Continuous Process Improvement

Applying Manufacturing Optimization Models to Process Industry

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2017
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Introduction

In recent years, derivatives of business information systems (Asset Managers, Data Monitoring and Data Analytics) have been successfully extended to manufacturing and process industries. Similarly, business optimization strategies have been successfully extended into the manufacturing sector.

Can manufacturing optimization models be further extended to the Process Industries?

Simple answer, yes.

Before discussing their possible application to the process industries, let's quickly review how continuous improvement models are commonly used in modern manufacturing.

There are a number of successful manufacturing optimization models including *Lean*, *Kaizen*, *Six Sigma* and others. All are built around a few common core principles.

First, the organization must be committed to continuous improvement. This is critical to success. The name *Kaizen* is a literal combination of two Japanese words: *Kai – continuous* and *Zen - improvement or betterment*. A half-hearted effort will fail – it is as simple as that.

Secondly, inputs to the manufacturing process must be controlled to provide for the timely delivery of materials, components and sub-assemblies with predictable, acceptable quality and price.

Thirdly, quality or production issues that arise during the manufacturing operation itself are quickly resolved with the root cause determined and an effective corrective action implemented. This correction results in an overall improvement to the process and prevents reoccurrence of the problem.

Finally, end of manufacturing quality checks, metrology and testing demonstrate the quality of the manufactured product. Deficiencies are handled in much the same was as are the production quality incidents. In addition to correcting the defects, both the manufacturing process and product design are re-examined to determine the corrections required to prevent a reoccurrence of the defect.

In this way, the manufacturing process is inherently self-optimizing over time and headed toward maximum productivity.

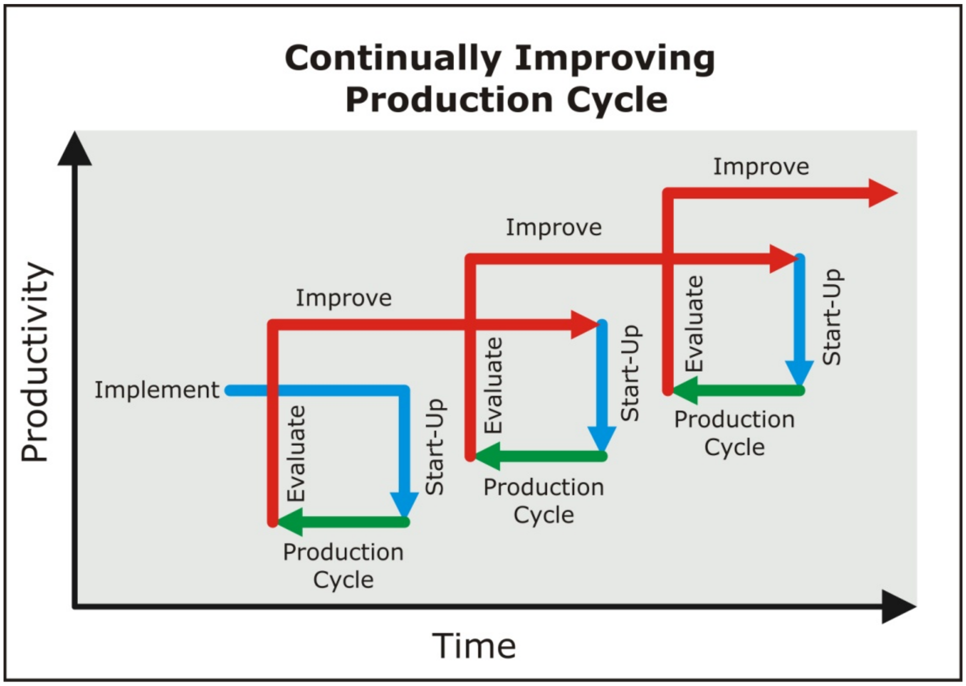

Figure 1: Continuous Improvement Illustration - Simplified

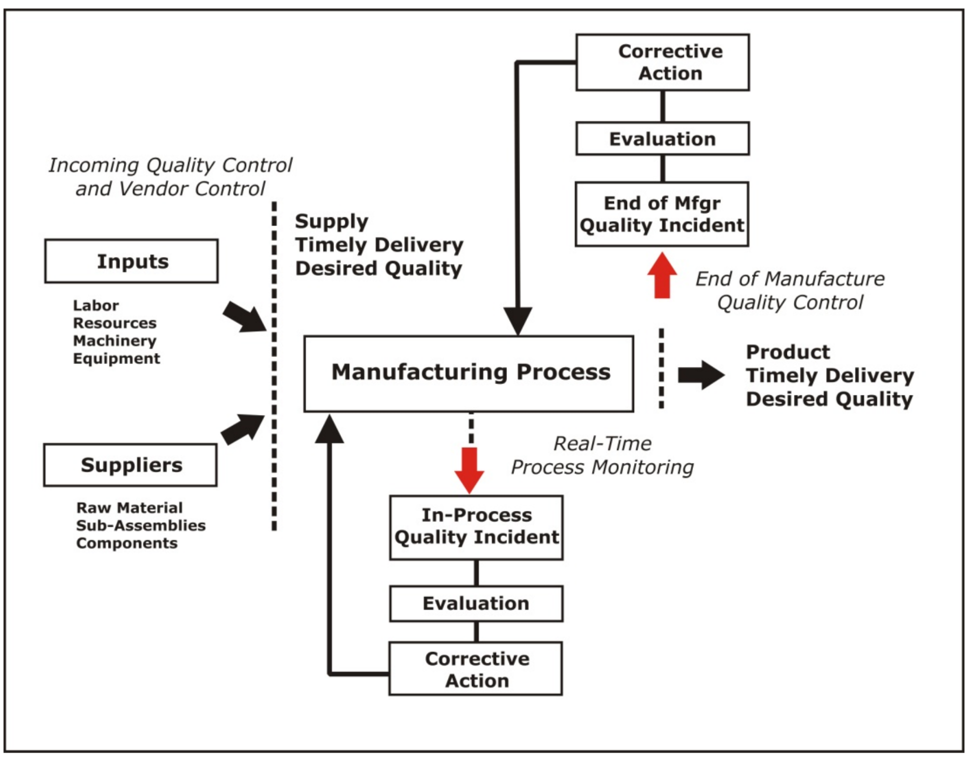

Figure 2: Manufacturing Model Illustration - Simplified

How can this model be applied to the Process Industries?

Current Situation

Inputs to the mill / plant are only partially controlled. While raw material quality controls are almost always in place, much less attention is paid to the performance quality of critical process devices and equipment entering the facility. If any inspection of these devices is made, it is generally only a cursory visual examination to ensure compliance with the order or specification. Performance testing of these devices on delivery or required vendor testing before delivery is not the norm.

When the process unit attempts to come out of the planned outage, tuning of the critical loops is commonly attempted. If this effort encounters difficulties, as is often the case, operators may simply move the loop to manual and move on. The most sophisticated control software is defeated completely if it is not used.

Critical loops may or may not be monitored during the process production cycle. Real-time monitoring from an unknown starting point and with possibly sub-standard control devices only adds to the complexity and diminishes the contribution of this valuable tool.

When a production issue arises, emphasis must be on returning quickly to production. Considerable expense is incurred with every hour of down-time. In current practice, modern diagnostic tools and communications are generally not available and trouble-shooting is based on the technical skill and experience of the personnel available at the time. Record keeping may or not be complete and a disciplined corrective action process is not followed.

At the end of the production cycle or in planning for a major outage, it is not standard practice to functionally test the critical devices to determine their condition. It is however, very common maintenance practice to place critical devices into a non-specific overhaul process. These critical devices are then returned to the plant/mill for re-installation without further functional or performance testing.

How would things change if the Process Industries adopted a manufacturing optimization model?

First, let's clarify a couple of frequently used terms.

Optimization is a term often applied in the Process Industries to describe the tuning or adjustment of a single loop or discrete production process. However, in this context, optimization addresses the big picture of improving the performance of the entire facility in an ongoing way.

Similarly, Production Cycle is used in this context as the general period of end-product production, either continuous, batch or other, followed by a period of planned maintenance (outage) or field days.

Business Goals

The primary goal of any business is to maximize return to shareholders. Business schools are wonderfully vague on just how exactly this is to be done. However, there is one method they all agree on: *identify corporate fixed assets and maximize the return on those assets*. How do you do this? Again, the business schools are not specific. However, almost all of the approaches involve a call (or maybe an email) to plant/mill manager with instructions to make this happen.

Since this entire issue is a matter of efficiency and profit, it would seem prudent for the plant/mill manager to critically examine the facility and the product and determine an effective course of action.

Since the current focus of most process facilities is on the individual tree and not the forest, a big culture issue is apparent. Business cultures are hard things to change. To be successful, a corporate commitment to an optimization strategy is a must. If a half-hearted commitment is made, the effort will become the next “flavor of the month” and will fail.

Big Picture

The following steps are necessary to implement this optimization model:

- Commit to Continuous Improvement - fully
- Determine Real Cost of Downtime, $/ hr.
- Define Success – Define Key Metric(s) – *Key Performance Indicators*
- Define Critical Processes
- Define Critical Loops
- Define Critical Devices
- Control the Quality of Critical Devices Entering Facility
- Verify Critical Devices are Operating as Designed
- Verify Critical Loops are Functioning as Designed - Tune
- Monitor Process with an Effective Incident Management Procedures
- Learn and Improve the Process Every Production Cycle

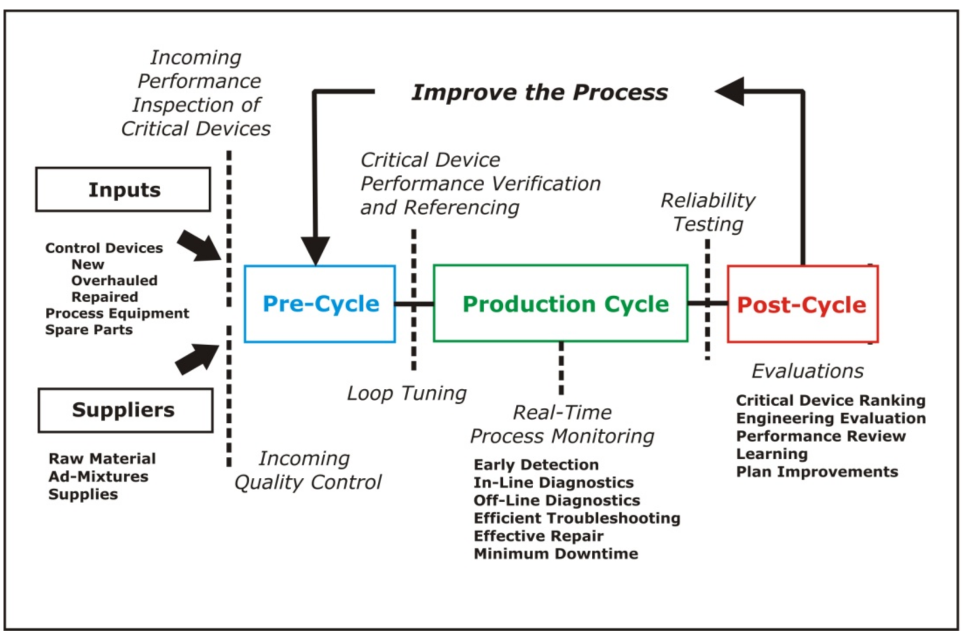

Figure 3: Continuous Improvement for Process Production

What are Critical Loops?

A modern production facility is composed of numerous process loops. For the purposes of this discussion, a **Critical Loop** is defined as a process control loop, the failure of which to meet specified performance or reliability requirements could cause a significant degradation in the productivity or profitability of a plant or mill.

What Are Critical Devices?

Similarly, one of the key steps described above is the definition of **Critical Devices**. What exactly is a critical device within a modern process loop?

It seems clear that a critical device must have a direct and significant impact on the performance of the loop. Also, the device actually controlled in the loop should be given special consideration.

Focus on Control Valves

The control valve meets both of these criteria listed above and is by consensus a critical loop device. Others devices also will fit this general definition, but this discussion will now focus on the control valve as the primary critical device.

Not only is the control valve a critical device, it is a critical device that is often functioning far from optimum and as such seriously impacts plant/mill performance. The standard maintenance repair practice is for a non-specific overhaul of control valves at each maintenance outage. In addition, replacement control valves are ordered and delivered for installation during the planned maintenance outage.

Significance of the control element (control valve) on control loop performance is highlighted below:

> *"Control valve performance has a significant impact on every factor of plant efficiency. As a benchmark, EnTech Control Engineering™ examined more than 5,000 control loops and found that nearly 80% of loops failed to reduce process variability to an acceptable degree."*

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.

A major control valve manufacturer reports:

> *"Far too little has been done over the years to sustain the performance of control valves once they go into operation, despite widespread agreement on the impact that valve have on process efficiency."*

Rethink Your Control Valve Management
Chemical Processing
Neal Rinehart
2006

Another later report from the same manufacturer concludes:

> *"A major control valve manufacturer in the hydrocarbon and chemical industries also performed an audit on loop performance and had similar findings. In more than 7,000 loops audited in refining and petrochemical plants, more than half the loops needed valve performance improvements to achieve optimal process performance. Most loops failed to respond to a 2% change in setpoint."*

“Establishing proper control valve performance is the foundation for establishing process loop performance.”

How to Achieve Optimal Control Valve Performance
Valve Magazine
Shawn Anderson and Neal Rinehart
2007

A commonly applied control valve specification identifies the control valve as the single biggest contributor to poor control loop performance:

“Plant process variability audits frequently find that product variability is increased by individual control loops that limit cycle because their control valves are unable to track their controller output signals closely enough….. This undesirable behaviour of control valves is the biggest single contributor to poor control loop performance and the destabilization of process operation.”

Entech Control Valve Dynamic Specification
(Version 3.0, 11/98)

Clearly the focus needs to be on the performance of the final control element, the control valve.

“In a comprehensive benchmarking study performed by Monsanto and eleven other chemical manufacturers it was determined that final control element performance had the largest impact on the cost of goods sold (COGS). As much as 1.5% of the COGS could be saved by employing best practices on the final control loop.”

Neal F. Rinehart
Fisher Controls International LLC
AspenWorld 97
October 15, 1997
Boston, Massachusetts

What Key Metric Should Be Applied?

It is important to establish a performance standard to assess improvements (or lack of) in the applied process improvement strategy. Obviously, each situation is different.

Many plants/mills have spent considerable sums on advanced process control software and systems. These systems provide many significant production and safety benefits. Unfortunately, they lose their usefulness entirely when the process is operated in “Manual” mode.

A very informative metric is the percentage of loops in “Manual” mode. More sophisticated tracking might report “Alarms”, “Operator Changes” or the percentage of “Time in Normal” to detect the number of operator interventions and their duration. “Process Loop Variability" is also a powerful tool for tracking the improvement of control stability at the operating set point.

It is important to also temper the idea that a control room solution is all that is required:

“Little can be gained by developing a sophisticated control room architecture that is capable of performing to half percent accuracy and then implementing that control strategy with a final control element that may only be capable of five percent accuracy at best!”

Neal F. Rinehart
Fisher Controls International LLC
AspenWorld 97 Boston, Massachusetts
October 15, 1997

Optimization Model Applied to the Control Valve

Specific strategies that improve critical asset performance and extend service life:

Incoming Performance Inspection of Control Valves

When considering the manufacturing optimization model, the need to control vendor inputs to the process was obvious. Sub-standard components or sub-assemblies injected upstream are obviously detrimental to the downstream manufacturing process and result in degradation of product quality.

Similarly, it is imperative to control the Inputs of critical control valves into the production process.

When a new, remanufactured or overhauled control valve is delivered on the loading dock, it may or may not be a valve that ***actually controls***. Most commonly, the valve is accepted without performance testing or similar documentation by the vendor and is simply placed in inventory awaiting installation.

When the valve completes that sometimes adventurous process of installation, it usually undergoes a configuration / setup procedure. At the time the unit is brought up and the control loop tuning started, it is finally determined whether the valve will function as an *effective modulating control valve*. Clearly, if a problem is found at this point it will seriously impact the production schedule.

If on the other hand, the valve is externally tested at delivery with an independent, fully capable control valve diagnostics system and found to be deficient, the end-user has the maximum amount of time to correct the problems**.** Additionally, the end-user has invested the minimum amount of money and time handling or installing a problem.

The need for performance inspection at this point becomes intuitive if you consider the following:

1) You can't tell if it is a ***properly functioning*** control valve by looking at it.

2) It is true that operation on the bench or loading dock is not the same as operation in line. However, it must be recognized that testing is done at the most conservative operating conditions the valve will experience. Temperature, pressure, line stress and vibration are not applied. If it will not function properly at this point, ***it will not improve when installed in-line*** (despite many a valve salesman's assurance to the contrary).

Control Valve Performance Verification Prior to Tuning

It is important to know that the control valve is performing properly immediately prior to tuning the loop. Loop tuning is a waste of time when the final control element is not performing properly.

Since the valve positioner is a key component of the system under evaluation, a couple of points must be considered. At one time, it was common practice to post mount the signal (I/P) transducer away from the valve to avoid the temperature and vibration of the process line. This logic has given way over the years to placing complex electronic valve positioners directly on the valve actuator and directly exposing them to the harsh process environment. Excellent engineering and experience has provided positioners with even more sophistication and with ever smaller control resolutions. However, this strategy has made this complex digital controller the key element of the modern control valve. Self-tests and internal diagnostics are all excellent ideas and incorporated on almost all of the newer devices.

However, the pressure transducers and displacement encoder or potentiometer are not calibrated against outside references. Additionally, the accuracies of these key components are generally not reported to the end-user. It is unclear whether positioner self-testing will detect changes in these components due to aging and degradation from the harsh process environment.

External testing with an independent, fully capable control valve diagnostics system is a must to verify and document proper positioner performance. Even the most ardent in-line valve diagnostics proponent will acknowledge the value of actually ***knowing*** that positioner is functioning correctly at each process production cycle start.

Loop Tuning

At production cycle start, it is important to know (and not assume) that both the critical control valve has acceptable performance and that the control loop is tuned properly. This represents the best performance state of the loop and is a very important baseline for subsequent on-line loop monitoring.

In current practice, the control loop is not always tuned at this point. In many cases, the operators assume that the control valve dynamic characteristics, (dead time, response time and gain) have not changed since the last loop tuning. Existing tuning is often relied on with process operators making *ad-hoc* adjustments as needed to achieve satisfactory control. Unfortunately, the control valve may be very different after the overhaul.

This seems to be a significant lost opportunity. It is relatively easy to obtain dynamic characteristics of the control valve and compare them to the characteristics of the control valve installed when the loop was last tuned. Significant differences would alert the operators to potential control issues in advance and avoid time consuming troubleshooting.

Real-time Process Monitoring

Once the loop is successfully tuned, baseline dynamic performance for the control valve can be established. This is a key step. This data is very important in on-line monitoring and in the maintenance interventions that may happen during the production cycle.

As noted previously, modern control valves are mechanical devices fitted with sophisticated electronic/pneumatic positioning systems. These mechanical and electronic systems contain many components which can and will degrade over time. If this degradation process occurs within the process cycle time frame, loop performance will degrade progressively and may result in a complete failure.

Real-time monitoring with sophisticated trending and data analytics is a very valuable tool and should be exploited fully. However, it does rely on the digital positioner being healthy and providing accurate data. It should also be noted that very sophisticated and effective real-time monitoring is possible using only control element position and applied control signal data which are available on even the most basic digital positioners.

If the loop tuning operation with a properly function control valve is successful, by definition the performance of the loop and control valve is acceptable. This point represents the baseline state of the loop and real-time tracking and data analytics can detect degradation from that point on.

It is important to understand the application of the control valve in the process and consider in advance the acceptable limits of performance. Further, it is advisable to establish an intermediate performance limit that causes the monitoring system to increase the frequency of control valve monitoring and a final limit at which point a physical inspection and/or further testing / maintenance intervention are made.

Effective Maintenance Interventions

When the process operator and/or the real-time monitoring determines that the performance of a control loop is degrading and the control valve is the likely cause, a maintenance intervention may be required. It is important to have an effective and efficient intervention strategy in place beforehand; because in this situation, time is literally money.

Unfortunately, most current maintenance interventions are *ad-libbed*.

Again, examination of other industries leads us to the conclusion that all life-critical processes, whether medical, space, high reliability or aeronautics involve standardized problem solving procedures and are designed specifically to avoid mistakes and lower risk.

The keys to an effective intervention strategy are to think it out beforehand, effectively communicate it to maintenance personnel, provide adequate training and exploit the many powerful enabling technologies available. Advanced inspection, digital record keeping, on-site communication and trouble-shooting tools are all readily available. On-line diagnostics, off-line diagnostics and internet consultations are all possible elements of a modern effective intervention strategy.

Emphasis must be on gathering needed information and following a disciplined problem solving process. Unfortunately, current practice does not emphasize this and the effectiveness of the maintenance process is dictated by the unique and varied skills of the personnel available.

During a control valve maintenance intervention, is important to quickly and accurately determine whether problems can be resolved with the valve in-place or whether it must be removed from line.

An effective maintenance intervention strategy requires the immediate availability of an independent, fully capable control valve diagnostics system and trained maintenance technicians capable of interpreting the test results on-site. In one of the very first steps in this implementation process, it was suggested that the "*Real Cost of Downtime, $/ hr*" be determined. Basic economics dictates that the maintenance intervention should be as short as possible. It is inconceivable to consider waiting for a vendor to mobilize and travel to the plant to perform this important service or interpret the testing results. Similarly, maintenance personnel need to have the training and skills needed to efficiently replace and setup key valve positioning system components.

Whatever methodology is employed, thorough event documentation is critical. It is vital to develop and maintain control valve histories and for subsequent review of correct actions taken.

Post-Production Cycle Evaluations and Control Valve Ranking

On-going continuous improvement considers each production cycle as a ***learning*** cycle.

The idea of a commodity valve must be discarded. Each critical control valve must be regarded as a system with a distinct function in the production process. Everything from the air pressure header and the control signal source through to the control valve body is a component within that functional system. All these components need to be inspected and their post-production cycle condition determined and documented.

To improve reliability and to provide feedback to the real-time monitoring effort, a post-production performance testing of the critical control valves should be undertaken.

> *"A control valve behaves much like other mechanical devices. Over time, wear gradually decays control performance. If left unchecked, this decay can eventually lead to failure. Often that decay is so subtle, it is not apparent to operators or to maintenance personnel. However, if it's compared to original performance levels, the differences become obvious."*
>
> *How to Achieve Optimal Control Valve Performance*
> *Valve Magazine*
> *Shawn Anderson and Neal Rinehart*
> *2007*

The real-time monitoring should be correlated to the degradations observed between original verification testing and the post-production testing with the particular emphasis on patterns, precursors and other indicators. Real-time monitoring should be continually refined and improved by this learning. Valuable reliability information can also be gleaned here.

As described earlier, current practice is to overhaul all control valves in a non-specific process of soft goods replacement and trim refurbishment. Deficiencies and component failures may be noted by the repair vendor but the general overhaul instruction is to *"repair / replace in kind".* This approach discourages improvements to the control valve. For example, the trim on a control valve may be damaged or worn during the production cycle and is dutifully repaired/refurbished at every outage, year after year. Nothing in the current maintenance practice would require an improvement in trim material or an evaluation of whether the valve is sized properly. Instead the standard practice continues the process "as is" without the benefit of possible refinement or improvement.

To address this, the history of each control valve should be reviewed and critical valves should be ranked from best to worst. A percentage of critical valves, let's say 10% or more as the budget permits, should be designated as worst performers and subjected to a thorough engineering evaluation. The goal of this evaluation is to ***correct the deficiencies with improvements***.

Worst performing control valves would be evaluated to determine:

- ❖ Appropriate Control Valve Type
- ❖ Correctly Sized for the Current Application
- ❖ Appropriate Materials of Construction for the Specific Application
- ❖ Valve Assembly Properly Installed
- ❖ Correct Positioner **-** Properly Installed, Aligned and Configured

Plan Improvements to the Process

It was obvious in the review of the manufacturing optimization process that positive corrective actions act as the driver to improve and refine the process. The same is true here.

It is imperative that the lessons of the process production cycle be learned and proper corrective actions implemented to improve the process for the next cycle. It is clear that the process is iterative and builds on the improvements and knowledge gained from the previous cycle.

Failure to fully implement the corrective actions will defeat the continuous improvement process.

The key performance indicators should be determined for the current production cycle and will serve as the baseline for the performance comparison at the conclusion of the next production cycle. If the process is improving, the key performance indicators will display that improvement.

Conclusion

Manufacturing optimization models can be applied successfully to Process Industry production.

All technologies needed are available, proven and affordable. Implementation of these technologies at key times in the normal production process cycle can provide effective and timely maintenance intervention, minimizing downtime and lost production. These technologies also provide the positive basis for a continuing refinement of the overall production process. This refinement leads toward improving productivity and lower production cost of goods sold by the plant/mill.

The key component is a true corporate commitment to a process of continuous improvement.

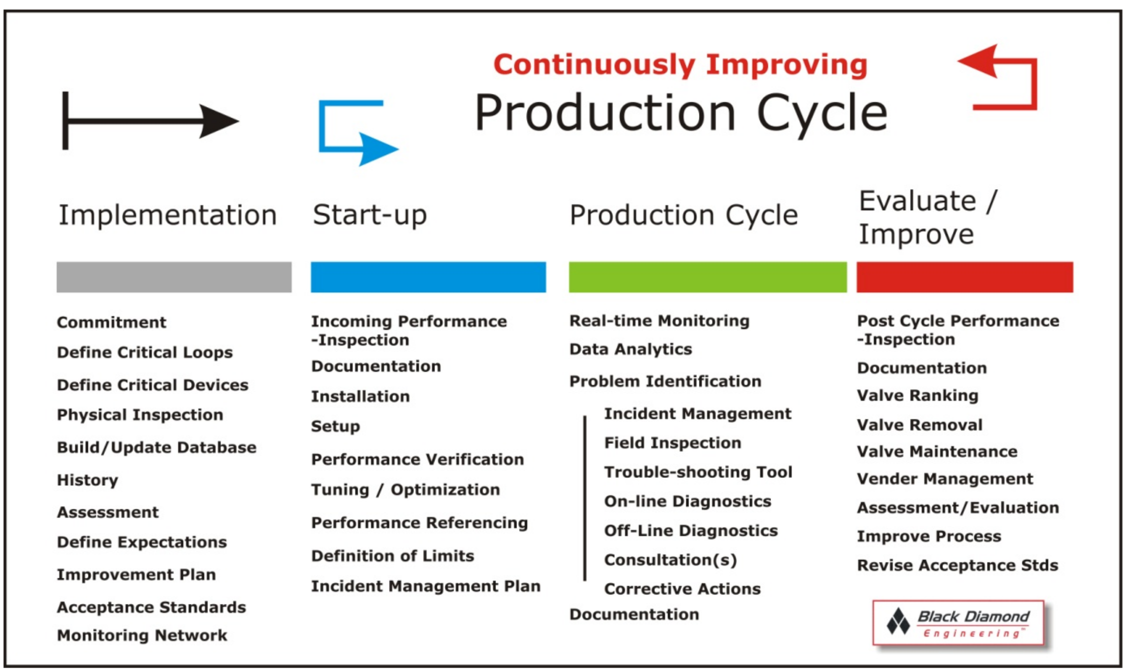

Figure 4: Summary - Continuous Improvement for Process Production