Business Driven Reliability at Mobil's Beaumont Refinery

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Mobil's Beaumont Refinery is striving to reduce the cost of unreliability (CoUR) by more than $100 million over the next 5 years. To achieve our objectives, we have integrated a front-line, bottom-up approach with a more traditional top-down reliability effort. This approach has begun to create a fundamental change in the culture of our site and is beginning to yield some substantial bottom line results.

The Beaumont Refinery has a rich history dating all the way back to the days of Spindletop when it was founded in 1902 and financed by the Standard Oil Company. Despite its origins in the birth of the oil industry, the Beaumont Refinery is also a modern facility utilizing one of the largest centrally located distributed control systems in the world with around 35 units on one central system. It also boasts the two largest continuous reforms. We have over 1,250 employed on site and input over 350,000 bbls of crude oil per day.

> ***Despite a history of high performance, we knew we were leaving money on the table.***

The Cost of Unreliability

The Beaumont Refinery has a history of high performance. For several years now, overall and maintenance performance metrics for the refinery have been in the first quartile of Solomon benchmarks. However, the culture at our facility is not to sit back and rest on our past accomplishments. There were several things that came together at the same time that pointed out the opportunity we had to improve our business performance by focusing on reliability.

First of all, we knew that the Solomon numbers did not tell the whole story. While they were a good indication of how we were doing against the industry, we knew that far too much of the work was being done on a reactive basis. We had numerous incidents and very few proactive measures to eliminate the problems. Mobil had made substantial investments in our facility in the early 90's but these investments had not boosted production to the levels we wanted. We commissioned a study of the cost of unreliability at our site to better understand the issues. The study confirmed our suspicions that despite our industry leading performance, there was a tremendous amount of opportunity being left on the table.

For us, the cost of unreliability created a sense of urgency around reliability improvement. We have institutionalized this measure which we now call CoUR. Our goal is to reduce the events that lead to CoUR and increase profitability by $100 million over the next five years. Our corporate drive for improved reliability also supported our efforts. Based on our corporate goals for return on capital, our CEO and senior management identified reliability as the number one goal of manufacturing. We have to get more out of our existing assets.

Developing our approach

The CoUR study and measurements shed new light on an old problem. We had been working successfully and unsuccessfully on reliability improvements for years. We formed a Business Driven Reliability Team (BDR) to develop our strategy and processes for making improvements. The BDR team realized that to be successful we would have to learn from both the successes and failures of past efforts. There were three paradigms that we realized would have to be broken to be successful.

Breaking old paradigms. The first paradigm was that reliability efforts should primarily focus on rotating equipment. Traditionally when we thought of reliability at the refinery we would immediately think of rotating equipment. It has always been our biggest group in maintenance and the largest source of work orders. The data from CoUR showed us that, counterintuitively, most of the dollars lost from unreliability came from fixed equipment like piping and vessels and heaters not rotating equipment. Paul Barringer, of Barringer Associates, backed up this analysis when he cautioned us to focus on overall costs and not failure events because they were likely to be very different. Our approach had to focus our efforts, especially our limited capital and engineering resources on the critical equipment.

The second paradigm was that the effort should be driven functionally by the maintenance department. In the past reliability improvement had been viewed as a task lead by and primarily done by maintenance. The maintenance functional approach that we normally take is doomed to have limited impact because most of the CoUR is on the process side. If operations is not on board and driving the process, you cannot get at most of the big issues. Our approach needed to be cross-functional.

Critical elements of Business Driven Reliability that were missing from previous efforts

1) Cross functional approach
2) Front-line enthusiasm
3) Change in culture
4) Union support
5) Criticality understanding
6) Integration with the way we do business

The third paradigm was that reliability was a technical task that a few highly skilled engineers needed to tackle. Most recently we had tried to address our reliability problems through a series of focused engineering projects. While these engineering projects achieved some substantial results, they did so at the cost of greater capital expenditure and with a long time delay. The new capital deployed often came with a new set of reliability problems and did very little to solve any of the existing ones.

Each of these past approaches while locally successful did not yield the overall results that we needed.While we were creating our approach we also came across The Manufacturing Game®. The Manufacturing Game® is a two-day workshop that includes an interactive simulation of an operating plant. It gives participants a bird's eye view of a manufacturing facility, allowing them to experience the impacts of poor reliability. Participants self-discover how to move a reactive plant into a world-class mode of manufacturing. The Manufacturing Game® also clearly demonstrates the need for a cross-functional approach.

Our senior management participated in a two-day workshop that reinforced our general beliefs and added an additional concept to our approach. The game points out that defects put into the manufacturing process at the front-line and allowed to stay in the system through a reactive culture are the root cause of most of the expensive CoUR events. The implication is that the problem cannot be solved by just a few engineers. Our approach needed to include the enthusiastic participation of all of our employees, but especially the front-line. We needed a shift in our culture from one that accepted defects as a normal part of operating to one where people actively sought to eliminate defects. We could not just pull a few engineers together and expect to make a big impact on CoUR. The approach would need to be both a top-down and criticality based process as well as a bottom-up effort to eliminate defects.

Engaging the Unions. Involving the front-line posed a potentially huge problem at our site. In the process of automating our facility in the late 80's, we had alienated many of our operators and crafts people. We had gone from a very typical union / management relationship in 1988 to a very adversarial relationship by 1993. Our approach had to find a way to re-engage the people who could have the biggest impact on reliability – the front-line.

Institutionalizing the change. We also recognized that in previous efforts to improve reliability we had started a lot of the right activities but had failed to make them part of the normal way we do business. Reliability activities were extras that were outside of, and in addition to the things that were truly required. Our approach would have to integrate the reliability actions and goals into the business plans, unit objectives, process flow and key performance indicators of the refinery.

We began working with Strategic Asset Management Inc. (SAMI) to perform an initial assessment and put together an integrated strategy to achieve our targets for CoUR. In the assessment, SAMI reviewed current practices in 15 different areas and evaluated our practices against their Reliability Maturity Model. The elements that SAMI evaluated included hard trade skills like rotating equipment, instrument and electrical and fixed equipment as well as softer skills like leadership, continuous improvement and stewardship. The assessment confirmed that we were performing well on the basics of maintenance but that there was still considerable room for improvement. More importantly the assessment pointed us toward some specific areas of focus. SAMI was able to work with us to customize an approach based on their asset management model that addressed our key issues.

Executing the Approach

We decided to start the improvement process in our Crude Unit in July of 1998. We chose the Crude Unit as the pilot area because the reliability problems there were less complex and the personnel there tended to be more receptive of change. The process we were rolling out was not perfect and we needed a place where we could experiment and make adjustments. We also needed to start with a win and we felt like the Crude Unit was the best area to get a win. After the Crude Unit was complete we have moved into other areas based on their cost of unreliability.

Kicking off the process. The process starts by communicating to all of the personnel in the unit the objectives of the effort and their role in it. The area supervisor typically makes this presentation with support from the BDR team. We also used The Manufacturing Game® as a kick-off tool. We felt that this tool was the most effective way to start changing the culture, to communicate the potential benefits of improved reliability, and to demonstrate how important it was for everyone to play their role.

Changing the culture and eliminating defects. When used as part of roll-out, The Manufacturing Game® launches action teams. Each team, made up of cross-functional, front-line personnel, focuses on eliminating a specific defect in a short period of time, typically ninety days or less. Action teams have helped us to accelerate our progress by 1) eliminating nagging defects that take time and attention away from proactive efforts and 2) demonstrating to the front line the role that they can play in improving reliability.

Figure 1: The Tar Booster Pump Team receives an award for their defect elimination efforts.

Table 1 gives four examples of nagging defects that action teams were able to eliminate.

Table 1: Example Action Teams

Team	Defect Identified	Impact
Coker Air Supply	Air supply used to power coke cutting equipment was unreliable with high costs	For an investment of less than $5,000, the team is realizing savings of $250,000 per year.
Tar Booster Pumps	Repetitive seal failures (MTBF 40 days) caused by lack of seal flush flow due to the waxy nature of the seal flush fluid. Each repair cost $5,000.	Switched the seal flush to eliminate plugging of restriction orifices. The seals have gone from nearly 9 failures per year and over 25 days of downtime to zero failures in over a year. This has easily freed up a minimum of 150 man-hours so far.
Crude Tower Corrosion	Overhead corrosion in crude tower due to corrosion spikes caused by variability in caustics strengths when tanks were switched.	Changed the mixing system and testing method to ensure consistency of caustic strengths across tanks. Direct results have not been observed yet but the team believes that corrosion will be greatly reduced.
Water in Bearing Oil Reservoir	Found water in pump bearing oil reservoir due to lack of proper sealing on the housing top vent cap.	Created and installed a vent cap seal using a rubber gasket and eliminated all water intrusion.

Participation on action teams seems to really trigger the transformation in culture that we are after. One of the operators who participated, J. W. Green, said that he learned a lot from the process and felt that action teams and RCM Teams (described in the next section) gave him a way to give input that would be used the running of the plant.

Most teams are able to eliminate small defects that cost a lot in terms of time and focus but only result in average savings of around ten thousand dollars. However, because action teams focus on reliability problems from a different perspective than engineers, we find that occasionally a team will come up with a truly revolutionary idea that has substantial bottom line impact. For example in the crude unit, a team found a way to up the incoming crude flow without adding any capital. The team was able to reroute some existing piping to allow the unit to run at a higher rate without a crude supply constraint. The redesign not only increases the potential inflow to the unit, it took a feed tank out of the process that was a major reliability concern and it eliminated pump cavitations in the system. While this idea has not yet been fully implemented it could potentially result in millions of dollars of improved throughput and reduced downtime. To achieve the throughput benefits identified by this team we are currently pursuing further debottlenecking of the unit. While it is not clear at this point whether we will be able to eliminate the internal bottlenecks, the team's efforts to improve the potential inflow pointed out the opportunity to increase the total throughput and provided valuable data to develop a crude optimization strategy.

We also have set up a reward and recognition program for action teams. Every person who participates in a team receives an acknowledgement of their effort. For teams that complete projects and eliminate a defect, the award is in line with the savings the team achieves. We are also publicizing these success stories to help change the culture and show everyone that we do not have to tolerate defects in the system.

To date we have held 13 The Manufacturing Game® workshops and launched over 90 action teams. Of these, 10 teams have fully completed their projects.

Building operator ownership. Another part of the defect elimination effort is a change in the role of operators. We had developed a culture where some operators believed that management expected them to check their brains at the gate. Our reliability improvement initiative requires that operators take responsibility and ownership for their area. Since our approach relies so heavily on front-line involvement, we decided early on to have union leaders on the BDR team. Changes in operating procedures were a natural place for these union leaders to focus. James Skipper, chairman of the PACE workman's committee, took the lead on designing and communicating the need for enhanced operator rounds and operator shift relief. We use role-plays to highlight the issues in shift relief and to redesign these procedures to eliminate potential defects. Operators also design enhanced rounds by creating a checklist that focuses on critical equipment.

The engagement of the front-line in our process and the involvement of key PACE and IBEW union leaders on the BDR team have significantly improved our relationship with the unions. The unions have more trust that management knows where we are going and that we have a well thought out plan to get there. They also see that we earnestly need their input and their effort. Management has seen that when the front-line workers understand the impact that reliability has on the business and their role in making improvements, they enthusiastically participate in the process. Management now believes that by tapping into the creativity and knowledge of the front-line, we can solve a lot of old intractable problems. The union / management relationship is now the best that it has been in a long time.

All of these efforts put together - The Manufacturing Game®, action teams and operator involvement - focus the unit on defect elimination. These efforts raise the general level of understanding about reliability and begin to get some of the nagging problems out of the way. This bottom up approach sets the stage well for our next step – a top down assessment of criticality and a component care strategy.

Front End RCM. Once we have communicated the objectives and energized the front line, we begin the process of focusing our efforts on the critical equipment. As previously mentioned, a very few number of CoUR events account for a large percentage of the costs. Most of these events do not come from the same problems that generate most of our maintenance work orders so it is vital that we have a front-end process that helps us focus on the things that are truly important. We use a process we call Business Driven Reliability - Integrated Process that is a combination of a Mobil corporate approach, the approach that was brought by SAMI and some modifications added by the BDR team. It is beyond the scope of this paper to describe RCM so we will highlight the differences between our approach and the more traditional approaches.

Figure 2 - Component Care Strategy

Replacement Value

Criticality / Level of Maintenance	Less than $1000	$1000 to $10,000	More than $10,000
H - 1, H - 2, M -1	S: Predict life, Schedule, Replace before failure	IPM: Predict life, Inspect, Preventive Maintenance	PCPM: Predict life, Continuous Monitoring, Preventive Maintenance
M -2, L - 1, L - 2	I: Inspect and Run to failure	IPM: Inspect, Preventive Maintenance	CPM: Condition monitoring, Preventive Maintenance
H - 3, M -3, L - 3	R: Run to failure	PM: Preventive Maintenance	PM: Preventive Maintenance

Match criticality & value to choose correct level of maintenance

The front-end RCM process starts by creating a hierarchy of functions, systems, and components within the unit. The system is diagramed and identification numbers are developed for each component. Next we assign criticality codes to each component. Criticality is assessed based on potential impacts to production, safety and the environment. We use previous failure data, area interviews and reliability modeling to determine criticality. By doing a quick and dirty assessment of criticality we are able to focus our efforts early and reduce the analysis time. For example, of the 1,400 components identified in the crude unit only 58 were identified as highly critical.

By streamlining the RCM approach based on criticality, we are able to complete the process in a complex unit with roughly 2,000 man-hours of work spread out over a quarter.

The downside of this approach is that we could miss a piece of critical equipment that further analysis would identify. However, we believe that taking some early action on obviously critical equipment is more valuable than delaying all action to identify 100% of the potential problems.

Once criticality has been established, the condition of the equipment is assessed. For less critical equipment the area operators, maintenance personnel and the component's manufacturer do the assessment. If defects are found, a work order is generated. For the highly critical equipment, the area team takes to the field and does an inspection. This process helps to quickly reduce the chances of a CoUR event.

The final step in our front-end RCM process is to determine appropriate component care strategies. Based on the criticality and the replacement value of the component we assign it to one of the component care categories shown in Figure 2. The new component care strategy is then entered into our computerized maintenance management system. New PM's are generated and many of the old ones are eliminated. For high cost systems, we also perform a formal Failure Modes and Effects Analysis, FMEA, to create a more in depth strategy for these systems and components.

Perhaps the most unique part of our front-end RCM is that all of the outputs go directly into our normal systems and processes for getting work done. Many of the published problems with RCM are related to the cost and delay with the up front analysis and the lack of implementation on the back end. By keeping the process simple and at a high level in the beginning and by channeling all of the outputs into our current ways of doing business, we have avoided these problems.

The front-end RCM that we performed at the Coker is a good example of what this process can accomplish. A cross-functional team made up of operators, mechanics, and engineers executed the analysis and developed a maintenance plan that will result in substantial savings.

The RCM team set up planned, programmed maintenance and operating tasks that will reduce costs by an expected 10-20% per year. This team also discovered the poor air supply defect mentioned above and handed it off to an action team to eliminate.

This top-down analysis gets the unit quickly focused on the failures that are most likely to have high costs. Combined with the bottom-up defect elimination from The Manufacturing Game® and action teams, we have seen dramatic results in a short period of time.

Results to date

Our improvements in reliability have meant that while others have struggled with the recent market conditions, we have prospered.

While we are still early in our implementation, we have already seen some substantial improvements from this process. Overall refinery availability has improved from 95.3% in 1997 to 99.4% in 1998 and 99.8% so far in 1999. The Cost of Unreliability, CoUR has dropped by about 30% over the last two years. This has meant that while some refiners have had a tough time with the market conditions over the last few years we are prospering.

Conclusions

At this point, we have completed the process in 4 of our 23 units. While we are still early in the implementation, our focus on the areas where the Cost of Unreliability was has already led to significant improvements in operating results. As we work in the more complex units, our process has been more difficult to implement, but is continuing to pay off well. In 1998 and into 1999 we have been implementing the processes described above. Starting in 1999 we will also be rolling-out some refinery wide initiatives to change the way we set objectives, measure reliability, track progress and change our production targets. These efforts will help to institutionalize the progress that we have made and ensure that it is a continuous process and not just a one-time gain.

We have found that success in our environment requires the following:

1. Engaging both the top and bottom of the organization
   RCM and the top-down process do a great job of engaging the top because these leaders want to see that you are focused on business results and not just interesting technical problems. The Manufacturing Game®, action teams and operational changes help to get the front-line enthusiastically on board. By getting your operators and craft people involved, you can quickly eliminate a lot of the nagging defects and begin to change the culture.

2. Being action oriented
   Previous efforts had failed because we had gotten into the "paralysis by analysis" mode. The equipment does not run better until you take some action to improve it.

3. Using the data that we have
   None of our data were perfect but it was often enough to point us in the right direction. If you wait for the data to be flawless you will never take action.

4. Including the union leadership was critical
   We were able to avoid an unimaginable number of mistakes and participation problems by having union representation on the team from the start. The result has been that union management relations have improved along with reliability results.

5. Analyzing criticality is essential to setting unit objectives
   By using an RCM approach that yields a quick assessment of criticality we have shortened the time required to start taking action on the most costly potential problems.

6. Recognizing that reliability is a cross-functional effort.
   The main costs of unreliability are in the process. Many of the defects come from the way equipment is operated and can only be detected early by the operators. If you cannot engage the operating group in reliability improvement there is not much point in continuing. There is limited value that can be added through only a maintenance functional approach.

While we still have a long way to go to get this process rolled out refinery-wide, we have been extremely pleased with the results to date. We have found that the top-down and the bottom-up approaches, far from being mutually exclusive, are actually complementary. The bottom-up approach improves front-line buy in for the top-down efforts and frees up time to actually accomplish the analysis and the subsequent actions required. The top down approach helps to focus the bottom-up action teams on the more critical problems. By combining a rigorous top down approach like our front-end RCM with the culture changing, defect eliminating, bottom-up approach like The Manufacturing Game® and action teams, we have made great strides in picking up that money we had left on the table.