long before severe process impact is experienced (Figure 5).

The following are a few examples that highlight the impact that “sustaining the gain” in control valve performance has on overall plant reliability and operations management system.

- The same naphtha cracker in Brazil that achieved \$4 million in process improvements (earlier

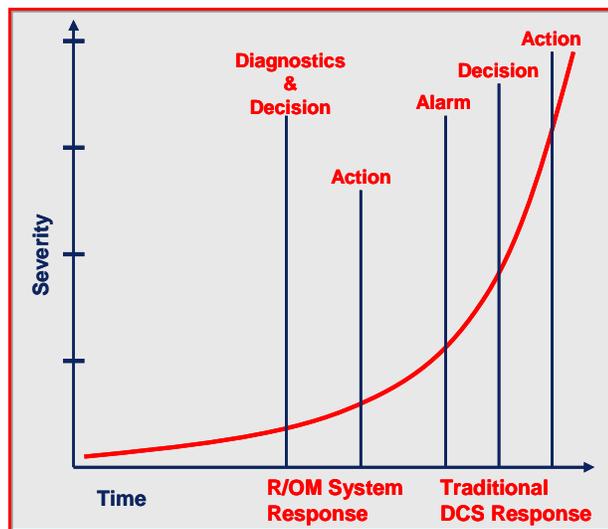


Figure 5. Predictive on-line, in-service control valve diagnostics allow earlier detection of process performance issues than possible in traditional DCS systems. Actions can be taken to minimize the severity of the problem on the process¹³.

example) had been shutting down its 32-year-old plant up to six times a year due to maintenance problems. Since installing control valve diagnostics as part of an overall control instrumentation optimization effort, the number of shutdowns has been cut in half. As a result, the annual maintenance budget for the plant has also been reduced by \$1 million.

- At an ammonia plant in Malaysia, digital valve technology is being used to perform on-line, in-service predictive maintenance of control valve performance. Previously, a 24 day shutdown was necessary after each 18 months of operation. By using predictive valve maintenance, the time between turnarounds at this plant has been extended to 36 months. The gain of an additional 24 days of production was worth over \$6 million.
- At a large North American Purified Terephthalic Acid (PTA) facility, a predictive diagnostic on a critical control valve with double acting piston actuator identified a leak in the actuator piston seal, and recommended that the actuator be checked for piston seal leakage. The actuator was disassembled and it was discovered that the piston seal was close to catastrophic failure. This prevented a costly unplanned shutdown and loss of approximately \$400K worth of catalyst.
- At a paraxylene manufacturer in Thailand, a critical pressure control valve was fluctuating despite a stable signal from the control system. The operator became concerned by the erratic control of the control valve. An in-service friction diagnostic on this valve determined that the friction was much lower than two years earlier. Adjustments were made to the boosters and tuning to compensate for the decreased friction. As a result, the process remained on-line and an unnecessary shutdown (~\$200K) was avoided.

CONCLUSIONS

Excellent process reliability is a requirement to be competitive in today's business environment. The marketplace demands high process availability and predictable output. Overall, a process must be efficient in terms of output (yield) versus input (costs) for an organization to be financially successful.

Although many factors can impact reliability, adding a "process" perspective to reliability is an essential step in achieving improved reliability performance. As noted by Solomon, approximately 70% of reliability issues were process (control) induced with the other 30% being mechanically induced. The need for an expanded approach to reliability that includes asset utilization and process performance is apparent. Indeed, both process and maintenance considerations are important elements required to achieve world-class process plant performance.

One of the best ways to initiate a process-focused approach to reliability efforts is to improve and then maintain the performance of existing process control assets. The performance of control valves is one of the most critical parts of the process control system. By improving the behavior of control valves considerable improvement in process efficiency and reliability can be achieved. With the advent of digital valve controllers and sophisticated sensor

technologies, predictive, in-service diagnostics are readily available to help sustain the gains achieved.

As the process industry continues to demand better and better efficiency and reliability, world-class producers will be rewarded by incorporating a process-focused reliability approach into everyday work practices.

¹ SAT Corporation Website, *Adaptive Process Management Section*; www.sat-corp.com/apm/apm.htm.

² White, D.C., *Creating the 'Smart Plant'*, *Hydrocarbon Processing*, October 2003, pp.41-50.

³ Mobley, R. Keith, *An Introduction to Predictive Maintenance* (Second Edition, 2002), Elsevier Press, p. 1.

⁴ Ender, D.B., "*Process Control Performance: Not as good as you think*", *Control Engineering*, September, 1993, pp. 180-190.

⁵ Bialkowski, W.L. and Elliot, Ross, "*Control Valves-The Biggest Single Contributor to Process Variability*", Instrument Symposium for the Process Industries, Texas A&M, January, 1996.

⁶ Desborough, Lane and Miller, Randy, "*Increasing Customer Value of Industrial Performance Monitoring – Honeywell's Experience*", Proc. CPC VI, Tucson, 2001. Manuscript reprinted from Honeywell website, 2004.

⁷ Birchfield, George, "*Olefin Plant Reliability*", presented at AspenWorld 2000. Reprint available on-line from www.aspentech.com.

⁸ Jones, W., Kubenka, J., and others, *Business Driven Reliability at Mobil's Beaumont Refinery*. Summary report was available on-line at www.marshallinstitute.com.

⁹ Benchmarking study performed by Monsanto and 11 other chemical manufacturers reported in World View, Volume 4, Number 1, January 1997.

¹⁰ Filho, A.G., *Benefiting From the Use of Smart Instruments and Asset Management Software in Naphtha Cracking*. Paper CC-02-156 presented at 2002 NPRA Computer Conference in Austin, TX.

¹¹ Rodda, James R., "*Predictive Maintenance for Control Valves*", Texas A&M Instrumentation Symposium, 1993.

¹² Clayton, David, "*Integrate Valves and Plant Asset Management Systems to Increase Profits*", ARC Insights, July 14, 1999, Issue 99-068.

¹³ Stout, Scott, "*Refining Reliability*", *Hydrocarbon Processing*, June 2002, pp.31-35.

Neal Rinehart currently directs technology and marketing initiatives for Fisher® Control Valve Performance at Emerson Process Management. Neal is involved with process improvement initiatives in the refining, petrochemical, and chemical industries. Much of his work is focused on the impact of the final control element on the efficiency of process unit performance. The development and application of predictive maintenance for control valves is also a key interest area. Prior to his current position, Neal was the Manager of Research and Analysis and directed research efforts for the Final Control Systems group. Neal joined Fisher in 1973 and is a Registered Professional Engineer.

Emerson Process Management
205 South Center Street
Marshalltown, Iowa 50158
Telephone 1(641) 754-2612
Fax 1(641) 754-2277
neal.rinehart@emersonprocess.com