ENGAGING THE ENTIRE ORGANIZATION IN IMPROVING RELIABILITY

Winston J. Ledet
The Manufacturing Game™
3355 Lenox Road Suite 700
Atlanta, Georgia 30326 USA
(404) 467-0911 Phone
(404) 467-0811 Fax
WJLedet@aol.com

ABSTRACT

By engaging the entire production organization in improving reliability, we have been able to achieve substantial results with less inherent risk and in a shorter time frame than the traditional approaches to reliability improvement. In the U.S., reliability has been traditionally tackled as a functional task for the maintenance department. The traditional approach to reliability improvement involves big investments in information systems, data gathering, planning systems, mechanic skills, scheduling systems and reorganizations. While this approach has produced substantial results at some companies, it has several inherent risks. Many industrial companies have begun traditional efforts at improving reliability only to see them sputter out over time.

Based on benchmarking and modeling efforts started at DuPont and work we have done with over 25 clients, we have seen that the best maintenance in terms of reliability is also the least expensive. The key to achieving this world-class performance is engaging the entire organization in eliminating the *defects* in the system. We have developed an approach using an interactive simulation called The Manufacturing Game™ that demonstrates the potential value of improved reliability, builds passion in the organization to make the necessary changes, creates a common vision of the "right ideas" and launches the action required to begin the improvement. The result has been dramatic improvements in operations and bottom line performance that have come quicker and with less risk than the traditional approach.

INTRODUCTION

Improved reliability can produce dramatic bottom line improvements but to achieve world-class performance a fundamental shift in the nature of the work is needed at all levels in the organization. By engaging the entire production organization in improving reliability, companies that we have worked with have been able to achieve substantial results with less inherent risk and in a shorter time frame than the traditional approaches to reliability improvement.

In the U.S., reliability has been traditionally tackled as a functional task for the maintenance department and has been primarily viewed as a technical exercise requiring large investments. While this traditional approach has produced substantial results at some companies, it has several inherent risks. Most large industrial companies have tried some version of this approach only to see it fail due to lack of commitment, lack of focus or lack of understanding.

The prevailing mental-model in industry has been that reliability can only improve with large capital expenditures or increased maintenance cost. However, world-wide benchmarking at DuPont showed that, in fact, the best maintenance in terms of reliability is paradoxically the least expensive. Just as importantly, these same benchmarks show that many of the technical elements of the traditional reliability approach are not present in many of the best-of-the-best performers. To understand this paradox better, DuPont created a model of plant reliability in the early 1990s using System Dynamics to get at the underlying structure. By applying that model to over 25 companies we have found that the key to achieving better reliability at a lower cost is to eliminate the *defects* coming into the system by engaging the entire organization in removing current defects and changing behaviors that introduce and ignore future defects. To create this sort of culture change in an organization, you have to find a way to: express the value of the change to people in a way that is meaningful to them; build the passion to change the situation; get everyone focused on the right ideas in a way that works in your environment and get the action of improving started.

DuPont created a workshop that we now use with other manufacturing and process companies that effectively engages all levels and functions of the organization. The centerpiece of this workshop is The Manufacturing Game™, an interactive simulation of a plant, that: allows participants to self discover the value of changing, creates a common vision of the "right" ideas, generates a lot of grass roots passion to improve things and launches the action required to get improvements started. Several large manufacturers and producers have used this approach with a large portion of their front-line workers and managers to jump start the change in culture required to achieve the best-of-the-best in reliability. By engaging the whole organization, the work that the traditional approach seeks to optimize is simply eliminated. Many of the tasks that seem important and daunting in the traditional approach are trivial when a large number of the defects in the system are eliminated. We have found that improvements in operations can begin within 90 days and bottom line improvements are possible within the first year versus the 3-5 years required by the traditional approach.

THE IMPACT OF POOR RELIABILITY

Everyone in maintenance always wants to know, "Why is maintenance treated like a cost?" The obvious first reason is that maintenance *is* a substantial cost. DuPont, for instance, spent roughly the same amount on maintenance as they earned in net income each year and as much as they spent annually on R&D. Maintenance costs can run from 5-50% (Campbell, 1995) of total manufacturing costs depending on the industry. The second reason maintenance is treated like a cost is that in spite of all of this expense, management often feels like they do not get reliable equipment. The impact of poor reliability, however, goes well beyond the maintenance budget.

As an example, let's consider a plant that produces 140,000 tons of product per year with a margin of $50 per ton (net margin of $7,000,000). It has a $29 million replacement value and a $6 million operating budget of which $1mm is maintenance. The operating profit of this plant would be $1mm ($7mm net margin - $6mm operating costs). Let's also assume that the plant is capacity constrained and has an availability of 90% (including planned down time), an efficiency of 90% and a quality rate of 90%. While this seems like decent reliability, the overall effectiveness of this plant is just 73% (90% x 90% x 90%) which is 12 points below world-class levels. The maintenance budget is 3.5% of replacement value which is 1.5% higher than world-class standards. This same plant with world-class reliability would make an additional 23,014 tons of product for an additional net margin of over $1.1 million and would have $420,000 less in maintenance cost. The overall plant profitability would soar to over $2.5 million - more than two and one half times its current level!

Once the value of world-class reliability becomes apparent, the logical next question is how to get there. In the U.S., most companies have taken the approach of improving the efficiency of the work that they are doing today. This article describes the traditional approach, some of its inherent risks and an alternative approach that we have seen work at several large producers.

THE TRADITIONAL APPROACH TO MAINTENANCE IMPROVEMENT IN THE U.S.

Once U.S. companies or sites decide to pursue increased reliability, they generally take the following approach which is recommended by several of the maintenance gurus and publications:

1. Reduce reactive work by building a Preventive (interval based) Maintenance Program which requires:
   - A good Computer Maintenance Management System
   - Computer skills training for operators and mechanics
   - Historical data loading and analysis
   - A reorganization to fill the roles of planners and schedulers
   - Training for maintenance on new procedures and roles
2. Add a Predictive (condition based) Maintenance Program which requires:
   - Acquiring appropriate predictive tools
   - Training for personnel on the use of technology
   - Creation of standards and readings database
   - Potential reorganization to put personnel in new predictive roles
3. Build a Proactive (root cause based) Maintenance Program which requires:
   - Root cause or RCM training for front-line personnel
   - Training for alignment and balancing
   - Potential reorganization to align maintenance and operations more closely

The entire process takes about 3-4 years and requires a substantial investment. This approach is very functional in nature; it is primarily a maintenance task. And it is a technical approach. The mentality is: “If we could just have all of the relevant data, and all of the best maintenance tools and training in the latest techniques, we could improve our performance.” Most large industrial companies have started down this path multiple times only to give up along the way because they just didn’t see the payback that they needed.

Why is this Approach so Hard to Implement?

The traditional approach outlined above requires a consistent and coordinated effort over a prolonged period of time. It also requires a large investment and performance often worsens before it improves. Finally, most successful implementations of this approach are “champion” driven which means the program is just one promotion, demotion, or loss of focus away from getting killed.

This functional/technical approach to improving reliability has risen out of two valid underlying assumptions: 1) maintenance work done in a predictable, planned mode is inherently more efficient and effective than work done reactively (Hudachek & Dodd, 1985) and 2) all of the systems, information and people must be in place to make the work more plannable and predictable. However, it ignores some very important realities. First, it requires that a lot of new work get done (e.g., planning, predictive work, machine history analysis, inventory management, re-engineering.) Most of this work is poorly understood so it is inherently slow as people work up the learning curve. In the meantime, the plant is still in a reactive mode and all of the old work is still there. While management might see the new work of planning and predicting as more important, they will invariably see the old work of failures and emergencies as more urgent. Second, there is a large monetary investment in skills training, computer systems, diagnostic equipment etc. that can be an easy target for future cost cutting. Finally, there is the risk that some of these projects, like installing a new Computerized Maintenance Management System, can take on a life of their own and lose the focus of improving equipment reliability.

DuPont was a classic example of the pitfalls of this approach in the 1980s. They would implement pieces of this approach only to see them peter out over a few years. It wasn’t until they took a focused approach with serious corporate buy-in and proper financial backing that they were able to achieve the impact that they desired. Once they took this coordinated approach it still took them nearly 10 years as a corporation to move from average performance to near world-class.

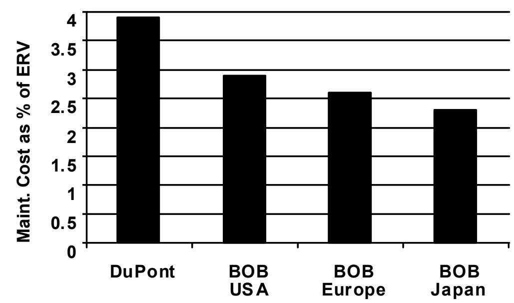
We have discovered, through efforts at DuPont and the work we have done over the last four years, how to accomplish similar results, attaining world-class performance, in a much shorter time frame with substantially lower risks. The key difference between our approach and the traditional approach is that we focus on eliminating the work that the traditional approach spends so much time trying to optimize.

ELIMINATING THE SOURCES OF POOR RELIABILITY - DEFECTS

The basis for our approach originated in DuPont in the late 1980’s. Faced with a decentralization of their maintenance department, DuPont was interested in how to sustain their functional excellence in maintenance. DuPont, normally an inwardly focused company, did something fairly unusual at the time. They engaged A.T. Kearney to benchmark their performance against the “best-of-the-best” in the U.S, Europe and Asia (Figure 1) (Jones, 1991). DuPont found that they didn’t need to worry about losing functional excellence because they did not have it to begin with. The most dramatic difference in performance was with the Japanese who had much lower costs with greater reliability and lower stores inventory.

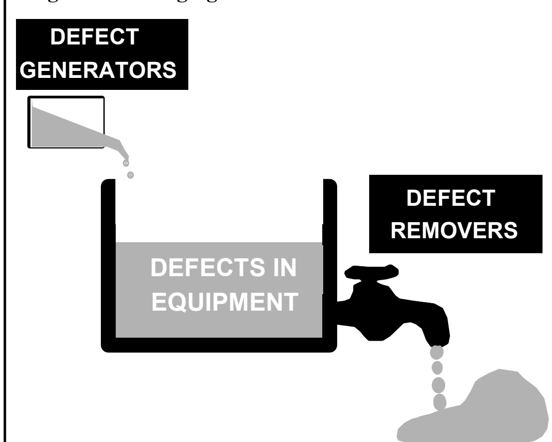
Up to this point, the focus of the benchmarks had largely been on the maintenance function and mainten-ance cost. Statistical analysis of the benchmarking data seemed to indicate that just a few variables in the benchmarks accounted for almost all of the variation in performance but all of these variables were fundamentally cost variables. The implication of this analysis was - focus on cost reductions to achieve "best-of-the-best" performance. However, the benchmarking team who had participated in the site visits during the benchmarking knew that the best performers did not focus on cost much at all. They had a suspicion that these improved cost factors were the *result* of good maintenance and not the *cause,* so they began to dig more deeply into the structure of reliability.

Figure 1: Best-of-the-Best (BOB) Maintenance Perfromance (1986)



DuPont decided to use System Dynamics Modeling to better understand the structure of reliability. System Dynamics is a discipline that came out of MIT in the 1960's and was created by Jay Forrester (1961). It has gained popularity in the last seven years with the publication of *The Fifth Discipline* by Peter Senge (1990) and the introduction of easier to use computer modeling tools. System Dynamic modeling focuses on discovering and articulating the underlying structure of a system and then looks for key leverage points to change the system. Instead of showing simply a snapshot of what performance might look like at the end of the journey, like a benchmark does, it shows the journey itself.

Figure 2: Managing the Flow of Defects

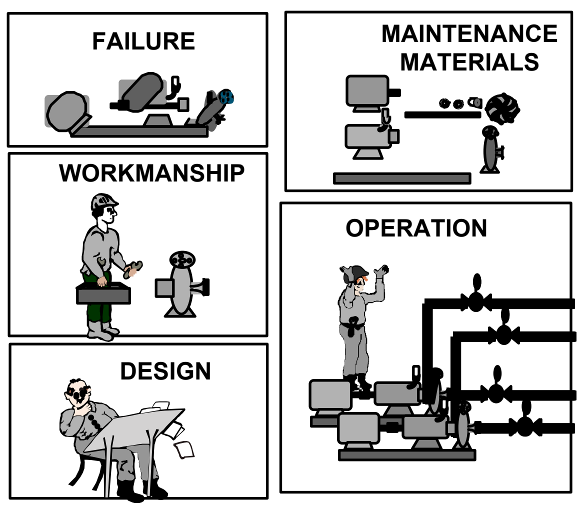


What DuPont discovered through this effort was that maintenance and reliability could best be described as a process of *defect* management. A simplified view of this "mental-model" is presented in Figure 2. We define a defect as “any deviation from perfection” to avoid long arguments about whether a scratch 1” long or 2” long is a defect. By this definition, all equipment has defects, it is just a matter of degree. Defects can come from several sources, discussed in detail later, and the greater the level of defects, the more reliability problems the site will have. Defects are removed through maintenance work either reactively, once the equipment fails or proactively through Preventive or Predictive Maintenance. Through this effort it became apparent that the “best-of-the-best” in the U.S. and Europe achieved their results primarily by removing defects more efficiently through better planning, scheduling, skills in their tradesmen, and predictive technologies. DuPont discovered that it was critical that these things be done in a coordinated manner and not just one program at a time. What was interesting was that the “best-of-the-best” in Japan did not simply have a souped-up version of these higher efficiency techniques. They had a fundamentally different approach; they removed the defects early in their life or avoided putting defects in the equipment in the first place which eliminated the work that came with these defects.

The Sources of Defects

To eliminate defects it is important to understand where they come from. Figure 3 shows the five major sources of defects.

Figure 3: The Sources of Defects



1. ***Defects from quality of materials***. DuPont found that one in three spare parts had a defect of some sort. These defects can be manufacturing defects that the vendor put in but they can also be defects in the way parts are stored, handled and sourced. (example: corrosion on a part from storing it outside)
2. ***Defects from workmanship***.

These defects come from failing to do a proper repair job. At times these defects come from skill gaps in the mechanics, but just as importantly, they can come from failure to apply the skills that are known. In a typical reactive plant there are usually a host of policies, systems and cultures that keep mechanics from doing the best job they know how to do. What counts in workmanship is the quality of the work you actually do, not the quality of the work you know how to do. (example: failing to align a pump before bringing it back on line)

3. ***Defects from failure events***. When a system of equipment fails, extra energy is typically directed to another part of the system. This extra energy will often add new defects that can be the source of future failures. (example: a bearing seizes causing a slight bow in the shaft)
4. ***Defects from design***. To whatever degree the design of equipment does not fit the *current* needs of the business, there are defects from design. These defects can come from poor initial design but usually are the result of changes in the business that do not get reflected in the operations. As the business and operation change over time, the requirements of the equipment will change as well. If the design is not updated and modified to fit the new conditions, defects will be added to the system. (example: the flow through a certain pump is cut way back causing it to run back on the curve and tear itself up)
5. ***Defects from operations***. By our definition of a defect, any equipment that is operated will accumulate some defects from normal wear. However, as any reader with a teenage driver can attest, the way you operate something has a huge impact on the level of defects that are introduced. Many of the defects that ultimately lead to failure are either introduced through operations or are detectable by operations long before they will cause a failure. (example: cavitating a pump, ignoring excessive vibration)

A traditional maintenance focused, technical approach to reliability will focus on the first three sources through preventive maintenance, predictive technologies, vendor audits, parts inspections and skills training but will typically ignore the last two sources. When you focus on limiting all of the sources of defects as well as eliminating the defects currently in your system, the performance improvement can be dramatic.

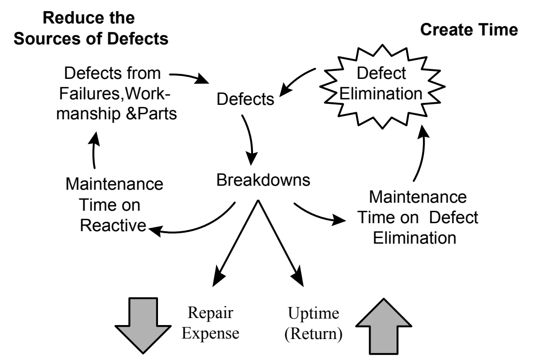
The Dynamics of Reliability

What the model suggested and experience has proven to be true is that by eliminating defects you can accelerate the improvement efforts. Figure 4 is a dynamic illustration of this principal. If you can begin to eliminate the defects in your equipment, (*e.g.,* convince mechanics to laser align all rotating equipment every time, help operations understand the impact of cavitating a pump, throw away parts with known defects, stop ignoring vibration in the equipment) over time there will be a reduction in the breakdowns and emergency jobs. This has two important effects. First, the **sources of defects are reduced** because:

- Defects from the failure events avoided will never be introduced in the first place,
- Defects from workmanship will decline as fewer jobs have to be done, especially the emergency rushed jobs that seldom allow mechanics to do the best job they know how to do,

- Defects from parts are reduced as fewer new parts are installed (*e.g.,* if a vibration is caught early and the equipment is realigned eliminating a failure, one less seal and one less bearing are installed)

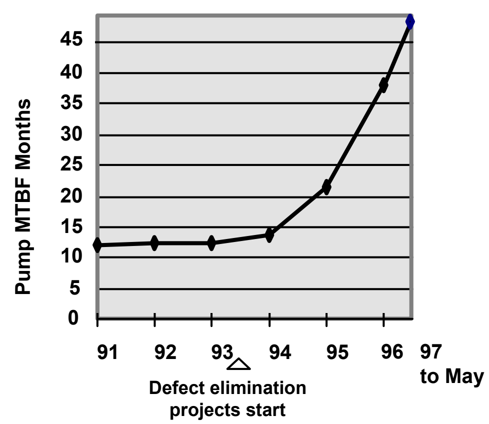
Figure 4: The Dynamics of Defect Elimination



This flow is shown in the left hand loop of Figure 4. This is a virtuous cycle that accelerates the improvement once you get the ball rolling. Second, **time is created** for mechanics to spend on future defect elimination, training , planning and scheduling. This is shown in the right hand loop of Figure 4. In the traditional approach to reliability, one of the risks is not having enough time for the new planned work and the old reactive work. By eliminating defects, you can eliminate some of the old work to make room for the new work and diminish the risk.

We have seen companies reduce defects dramatically over a very short period of time by working on defect elimination. In less than a year, a British Petroleum refinery was able to double its Mean Time Between Failure (MTBF) rate for pumps from 12 months to over 24 months and has since doubled their performance again to 48 months (Figure 5) (Monus, 1997). A major pipeline company was able to reduce call outs in one area from 8-10 per week to less than 1 per week. In both of these cases, there were some benefits in terms of maintenance savings and some potential gains in uptime but most importantly, several man-years of work were eliminated. This time can be re-deployed to more value-added work. This time would never have been available in a traditional implementation.

Figure 5: Pump MTBF Quadrupled at BP's Lima Refinery



Creating a Culture to Eliminate Defects

The key to the improvements at BP's refinery and at the pipeline company was engaging the front-line in identifying and eliminating defects. Our experience has been that it is not enough to get just the managers interested and motivated. This is not the kind of a change where a few committed managers can drag the rest of the organization along with them. The challenge is creating a culture of defect elimination. To create any real change in a large organization, you must find a way to:

- Communicate the **value** of the change both for the business and the individual.
- Build the **passion** in the organization to get the change implemented and overcome the inevitable hurdles.
- Focus the majority of people on the "right" **ideas.**
- Be **sensitive** to the important parts of your organization and culture that shouldn't change or be lost in the process.
- Launch the **action** required to turn your strategies into reality.

The Manufacturing Game™ has been used inside of DuPont for the last six years and outside of DuPont by our organization for the last four years to provide the starting point for this type of change. The Manufacturing Game™ is a simplified version of the System Dynamic model created at DuPont and is played by a team of six on a six foot multicolored game board. Usually four to six teams play simultaneously. The game allows people to experience in a day what would normally take over a year to experience in the real world and gives them the opportunity to take risks that they would not normally take. There are three roles in the game: operations, maintenance and business services, which includes stores and logistics. The game gives these participants a chance to see the whole system and the impact of decisions made in one function on the others and the performance of the whole plant. Participants are also required to play a different role from their normal position so they get a chance to see their world from another perspective and gain some insight into the pressures faced by their counterparts.

The plant in the game starts out with typical reactive performance and the team attempts to make the journey to proactive and profitable operations.

The game is facilitated in a way that participants can self-discover the value of the changes and the ideas needed to accomplish the improvements. Having participants invent the answer themselves is critical for creating the passion needed to make a change this big happen. Instead of tapping into fear as a motivator as many change programs do, the game taps into one of the few sources of intrinsic motivation - invention. And it gets the majority of participants to invent roughly the same idea. But alignment and passion around the "right" ideas is still not enough. For real improvement you need action.

Action is the second key element of The Manufacturing Game™ workshops. The second day of the workshop is primarily focused on translating the ideas and passion developed in the game to the real world through action teams. The concept of action team comes from Richard Schaffer's book, *The Breakthrough Strategy.* (Schaffer, 1988). An action team comes together to work on a specific issue with a very clear goal for a short fixed period of time. In our case the issue is defect elimination. The best teams are small (5-7 people) and cross-functional; they have operators, mechanics, engineers and procurement people from a given area. The team identifies defects in their equipment and processes and creates an action plan to eliminate one of them. They have a goal of eliminating that defect within 90 days. A typical workshop will launch 4-6 action teams. Action teams are the vehicle to both begin the process of eliminating defects and continue the change in culture.

A lot of companies balk at the idea of action teams. A common objection is, "We just want to train the managers. Our operators and mechanics don't have time for this." Unfortunately in a reactive mode, the front-line people will never have time. More importantly, our experience has been that only the front-line personnel know where the majority of the defects are. Management can typically point to a few defects that are production bottlenecks but they cannot identify the hundreds or thousands of little things that eat up time, process efficiency and quality. Companies also resist action teams because logistically it is harder to run workshops with action teams. It is easier to find 36 random people to fill a workshop from the site than to carefully pick five teams of seven individuals to tackle a real project. Finally, the biggest barrier to launching action teams is management's perceived loss of control. To make a big change quickly in reliability, you cannot have a few highly managed and facilitated teams. You need to get 80%-90% of your site out there eliminating defects to get the impact. If every improvement and change has to come through one or a few people, the process will move very slowly and there will be little passion from the front-line.

RESULTS

This section will illustrate the type of improvements that we typically see once a shared vision is built and a large number of people at the site have the ideas and passion to eliminate defects.

Creating a Culture of Defect Elimination at Eastman Chemical

Eastman Chemical has used The Manufacturing Game™ workshops to help accelerate their improvement efforts at their Kingsport site. While they are still early in their implementation, they have already begun to see the impact from defect elimination. The Power & Services Division has made the most progress. The teams from Power & Services went back to their area and identified over 80 defects that could be eliminated. They then focused on the top 10 that they knew were both important and that they could have an impact on in a short period of time. A good example of this approach is the work that they did with metering pumps.

The Power & Services group had several positive displacement metering pumps that were causing a lot of problems. They were having about 2 failures per week and Eastman was spending around 20 hours per week fixing these pumps. A team took this on as a defect to eliminate. They researched the type of problem they were having and contacted the vendor. The vendor came out and inspected the pumps and found that they had been running backwards and as a result were not getting proper lubrication. It was not possible to determine the direction that the pumps were running just by looking at them. The pump manufacturer's technician also showed the team several "tricks" to setting up the pumps that the mechanics and operators did not know. Since this action team completed their work, the pumps have not had a single failure. The entire effort took less than 90 days and required basically zero investment. Eastman will save over $26,000 in direct costs but more importantly they will free up ½ of a man year of maintenance time to do more value added work.

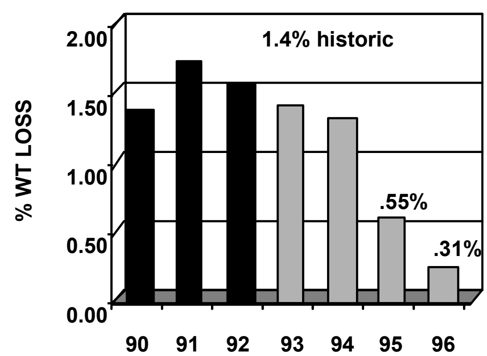
While action teams are extremely helpful in starting the process of eliminating defects, they also play an important role in building a culture where defects are not tolerated. Mickey Logan of Eastman Chemical's Power & Services Division describes this change in culture as "…it starts out as a series of projects but it has become the way we do business now." This new approach was critical in solving a chronic problem that they were having with their generators.

Soon after the first Manufacturing Game™ workshop in Power & Services, one of the turbo generators had to come down because of vibration problems. The mechanics determined that the bearing had been wiped, the surface was no longer smooth, and was causing the vibration but they could not determine the root cause of the bearing getting wiped. The generator was critical to operations so they had to get it back up. The wiped bearing was replaced and the generator restarted. On start-up the vibration spiked up and then dropped off to acceptable but higher than normal level. The generator ran over the weekend but once the operating team saw the data on Monday morning, they did something that was very counter cultural. They took it back down. Normally, a critical piece of equipment that is running in the acceptable range would not be taken down but the team knew they still had a defect. The bearing was slightly wiped again when they examined it and again no root cause could be determined. They replaced the bearing and started it up again. When the vibration spiked on start-up again they immediately took it down. Instead of giving up and letting the generator run with a known defect, the team was determined not to allow this defect into their equipment. When they examined the generator, they found what looked like a photographic image of the bearing on the shaft. After consulting several experts they determined that the shaft was not properly grounded and an electrolytic effect was causing the damage to the bearing. The brushes that were supposed to ground the shaft were not making good contact anymore and this was causing the bearing to form a pitted surface that caused it to get wiped very quickly. The fix was easy. They cleaned the contact brushes, replaced the springs that held the brushes against the shaft and implemented a PM program to make sure that these were maintained. The cost of this solution was negligible. The team also determined that this same problem had been the cause of several previous generator failures over the last few years and they came up with a new design to eliminate this problem in the future across all of their generators. The savings from this change in approach is well in excess of half a million dollars per year and as important, will save over 128 man hours per generator per year.

Bottom Line Improvement Through Reliability at BP's Lima Refinery

The results at British Petroleum's Lima refinery, another client, have also been impressive. They have published the results of their efforts at improving reliability at the National Petroleum Refiners Association and at the Society for Maintenance and Reliability Professionals (Monus, Griffith 1996 & Monus, 1997). They found that within the first year they had significantly improved the reliability of the plant, reduced maintenance costs and dramatically reduced operating costs. The operating costs improvements came as a surprise to the group at Lima. It turned out that by focusing on a broad definition of defect elimination and reliability they could cut a lot of waste in their operations. The best example of this approach was the Butane Action Team.

Figure 6: Operating Improvements from Reliability



1995 improvement vs. 1994 is worth $8MM/yr
1996 improvement vs. 1995 is worth an incremental $2MM/yr
Total improvement vs. normal history prior to 1995 is $10MM/yr ongoing

The Butane Action Team decided to work on a defect in the butane sphere that they felt was a safety hazard. In the summer months, these spheres would heat up and the pressure would increase. Operators would open a valve to the flare to release the pressure and avoid safety problems. For years, the operators and mechanics had complained but it wasn't anybody's job to fix it. Once the team started working on this defect they quickly determined that the cooler on the compressor was undersized; it was very hot to the touch. They went to the plant's "bone yard" where scrapped equipment was kept; found a larger cooler; had it refurbished and passed it on to engineering to ensure it passed through their management of change process for safety. They installed the new cooler and immediately the pressure on the vessel came down and the valve to the flare could be closed. The team eliminated the safety issue and in the

process cut out over $1.5 million worth of butane going to the flare annually. As a result of several action teams like the Butane Action Team, the Lima site was able to reduce their hydrocarbon weight loss by more than 1% resulting in a $10 million reduction in annual operating costs (Figure 6).
The Lima refinery put 80% of their site staff through The Manufacturing Game™ workshop and they have completed over 30 action team projects. The culture of this plant has truly transformed from a mentality of "if it aint't broke, don't fix it" to one of "don't just fix it, improve it." Capacity is up significantly, maintenance and operating costs are down.

CONCLUSIONS

To reduce maintenance costs and improve uptime, most large process companies have taken an approach of building all of the systems and infrastructure first. The mentality is to improve the efficiency of the current work by planning and predicting it better. The result of this traditional approach has been erratic implementation efforts that often stall out or are killed before the benefits come. Plants can accelerate their improvements with much lower risk by reducing the current workload through the elimination of the defects that create the work. Reducing the workload will both increase the time available to do further improvements and will reduce the defects that come from poor practices that are inherently part of being in a reactive mode. To effectively eliminate defects we have found that you must engage the front-line in a process that communicates the value of improvements, builds passion for the change, aligns them around the right ideas and launches the action to start making improvements. Several large manufacturing and process companies have used The Manufacturing Game™ workshops and action teams to help create a culture of defect elimination and make substantial improvements to their operating and financial performance. By focusing on eliminating the work that the traditional approach attempts to make more efficient, these companies are reaping the benefits of world-class manufacturing without having to endure the large investments and risks of the traditional approach.

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