Where Lean Works for Process Manufacturers

First of a series.

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As lean makes inroads into non-manufacturing sectors of the economy — into healthcare, government, education, financial services, etc. — it's time to take a step back and complete some overlooked work. Lean in process manufacturing industries hasn't received the attention it deserves, leaving the impression that lean isn't as applicable to process manufacturing as it is to discrete. Too many executives running process manufacturing facilities still don't see how a system designed by a maker of discrete parts can possibly work in their factories. But it does. It just works differently.

Discrete manufacturers, too, should become more familiar with how lean works for process manufacturing. Plenty of good ideas about implementing lean in process manufacturing can be used in discrete. Many facilities that make parts have areas where processing activities take place, including painting, sealing or coating, and heat treating. Indeed, any operation where equipment paces the work and manages multiple variables can benefit from a process-manufacturing approach to lean. Most important, understanding how lean principles translate to solve process problems will help executives achieve a deeper understanding of lean.

In this article, the first of a series, *Target* explores the process manufacturing sector's adoption of lean and identifies lean principles and tools that provide the biggest benefit for process manufacturing. Future articles in the series will feature the stories of process manufacturers who are among the best at implementing lean and will highlight specific areas where lean works best to streamline process manufacturing.

In Brief

Discrete manufacturers have tended to dominate lean discussions, but that's about to change. Increasingly, process manufacturers at the forefront of adapting lean principles to meet their needs for continuous improvement are beginning to tell their stories. With this article, *Target* launches a series of articles describing where and how lean principles work in process manufacturing. Future articles in the series will feature the stories of process manufacturers who are among the best at implementing lean and will highlight specific areas where lean works best to streamline process manufacturing.

Some Commonly Accepted Characteristics of the Three Approaches to Manufacturing

Manufacturing operations are commonly categorized into three groups: discrete, batch, and process — though often the batch and continuous operations are lumped together as process manufacturing. Many plants actually run two or even all three types of operations, but are generally categorized based on the primary operation. For example, making cereal is a continuous process, while packaging cereal is a high-speed discrete process, yet food manufacturing is traditionally considered a process industry.

The secret to adapting lean to process manufacturing — that is, the batch and continuous flow operations — is to get beyond the labels and look at the work being done. A closer look often reveals work that can significantly be improved with the application of lean principles. No two facilities are alike, and there can be major differences in how lean principles are applied — even in facilities using the same manufacturing approach. For example, perhaps the most often discussed example of this within the discrete industries is the difference between how lean works in a high-volume, low-mix plant verses a low-volume, high-mix plant. The principles of lean work differently, but they work in both situations. As with implementing lean in a discrete operation, all of these concepts are intertwined. In batch processing, achieving cycle-time reduction, one-piece flow of inbound raw material and outbound products, while maintaining just enough inventory and producing the right variety of products to meet customer demand, depends on an endless variety of considerations. In applying lean, there's just no getting around looking closely at the work and the lean principles, and thinking for yourself.

The chart on page 12 provides a starting point for such an analysis, by listing some of the more commonly accepted characteristics of the different types of manufacturing. A "complete" list of characteristics or firmer definitions is not possible due to the incredible variety within each general manufacturing approach.

First, Some Ground Rules

Translating lean for process industries requires looking closely at and, in many cases, comparing the work characteristics of discrete, batch (hybrid), and continuous process manufacturing. However, specific definitions or characterizations of the different types of manufacturing remain elusive — there's just too much variety within each approach to summarize in an article or chart. The generalizations made in this article are not meant to be definitive, but rather to serve as a guide and an example showing how executives might look at the work they do differently, so they can apply lean principles. See the box above, "Some Commonly Accepted Characteristics of the Three Approaches to Manufacturing" and the chart on page 12.

What Took So Long?

Aside from a few exceptions, most process-industry lean journeys began within the past decade, nearly a decade after discrete companies. Bill Schwartz, executive vice president of TBM Consulting Group, said his firm started seeing increased interest from process companies about five to six years ago. "They'd call and say, 'We make things, but we don't make parts, we don't assemble. Will lean work for us?'" Schwartz said. Other consultants and practitioners tell a similar story. Jamie Flinchbaugh, founding partner of Lean Learning Center who worked at DTE Energy during its initial lean transformation nearly a decade ago, said the number of food manufacturers that his company works with has steadily increased since his firm launched in 2001. Bob Iversen, managing partner, The George Group, figured the time frame at around six or seven years ago. Exploring the reasons for this delay provides clues to why and how lean needs to be translated to meet process manufacturers' needs.

Perhaps the main reason lean took longer to gain widespread acceptance among process manufacturers is the same reason any company or group of companies give for not implementing lean: "Because we're different." Part of this is human nature: When presented with change — a new approach to work, a new organizational structure — it is common to

recoil and reject the new idea. Because lean originated at an automobile company, other similar OEMs and tier one suppliers simply found it easier to adapt. People in discrete manufacturing could relate to it, people in process could not.

For some process manufacturers, the slow uptake could be the result of a more visceral reaction: "Often these executives do not think of themselves as manufacturing companies," Schwartz said, noting that process company leaders identify more with the vertical industry than with manufacturing in general. "They almost bristle at the suggestion; they just think that process is different." Indeed, process manufacturing is different from discrete — in many cases so different that it's easy to see why many executives at process manufacturing companies initially don't think lean applies to them.

In the most extreme, discrete and process manufacturing can be diametric opposites. With discrete you are putting things together, but with process you're pulling things apart. Examples include oil refining, paper-making, and some food processing, such as with chicken and beef. Oil refineries pull apart molecules in crude oil to produce gasoline, kerosene, diesel, and other products. Paper mills produce huge rolls of paper which are cut into smaller units for sale. Chicken and beef disassemble, well, you get the idea. "You have assembly lines for discrete and disassembly for process," said Peter G. Martin, vice president, Invensys. Similarly, discrete builds products from parts, while process creates products through material transformation.

Also, in many continuous process industries the concept of customer demand — let alone the lean concept of demand leveling — is a foreign concept. These industries, such as oil refining and mining, operate in markets where there's a market-clearing price. "Reasonably, you can sell whatever you can make," noted Iversen. "The price may go down, but you can sell it." In such situations, the single constraint is throughput velocity, and what matters is optimizing the product from an economic standpoint.

Lean's focus on making work visual also can be difficult for process manufacturers to understand. While in a discrete process, the work is done in full view of operators and managers, in process, much of the work is completed inside a series of pipes and tanks, essentially invisible. "A lot of this work is harder to see, so we need better skill, more tools or better observation," Flinchbaugh said. In most continuous and batch processing plants, technology — especially instrumentation — not lean, has been the method by which they've made production more "visible" to the operators.

Other Improvement Tools

These and other differences likely drove process companies to pursue other improvement efforts, such as new equipment, six sigma, and technology, before pursuing lean. For example: "A lot of process manufacturing is capital intensive by nature, so a lot of process improvement was focused on capital, not on how I design, manage, and improve the work," Flinchbaugh said. They could make significant improvements by buying a higher capacity furnace or bagger and double output, so they did.

Likewise, process manufacturing tends to require the simultaneous management of many variables during production, so six sigma promised bigger benefits compared to lean. For example, Eastman Kodak's photography paper-making process has paper running through equipment at 1200 feet-per-minute while being coated with eight or nine chemicals, at a particular temperature and for a specific length of time. "They'd have this huge six-foot roll of paper, and would have to go back, test the paper, and cut around the bad stuff," Schwartz said. "They'd get good quality, but a big loss." Six sigma was the best way to improve yield.

Interestingly, just as many process companies who've spent time implementing six sigma are now implementing lean, many discrete manufacturers who've implemented lean are increasingly integrating six sigma.

Another common hurdle that deters manufacturers from pursuing lean is that

Discrete	**Batch Process (often called "Hybrid")***	**Continuous Process**
Production or assembly of parts with measurable dimensions	Production of batches of product	Continuous production of product usually measurable by weight and volume
Focus on one-piece flow	Focus on appropriate batch size	Focus on speed, throughput
Production staged through work cells	Production determined by time/end point of batch processes	Production runs may last years; output may vary depending on raw material and run conditions
Parts are assembled on assembly lines or in work cells	Product is made through material transformation, most often by combining fluid and dry raw materials and the application of heat or pressure and time	Product is made through material transformation, by either combining or separating liquids or gases (or fluid-like substances, such as powders) and applying heat, pressure, and time May involve chemical/biological reactions
Work is visible	Work is invisible in the batch stage, but visible in the packaging stage	Work is invisible to employees. Sensors and and other instrumentation make work "visible"
Tends to be more labor intensive Can be manual or automated	Tends to be more capital intensive Highly automated	Tends to be highly capital intensive Very highly automated
Uses relatively smaller, moveable equipment	Uses large, interconnected and co-located equipment for both batch process and packaging	Uses large, interconnected and co-located equipment
Examples include: automobile aerospace medical devices	*Examples include:* brewery pharmaceuticals food	*Examples include:* refining power generation (output not measurable by weight and volume) paper

* Many factories and even industries that produce batch quantities of product sometimes are referred to as "hybrid" operations because they employ significant amounts of both batch and discrete operations in the same facility; they make batches of product, then package it on high-speed lines.

many executives still mistake lean tools for lean. They think if they use lean tools, they're lean — or at least "doing lean." As many discrete manufacturers have found, that's not true. For discrete manufacturers, this mistake limits lean's power; for process, it makes lean appear irrelevant. Some of the most prominent lean tools focus on material flow — a problem that process manufacturers don't have because it is automated within the process. Therefore, such tools as kanban, kitting, water-spiders and milk runs don't translate well to process manufacturing.

Similarly, the idea of one-piece flow is difficult to translate to continuous process operations because there are no "pieces" to flow. The raw material is most often a liquid, such as crude oil in the refinery process, or a solid that behaves in a fluid manner, such as the sand and other materials that go into plate-glass production.

Flinchbaugh explained: "Material moves, but it's all in a pipe; there's no managing it. You have no intervention as you process coal into heat, water into steam, and send steam through a generator to generate volts or amps. The same goes with turning cream into butter." Indeed, Martin said, "If you think of lean's emphasis, the object is to get discrete manufacturing working more like continuous process manufacturing." Viewed from this perspective, lean doesn't appear to offer much benefit to process manufacturers.

Also, with such intense focus on capital as having the biggest impact on production improvements, lean's focus on employee engagement as a source of improvement seems less important. Though some discrete manufacturers have made great strides in creating cells where one line worker operates more than one piece of assembly equipment, process companies routinely have very few operators running huge lines. For example McCain Foods Limited, maker of

frozen foods, makes 15 tons of French fries per hour on one line with five operators. Likewise, cellular manufacturing is another prominent lean approach that does not translate well to process operations. Most equipment in process operations is already co-located and tightly linked — it's cellular by design.

Translating Lean

As advanced lean practitioners will tell you, however, lean isn't about applying a generic tool to a standard practice; it's about understanding specific work within the context of the value chain and adapting lean tools to improve work flow, eliminate waste, and make the work visual and self-diagnostic. It's about creating a culture of continuous improvement where work is designed to reveal problems that employees are trained and empowered to solve. To understand how lean applies to process manufacturing, executives must look beyond the differences that traditionally define process and discrete manufacturing. They must also realize that lean is about more than just the tools and understand the lean principles upon which lean tools are based. Process manufacturers who have been successful implementing lean don't dwell on situations where lean concepts don't apply; they get to work identifying where lean concepts work.

Each industry — some would say each company — has particular characteristics that influence how work gets done and the relative importance of particular lean tools. Looking closely at the work reveals the areas where discrete and process manufacturing are similar and, therefore, where lean will be effective in process manufacturing. Some industries traditionally classified as process manufacturers contain significant discrete characteristics — just as many discrete manufacturers run process-like areas within their factories. The food, beverage, and pharmaceutical industries, for example, produce large batches of product at the beginning of the line, then boxes or bottles — discrete units — for shipping at the end. These companies are traditionally considered process industries because they produce big batches and their highly automated filling lines (the disassembly of the batch into saleable units) are so fast they operate more as a process. These and many other industries traditionally known as process industries aren't "pure" continuous process manufacturers like, say, oil refineries.

For example, paper manufacturers continuously make huge rolls of paper which are cut to make smaller rolls while the equipment continues to run. Once a roll is cut off, it is moved to another location for further processing, perhaps to add a coating, to cut into smaller rolls, etc. — there's material handling and WIP, but there is no assembly. Consumer packaging companies run huge printing presses, producing monstrous rolls of product. But they aren't assembling; they're moving skids of cardboard — WIP — around. Both are traditionally considered process industries, but a closer look at the specific work reveals where lean could streamline operations.

To help translate lean to process manufacturing, Iversen recommended viewing manufacturing operations not as a discrete versus process dichotomy, but rather as a continuum from "pure" continuous process manufacturing to "pure" discrete. While more a mental exercise, doing this will force executives to look more closely at the work, and help reveal where lean may apply. For example, if placed on a continuum rating industries from "pure" continuous process on the left to discrete on the right, oil refinery, electricity generation and mining operations would be placed to the far left, as the more "pure" continuous process industries. By comparison, paper mills, pharmaceuticals, food and beverage manufacturers would fall in the middle, as batch operations, with some process characteristics and some discrete characteristics. Automobile, aerospace and other discrete manufacturers would be placed furthest to the right.

Viewed this way, it's easier to see that many process manufacturing companies, especially those with batch operations, can benefit from lean practices. Ultimately, "You've got to understand what processes

and which problems matter, and where you have opportunities to improve," Flinchbaugh said. "The operating system principles come first; then you pull out the tools."

Where Lean Works

Some lean tools and concepts are easier than others to adapt or translate to process operations. Keeping in mind the dangers of oversimplification and the need to understand work in the context of the value chain, what follows is a list of tools that are most likely to benefit batch and continuous process manufacturers.

Total Productive Maintenance

The lean concept that most easily translates to the process industries, with their dependence on huge, continuously-running equipment, is Total Productive Maintenance (TPM). Relatively speaking, process manufacturing is more dependent on automation than discrete manufacturing. The equipment in process tends to be much bigger and more expensive than that used in discrete manufacturing, and keeping the equipment running and making good product is that much more critical.

Schwartz said that TPM was among the first aspects of lean that TBM offered for process manufacturing clients, conducting what's become known as a TPM blitz. With a TPM blitz, a cross-functional team reviews all the equipment manuals, observes the equipment as it works, and talks to the operators. They "blue tag" everything wrong with the equipment: dirt, sensors, guards, oil leaking, product leaking, and the like. The team also watches the equipment for a day, noting every time it slows down or stops, which helps identify the most critical bottlenecks. Then maintenance fixes all the problems with the equipment, cleans it from top to bottom and starts an autonomous maintenance program, including a flight check of the maintenance tasks an operator should do everyday, such as checking oil level, temperature, safety guards, and sensors.

"At the end of the week, we'll have restored the machine to like-new and have taught the operator to hear and see, for example: This vibration isn't normal, so the bearings might be a problem." Schwartz said. "It's phenomenal to see how the operator takes ownership of the machine: It connects the operator with the machine in a wonderful way." Average OEE improvement from a TPM blitz is five to ten percent.

Iversen recommended that process manufacturers go beyond TPM and consider implementing more sophisticated maintenance techniques such as Reliability Centered Maintenance (RCM). Martin said that industry giants such as Exxon, BP, Dow, and DuPont and others pioneered and set the pace in RCM, preventive maintenance and predictive maintenance, though they did not call it "lean;" they did so because equipment uptime is so critical to their continuous process operations.

5S/6S

Another lean concept that directly translates to process manufacturing is 5S (some companies call it 6S). While lean practitioners agree the tool works nearly everywhere, process manufacturers have found particular benefit by implementing 5S in offline maintenance. Iversen said: "In the manufacturing work that I've done, we've increased the number of work orders — the number of routine maintenance completed — per hour by 50 percent to 60 percent by using lean techniques to frame the problem, understand the value driver, pick the right tool, and use it."

Particular attention should be paid to reviewing — and challenging — maintenance standards, according to Keith Sinclair of Sinclair Associates, Inc. Work his company has done found the real time to perform routine maintenance work is a fraction of the benchmark metric. He noted that in one example they found that truck maintenance that historically was expected to take eight hours, upon examination took only four hours. "We had four hours of looking for tools, waiting for parts, and material, etc.," he said.

"We have built waste into the structure and we don't challenge ourselves to say 'Why not six hours,' because we're happy that we met the expected time,"

Sinclair added. "But the essence of continuous improvement is that we challenge the standards."

Theory of Constraints

While theory of constraints is used in discrete manufacturing, it's more important to process manufacturers, "because the big value lever in process is throughput velocity," Iversen said. Process manufacturing facilities tend to have more, and more tightly, interconnected equipment and processes than their discrete counterparts, making the optimization of the links between equipment more critical. Products at discrete plants are more often produced at assembly equipment and workstations, where a problem at a particular piece of equipment remains contained to a small part of production. Products in process facilities often progress through the same processing line, so anything that affects step one affects step two and can affect the entire factory. "You have to find the limiting resources and set up systems to maximize them, to make sure the throughput isn't constrained by that process," said Sinclair. This means process manufacturers may have to run equipment on either side of slower equipment at less than rated capacity to maintain continuous flow and to avoid excess WIP inventory. Lean tools, such as value-stream mapping, can help identify these bottlenecks.

Inventory and Leadtime Reduction

Inventory and leadtime reduction is where adapting lean to process industries gets interesting because it is where continuous, batch, and discrete manufacturing require significantly different approaches to lean. Continuous process companies don't produce inventory because raw materials are continuously transformed into product within the equipment and sold at the market-clearing price. "In some operations, on the discrete side of the world, we talk about inventory reduction, but look what's underneath that, it's that and that the processes are highly reliable and the ability to meet takt time is reliable," said Sinclair. Continuous- and batch-process manufacturing are very highly reliable in this regard.

Batch process operations are similar to continuous processing in that they do not produce WIP inventory in the process that makes the batch, but are similar to discrete operations in that a batch can be viewed as a part — as a consumer product to be packaged into smaller units for sale, as an intermediate to be added to another process at the plant to make a final product, or as an intermediate to be sold to another company for incorporation into its product. Because process companies do not generally refer to intermediates as WIP inventory, many executives running batch process operations don't believe they need to use the lean tools that reduce inventory — and many batch manufacturers have other approaches to keeping intermediate product production to a minimum. However, significant reductions in the amount of product waiting in holding tanks for further processing can be achieved by applying lean principles.

Also, because batch manufacturers run multiple products through the same equipment, they tend to produce more excess finished goods (FG) inventory and have slower FG inventory turns. This results because the time to cycle through all the different products can be long and inventories must supply demand during the cycle. Plants that produce a wide variety of products are particularly vulnerable to this problem. For batch-process manufacturers then, inventory and leadtime reduction are achieved by producing smaller run sizes more often, which in turn can be achieved by reducing changeover times (as well as by increasing up-time of equipment). Lean techniques are perfectly suited to help batch-process manufacturers achieve these goals.

Quick Changeover

Likewise, the concept of changeover is different for process and discrete manufacturers — and different for the two types of process manufacturers. By definition, continuous process manufacturers do not conduct product changeovers. Continuous process facilities, such as those in refining, power generation, and paper mills often run for

years without stopping. If they change their output, they do so by adjusting the settings on the equipment. For example, an oil refinery might change the temperature to produce more methane and less diesel, or a rolled steel plant would squeeze the roller down or open it up while the equipment continues to run to produce a different thickness of rolled steel.

Also, unlike discrete parts manufacturers who make cars or refrigerators, the goal for continuous process manufacturers is to make as much product as you can for as long as you can. Eventually, however, after a certain number of years, the continuous process manufacturers must shut down the entire plant for maintenance and, often, to upgrade the equipment. When it is shut down, it is generally down for a long time, which is very expensive. Indeed, the profitability of the plant can depend on how well the multi-week downtime is handled. According to consultants at A.T. Kearney, a day of lost generation might cost a utility as much as a quarter of a million dollars.

"In the case of an electric utility, you run a power plant 24/7 until you take it down for the multi-week downtime, which could last as long as ten weeks. If the company can take that down to eight weeks, that's two weeks they don't have to buy power on the open market," explained Flinchbaugh. (Power plants are legally obligated to provide power to their customers). "If they take longer or don't plan well, they'll have to buy on the spot market." Using lean principles, continuous process manufacturers can streamline and reduce the length of such planned downtime.

For batch process manufacturers, changeover is more frequent than continuous process but less often than most discrete manufacturers. While at first glance it therefore might seem that changeover would matter more to discrete parts makers — especially those with low-volume, high-mix production — changeover can be just as crucial to the overall business performance of a batch process operation. For the discrete operations, frequent quick changes of equipment to make a different product can be vital to achieve a work-to-order system, a common lean goal. For batch operations, faster changeovers are key to controlling inventory.

Also, in discrete manufacturing, changeover tends to be repeatable, because it's more frequent. In process, because changeovers are less frequent, they tend to be less repeatable — indeed, it's possible that no two changeovers will look alike. "Some of the routines in process may never happen again," Flinchbaugh said, noting that standardization should therefore focus on pre-observing the changeover. "Get material in place, resources in place, and the plan in place — everything lined up like a pit crew."

For example, E.A. Sween makes a million sandwiches a week and every evening must completely sanitize the entire line. A recent kaizen event reduced this changeover time from eight hours to four hours, as well as reduced the number of people needed to complete the task, cutting costs dramatically. Similarly a brewery or other beverage maker that makes multiple products in sequence on a particular line must clean the tanks, change bottle lines, etc. Doing that faster helps them to make more of each product, and lean concepts can help.

Cycle Time Reduction

Cycle time reduction also takes on a different meaning in batch process manufacturing compared to discrete. When making parts, the emphasis is on maintaining takt time, something that is largely taken care of by the equipment in process manufacturing. Still, process manufacturers should be on the lookout for steps in the production process that take place outside of the equipment. For example, Sinclair described a precious metals recovery operation. The company takes in the customer's metal in a variety of forms (scrap, powders, blocks, etc), they assay it to determine the amount and type of precious metals (such as gold, silver, platinum, and palladium) that can be recovered, and pay the customer accordingly. The number, timing, and processing complexity of each batch receipt is "undefined and unpredictable." Once these initial steps are completed, the material enters the process of smelting, leaching, and extracting the precious metals,

which are sold to the metals market. To assay the incoming metal, technicians must follow discrete steps. They log, prepare, process, and sample the material, then predict how much value there is in it. "It's a four-hour touch time with a four-day flow time, and that's at the front end of a processing plant," Sinclair said. "There is a lot of touch and wait time, there's queuing up between the steps — that's textbook lean flow." However, because these discrete steps are part of a process operation, they often can be overlooked.

Cycle time as it is defined in discrete manufacturing (the length of time from the start of production to the final assembly and testing for a particular product or customer order) translates to batch processing as the time it takes to make a batch of product. In addition, many batch process manufacturers, such as Dow, have successfully used lean concepts to reduce the time it takes a processing line to cycle through making one batch each of all the products made on that line. Dow calls the concept "Every Product Every Interval" (EPEI), while others refer to it as "Shrinking the Product Wheel." By shrinking the product wheel, the batch processor becomes more flexible and produces less inventory (to meet demand while the line produces other batches of other products). In some cases, shrinking the wheel can eliminate the need to install a parallel line to meet an increase in demand.

One-Piece Flow

As mentioned above, one-piece flow is incorporated into the equipment in process manufacturing, so executives often fail to see how a lean initiative to achieve one-piece flow is necessary. But process manufacturers can gain significant improvement streamlining inbound material and outbound products by focusing on material handling outside the four walls of the plant.

Though getting material into the factory is similar for both process and discrete manufacturers, the amount of material being handled by process manufacturers can be vastly different. "A utility buys coal by the freighter full, not a milk run," Flinchbaugh said. "The material ordering system, getting raw materials in the door — those transactions are more important in any business, but they're probably more important in process industries." Smaller operations, such as some biopharmaceutical operations, may handle small quantities of material, or material that requires special handling (storage within a particular temperature range) or that must be used by a specific date. Either way, the more efficient material handling gained by applying lean principles is beneficial.

Quality

Even the concept of quality is different for discrete and process manufacturers. "In parts manufacturing, you typically cannot measure a quality variable until after the component is made, such as the diameter or roundness of a hole," Martin explained. "In process you measure your quality variables in process." This difference affects the types of quality measurements you implement, the way you respond to a mistake, and the way you apply lean. For discrete, you'll probably take random samples of product, measure how you're doing to a specific metric, then use statistical techniques to figure out the root cause of the problem. In continuous process manufacturing, if you take a sample of gasoline and the octane level is 97, the entire batch is 97. "If you're supposed to make 88 octane gasoline and you're making 87, you just add octane," Martin said.

"Quality in discrete is a reduction in defects," he explained further. "In process, quality is a limit." For example, if you want to sell gas as 87 octane but you mix up and deliver 88 octane, the driver is not going to give you any additional credit for that improvement in quality. "So quality in process isn't a matter of having higher quality, it's to control the quality variable to where they want it, without going over."

In process operations, quality often is referred to as the "grade" of a product and, consequently, determines the price the manufacturer can charge for it. This is

hardly ever the case for discrete manufacturers. However, bearing manufacturers who can determine the tolerance within which a bearing is made have been known to sell higher-grade bearings to customers who require them — presumably at a higher profit. The processing of agricultural products, carpet, and paper are other examples where the manufacturer can choose which level of quality to produce based on demand. Of course, the highest quality will sell for the highest price, and the highest possible yield of the highest quality, therefore, often is the goal.

Standard Work

For a discrete manufacturer, standard work refers primarily to detailed work instructions for line workers to assemble components, sub-assemblies, or end products. Process manufacturers usually employ equipment operators whose job largely is to monitor the equipment. In continuous operations, the operator can be expected to do essentially the same job day after day. In batch processing, the operator's role may vary hour by hour, day to day, depending on which product is being made or whether a changeover is being done. "In a lot of process industries you won't have a single person performing closely-defined repetitive work," Flinchbaugh explained. "They'll have a technician with a range of skills. You don't know what a day will look like." Still the standard work concept applies to both continuous and batch processing operations. "Their job isn't standard, but they have routines and activities within their job that are, such as how to respond to an alarm." Flinchbaugh said. "I don't standardize the job; I standardize the activity within the job."

Culture Change

At the more sophisticated level, creating a lean culture is a strategy that can benefit any business, but even here some process manufacturers may need to make some adjustments to the standard lean approach. Since many processes run within the equipment, they tend to be very stable. Changes to the processes often must be cleared through multiple layers of management to avoid costly mistakes. Other process manufacturers may be required to clear any changes with regulators. The standard lean approach to employee engagement, which encourages frequent and sometimes autonomous employee-driven changes to standard work, may not apply. Still, in such situations, striving to have every employee see and solve problems can be applicable. For example, an employee monitoring a continuous process could be trained to notice, quickly diagnose, and fix certain problems with faulty sensors by following a specified standard procedure. (Again, most of the largest global process manufacturers practice such an approach, but may not call it lean.) Also, process manufacturing executives can create a lean culture for work done outside the equipment and where work is not regulated.

Key to creating a lean culture is designing work processes that are self-diagnostic and where employee engagement in continuous improvement is high. "It's all about designing processes to reveal problems," is a popular refrain of advanced lean practitioners. In such an environment, Sinclair said, "standard work — work systems, content sequence and output, work procedures, and work design — will have been built on an underlying hypothesis, such as: 'If I perform this task in this sequence, I will build it in this time. The learning cycle takes place as part of the work — every time I am unable to perform the task in sequence is a signal that there is a problem. Fixing the problem is a learning and continuous improvement opportunity.'"

Further, Sinclair said: "All systems are basically comprised of a collection of work tasks. They connect. You start to talk about if I have a task and another person has a task that's depending on mine. Then that naturally leads into, 'Let's examine the workplace and see whether it is designed to inhibit or interrupt that work.' We've had incredible success with that concept by itself."

As for the idea of getting the worker involved in daily improvement, most people would agree with Schwartz: "That's the same in any plant, even a service company."

Why Now?

The push by increasing numbers of process manufacturers to implement lean is being driven by several forces. For some process manufacturers that have continuous improvement mindsets — those who've aggressively deployed automation, total quality management, six sigma, and other initiatives — lean is the next logical step. As the realization that lean is transferable to non-manufacturing industries and to non-production functions, more process manufacturers who initially may have been skeptical are ready to take another look. If lean can be translated so it works in government and health care as well as in accounting and human resources, it can work in process manufacturing.

Meanwhile, the market is forcing process manufacturers to become more flexible in order to satisfy customer demand for a wider variety of products. Toothpaste manufacturers don't produce a few brands of toothpaste, but rather a bewildering array of gels and pastes, each in a variety of flavors and targeted to specific dental health needs, such as whitening, tartar control, and cavity protection. Also, big-box retailers, such as Wal-Mart, often require special packaging. Even rolled steel manufacturers who once enjoyed the luxury of scheduling customer orders in a sequence best for the manufacturer, are now forced to alter the manufacturing schedule to better meet customers' more stringent delivery requests. Producing this variety and meeting customers' shorter leadtime requirements challenges the process manufacturers' traditional focus on long runs and big batches, and lean can help them make the transition.

Initially, batch process manufacturers might react to a demand for a greater variety of products by increasing inventory of the product. "They figure: 'I have the thing running corn flakes, why would I want to change over to [something else] and mess up my absorption credit?'" Schwartz said. Increasingly, however, they're recognizing the additional inventory as expensive waste and find they have to find a way to accommodate the additional changeovers. "It's changing their philosophy." Schwartz said. "A [batch] process plant is typically not designed or engineered to be flexible and that's part of being lean, to make the lines more flexible."

Executives also are facilitating the translation of lean to process industries. As executives running discrete facilities move to run process industries and consultants expand their client base outside of discrete manufacturing they're transferring — and translating — lean concepts. The translation requires sometimes subtle, sometimes substantially different interpretations of such basic lean terms as one-piece flow, quality, inventory reduction, changeover, and others. It's only when you are willing to look closely at the work through the lens of lean principles that you'll be able to unlock the potential of lean for a process operation. What most processing companies who've implemented lean have found is: "The concepts apply, but the way you apply them is very different," Martin said. As more process manufacturers implement lean and begin telling their stories, more ways to implement lean concepts to meet the needs of process manufacturers will become more apparent — and will open new doors of lean opportunity for all manufacturers.

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