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Delayed Coker Solids Handling System Reliability Improvement Model with Extended Application to Sulphur Solids Handling[1]

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Current Operational Challenges & Business Case

Petroleum refineries in North America and abroad are increasingly adding cokers and hydrocrackers to meet future refining challenges from both feedstock (i.e., heavier and more sour) and product perspectives (higher distillate/gasoline ratios with very low sulfur levels). Uplift margins on USGC cokers have recently moved back to over $20 per barrel and as such, represent one of the most critical units in a modern, complex refinery. Unfortunately these new process configurations create very high volumes of solids (a typical world scale delayed coker will produce well over 1 million tons per year or over 3000 tons per day, which would fill 30-35 railcars per day). That's a lot of solids handling, which for most refiners, is not a core operational competency. Sulphur is a similar story and with North American consumption of molten sulphur expected to remain flat while the amount of sulphur production, particularly in the USA, is expected to rapidly increase, export of solid sulphur prill will likely grow in importance as a critical outlet of sulphur by-product.

There are widespread reports of coker unit interruptions due to unplanned outages in the industry as a result of breakdowns in the solids handling systems. Additionally, as refiners try to make up lost time, shortening coke drum reheat cycles can lead to premature drum cracking and replacement which create much longer periods of downtime, and significant lost profitability.

The authors work for Marsulex, a provider of outsourced services for coke cutting and complete solids handling and logistics operations from the coke drum to the railcar, truck or barge. Marsulex also has extensive experience in both sulphur recovery operations inside refineries, as well as sulphur forming and export for clusters of refineries that need an export outlet option for their by-product sulphur. As a result, we have observed first-hand how refiners often struggle with these

[1] This paper will focus primarily on DCU operations with a concluding section showing adaptability to sulphur forming.

operations and the aforementioned problems. Besides providing highly safe and productive operations, we have developed a total maintenance model for Delayed Coker Units (DCU's) that can help refiners plan their appropriate preventative maintenance strategy which will significantly reduce the Total Cost of Ownership (TCO) for coke handling and disposition. Most importantly, coker profitability can be maximized as a result of reduced unplanned outages, both of short and long duration. Refiners who choose to self-perform are encouraged to adopt a similar total maintenance cost approach if they have not already done so.

Similarly, these same models can be adapted to sulphur forming, handling and logistics operations where reliability of the sulphur export option is critical to long-term refinery success and performance.

Marsulex DCU Experience and Understanding of Challenges

Marsulex conducts its operations in the very competitive, mechanically intensive business of outsourcing coke cutting and coke movement for refinery customers. Since most refinery operations are continuous and are not concerned with handling solids, the coking business comprises a critical, yet non-typical, batch operation. Making the business work requires excellence in three major areas:

1. Safety
2. Operations
3. Reliability

Safety is the primary area of excellence. It is the foundation of the coke cutting business, which does not allow for compromise. Due to intensive effort, effective training, and most importantly, a strict compliance philosophy and "mindset" developed and reinforced over many years of providing these services to refineries, Marsulex has achieved a level of safety equal to or better than the refining customers it serves. Over the last 4 years the average Total Recordable Incident Rate (TRIR) in Marsulex's refinery coking business has been 0.29 reportable injury cases per 100,000 hours worked. Marsulex was recently awarded safety excellence awards from the NPRA for years 2008 and 2009.

Operations know-how and deep experience is the second critical factor for the coke cutting business. While cutting coke has a low tech reputation, it is not low tech. The coke drum heading and un-heading systems, the coke pit and the coke conveyance areas are highly automated with leading edge solids handling technology that requires well trained operators. Marsulex has advanced coke cutting and movement methods with experienced operators that embrace high technology and deliver maximum performance and productivity.

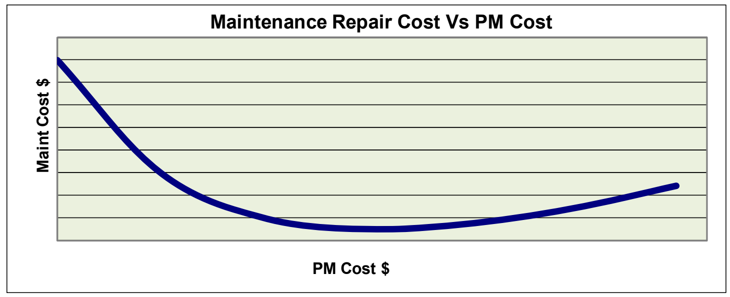
The third area of expertise is reliability, which is the focus of this technical paper. Since the coke cutting and movement business is so mechanically intensive, this is an area of high cost and an area that has many opportunities for cost reduction, particularly during the contract bidding process if the refiner has decided to contract out this service and discontinue self-performing this activity. The reliability area is considered a "fighting" area, or the area that separates competition; however, even with pressure to reduce cost and subsequent price, it is Marsulex's philosophy and experience that reducing the reliability investment, namely scaling back preventive maintenance labor, materials and systems investment, can be a very expensive decision in the long run. The "acquisition cost" dollars saved when bidding a services contract are insignificant when compared to the total lifetime cost of ownership of this service derived from a highly reliable, well-maintained operation. Marsulex believes that a world-class preventive maintenance program is key to delivering such a successful operation, whether the refiner chooses to self-perform in this area, or elects to outsource these services.

Large USGC Coker Operated & Maintained by Marsulex

Reliability Philosophy

Marsulex has an uncomplicated, yet powerful reliability philosophy, which can best be described in the "maintenance parabola" concept as shown in Figure 1 below:

Figure 1: "Maintenance Parabola"
Total Maintenance Costs vs. PM Costs



The concept is well established, but subtle. The curve shows the relationship between PM expenditures and maintenance repair expenses. As effective PM activity is increased on the left side of the curve-minimum, maintenance costs are reduced, significantly at first. As PM expenditures continue to increase, moving right on the curve, maintenance cost reductions start decreasing to a point of diminishing returns. To the right of the curve-minimum, costs actually start to increase with increasing PM expenditures. Marsulex's philosophy is to stay focused on delivering an effective PM program to model the above relationship. The program optimizes PM costs to deliver the lowest total maintenance cost, which includes total preventative and corrective maintenance, as well as consequential opportunity costs related to lost production experienced during unplanned outages.

Reliability Background

Looking at the reliability concept in more detail, Marsulex categorizes repairs, or failures, into four Types as shown on Figure 2 below. Type I is a planned or an expected failure. It almost never involves a complicated failure and it has a cost of 1X. Type II is an unplanned premature failure. It has a cost that typically averages 3X , or three times a Type I failure. A Type II failure occasionally has a complicating additional expenditure, such as an operational outage. A Type III failure is called an incident. It is a very premature failure that has a typical cost of 6x. It often involves an operations loss or a logistics cost to avoid an operations loss. Type IV, a wreck, is the most severe failure. It has at least a 9x or greater cost. It usually involves a significant premature failure, an operations or logistics cost, and it often involves an insurance claim.

Figure 2: Maintenance Failure Types and Cost Impact

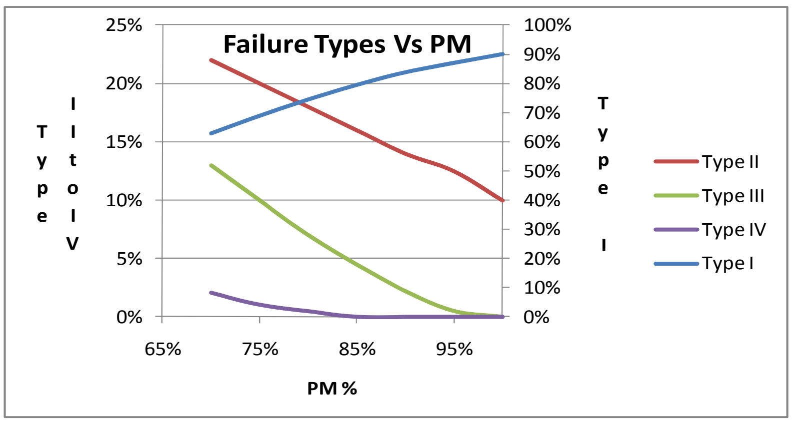


Table 1 below shows a typical failure distribution as a function of PM compliance levels:

Table 1: Failure Types vs. PM Compliance

			Typical Failure Distribution Vs PM level				
PM %	100%	95%	90%	85%	80%	75%	70%
Type I	90%	87%	84%	80%	75%	69%	63%
Type II	10%	13%	14.0%	16%	18%	20%	22%
Type III	0%	0.5%	2.2%	5%	7%	10%	13%
Type IV	0%	0%	0%	0.0%	0.5%	1%	2.1%
Total	100%	100%	100%	100%	100%	100%	100%

While the data in Table 1 can have a high variance, the trend is always toward increasing Type I failures with increasing PM compliance, and conversely, increasing Type II through Type IV failures with decreasing PM compliance or an ineffective PM program. A prime objective of an effective PM program should be to avoid unplanned, premature failures particularly, Type III and Type IV failures.

Large Customer Reliability Study

A large coker customer was chosen as a test site to perform a detailed reliability assessment. The main purpose of the study was to examine the Marsulex reliability philosophy, attempt to quantify the level of PM compliance at the site, and determine the benefits from this compliance. The assessment consisted of the following:

1. A detailed review of the preventive maintenance program.
2. Development of an equipment repair table consisting of expected mean time between failure, MTBF, for each piece of equipment, with predictions of the cost of each failure, including both material and labor.
3. A multi-year review of actual maintenance repair statistics consisting of the MTBF, the types of failure and the repair cost.
4. Using feedback from the study, the construction a Monte Carlo reliability model relating PM compliance to actual maintenance repair cost experienced.

The Preventive Maintenance Review

The PM review consisted of examining a detailed equipment list, and using the detailed list to determine the following:

1. PM task
2. Time for each task
3. Task frequency
4. Number of similar components
5. The period for each task i.e. days, weeks, months
6. Job task assignment
7. Total time spent on each task
8. Full time equivalent for each task

A sample PM is shown below in Table 2

Table 2: Crusher PM

CRUSHER DAILY PM	Task	Time min	Freq	Period	Number	Total	FTE	Assigned
Check Oil Level in Sight Glass on Guard (85 – 140 Super Red)	Oil	10	2	D	1	20	0.042	Oper
Inspect Hopper for Uncrushables	Visual	10	2	D	1	20	0.042	Maint
Make Sure all Safety Guards are in place	Visual	15	2	D	1	30	0.063	Maint
Inspect all Mounting Bolts for tightness	Visual	2	1	D	10	20	0.042	Oper
Listen for any Unusual Noises like metal to metal, belts slapping	Visual	10	2	D	1	20	0.042	Oper
Inspect Crusher for any Leaks	Visual	5	2	D	1	10	0.021	Maint
Check for Excessive Vibration	Visual	5	2	D	1	10	0.021	Oper

Repair Expectation Table

The repair expectation table (a portion which is shown on following page) used the same detailed equipment list as the preventive maintenance effort in order to set realistic goals of repair frequencies and cost.

Table 3 (next page) looks at the following for each piece of equipment:

1. Predicted material cost
2. Predicted Mean Time Between Failure (MTBF)
3. Number of similar items
4. Time spent on each repair
5. Total cost of repair
6. Cost per year equivalent.

Table 3: Bridge Crane Systems Failure Expectations

		Material			Time	Cost
Equipment		$/Failure	MTBF Years	No	Hrs	$/y Eq
Bridge Crane	Hold Cable	$1,000.0	1.0	2.00	24.00	$2,000.0
	Close Cable	$500.0	2.0	4.00	24.00	$1,000.0
	Bearing	$2,100.0	4.0	2.00	4.00	$1,050.0
	Coupling	$12,500.0	5.0	2.00	4.00	$5,000.0
	Housing	$30,000.0	20.0	1.00	2.00	$1,500.0

The failures were divided into classes based on MTBF. Generally, the shorter term MTBF repairs had lower cost than the longer MTBF repairs. All losses were evaluated on a yearly equivalent basis which considered the Time Value of Money (TVM). For example, a repair cost of $5000 with a one year MTBF frequency, using an NPV method with a 6% interest rate would be equivalent to an expected 20 year MTBF repair cost of $184,000 instead of the simple yearly equivalent of $100,000. Using the NPV method with a $100,000 repair cost and 20 years MTBF frequency would produce a yearly equivalent of $2,718.

DCU Bridge Crane & Crusher

Detailed Review of Actual Repair Cost

The third element of the study was a multi-year review of maintenance repair cost on an actual DCU. The key components of the review were the repair cost, the number of failures per year or the MTBF, the cost per year equivalent, and the Failure Type, I through IV. Table 4 below is a sample of the review:

Table 4: Maintenance Repair Cost Analysis Sheet

Analysis Sheet	Repair Expense	No/Yr	Yearly Expense	Type Failure
Top Head	4.17	5.0	20.8	1
Bolts & Nuts	3.47	0.3	1.0	1
Bolts & Nuts	0.80	3.0	2.4	1
Gasket	1.33	0.5	0.7	1
Gasket Surface	1.10	0.5	0.6	1
N2 Skid				
N2 Pumps	1.00	0.2	0.2	1
N2 Skid Controls	75.00	1.0	75.0	2
N2 Bottles	75.00	1.0	75.0	2
North Console #5&6	7.00	1.0	7.0	2
South Console #3&4	0.50	3.0	1.5	1
Terminal Load Out				
Filters	2.50	4.0	10.0	1
Silo	2.00	1.0	2.0	1
Scale	3.00	0.5	1.5	1
Hydraulic Pressure Unit	4.00	1.0	4.0	1
Hydraulic Pressure Unit	8.33	1.0	8.3	2
HPU Pump	1.00	0.5	0.5	1

Study Feedback

The study feedback is summarized in the Tables 5-7 below. Table 5 is the PM analysis feedback. The column on the left shows the type of PM activities. Note that all of these activities were relatively simple tasks, such as visual checks, changing oil, lubrication, sampling oil, and housekeeping. There were 156 activities in the total PM stack. The table shows the division between activity and cost. The take away from this feedback is that PM tasks are generally uncomplicated, but very important activities. They must be performed routinely. They must be done on time, and they must produce action when there are problems.

Table 5: PM Procedures

PM Procedures Analysis				
PM	No	Activity	%	% Cost
ChgFilters	1	1.00	0.6%	23.3%
Clean	2	5.00	3.2%	14.1%
Housekeep	3	1.00	0.6%	11.1%
CheckVisual	4	78.00	50.0%	26.1%
Lubricate	5	5.00	3.2%	2.6%
Change Oil	6	27.00	17.3%	3.5%
Refurbish	7	10.00	6.4%	2.7%
Test	8	2.00	1.3%	0.4%
Grease	9	18.00	11.5%	1.4%
Calibrate	10	4.00	2.6%	1.4%
Torque	11	1.00	0.6%	0.1%
Inventory	12	1.00	0.6%	8.9%
Hydroblast	13	1.00	0.6%	3.3%
ChgBulbs	14	1.00	0.6%	1.1%
Sample Oil	15	1.00	0.6%	0.0%
		156.00	100.0%	100.0%

Table 6 shows the results of the maintenance repairs analysis on the actual unit vs. the ideal maintenance levels to deliver the lowest TCO. The costs were calculated using the TVM method, as described earlier, to establish a base, overall repair cost expressed as a dollar yearly equivalent.

Table 6: Ideal vs. Actual Maintenance Cost Comparison

EQUIP	MAINT % IDEAL	MAINT % ACTUAL
Misc	0	42.10%
Crane	27.24%	25.64%
Feeder	2.31%	8.65%
Crusher	3.83%	0.55%
Heads	9.61%	28.02%
Cutting	30.73%	34.24%
Transport	2.49%	5.70%
Conveying	9.67%	5.34%
Rail	12.63%	15.50%
Loading	1.50%	2.10%
TOTAL	100.0%	167.8%

The costs are a percentage of the base yearly equivalent cost. The largest variance was in the miscellaneous category, which tends to be a catch-all for maintenance cost. The total cost was 167.8% of the base, which reflects the repair Type distribution as shown in Table 7 below.

Failure Type	% Task	Count
1	85.3%	81
2	12.6%	12
3	2.1%	2
4	0.0%	0
Total	100.0%	95

Table 7: Actual Failure Types Observed

There were 85.3% planned, expected Type I repairs. There were 12.6% unplanned Type II repair cost, and 2.1% Type III incidents with no Type IV wrecks. Looking at the projected repair distributions shown earlier, the study distribution would suggest a 90% PM compliance.

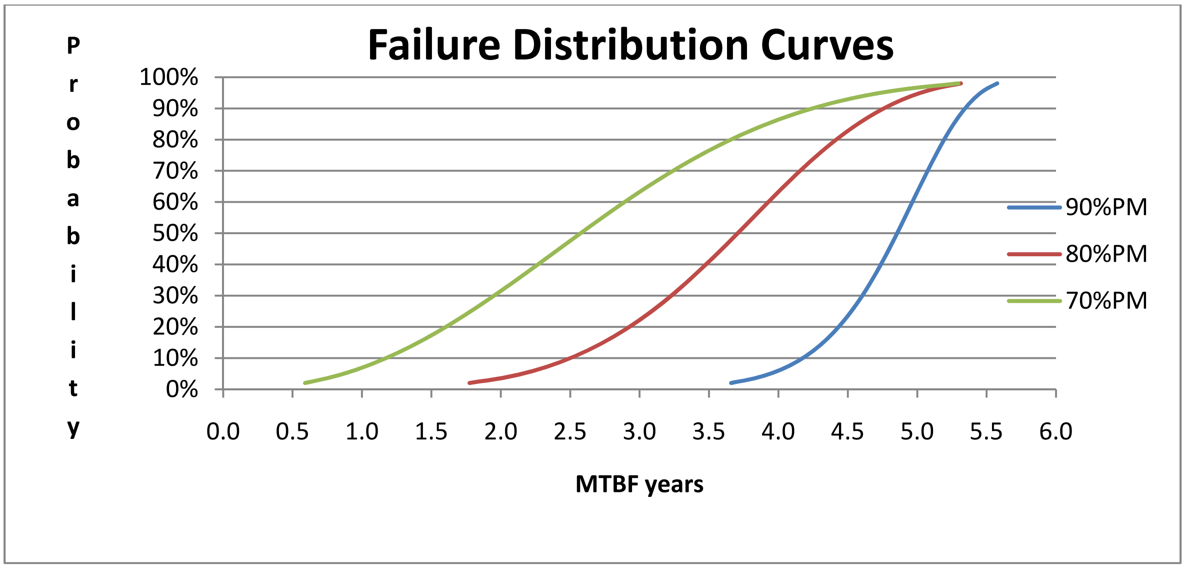
Development of a "Monte Carlo" Predictive DCU Maintenance Model

In order to expand and enhance the site customer study, and to examine all the cost components impacted by P/M compliance levels, a statistically based, Monte Carlo method analysis was undertaken. The cost components examined in the effort were:

1. Repair cost
2. Frequency of repair or MTBF variation
3. Severity increases to base repair cost
4. Operations losses
5. Logistics expenditures in order to avoid operation downtime
6. Impact from the lack of timely spare parts
7. Impact of the time value of money

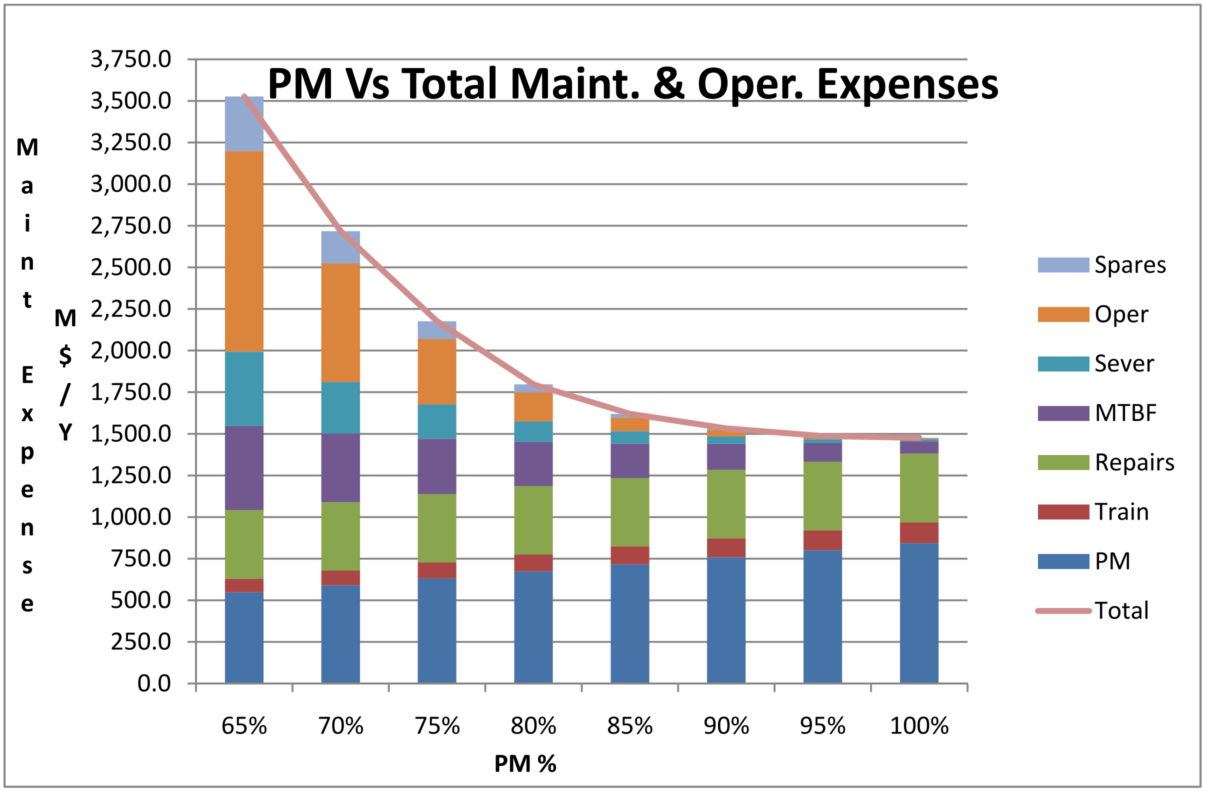
Using the data collected from the customer study, specifically the Failure Expectation Table, coupled with the reliability historical information as described previously, the site specific, spreadsheet based, failure cost tables were developed. A Weibull distribution was used to simulate failure frequencies at varying PM compliance levels. The relationship assumed that as PM compliance was reduced, the failure frequency widened and the MTBF was reduced, or shifted left as shown on the distribution curves below in Figure 2:

Figure 2: Predictive DCU Model Assumed Probability of Failure vs. P/M Investment



The results of the model runs, which simulated numerous 20 year cycles and were based on actual maintenance schedules, failure rates and costs, are shown in Figure 3 below:

Figure 3: Predictive Working Model of DCU Total Maintenance Costs vs. P/M Compliance



Explanation of the Model Results

The above chart has the following vertical bar cost stack:

1. Preventive maintenance
2. Training and safety
3. Repairs
4. Frequency increase from expected
5. Severity from expected
6. Operations and logistics
7. Spare parts

Looking at the cost stack, the first and second cost elements, PM and training, increase as PM Compliance % increases. The third cost element (repairs) remains constant on all the bar stacks. The remaining cost elements (four through seven), increase with decreasing PM compliance. Note that with a relatively small decrease in PM investment from 90% to 65%, which nominally saves $250,000 in budget investment, the actual total cost of maintenance actually rises dramatically by over $2,000,000! The costs predicted by the model showed excellent agreement with our actual experience over several years on this large delayed coker on the US Gulf Coast. The initiative to reduce budgeted, planned costs like PM can be prompted by many things—1) budget cuts to reduce operating expense and/or headcount, 2) short-term production increase requirements that tend to drive operators to defer PM, and 3) evaluating service suppliers based on the lowest bid price vs. lowest total cost of ownership.

The conclusions from the modeling exercise were:

1. The model assumptions and development yielded predicted results that matched actual experience and costs very closely and **<u>thus provides an excellent planning and operations tool</u>**.
2. Ancillary cost, MTBF, severity, operations losses, and spare parts cost, are much larger than the base repair cost at low PM compliance.
3. Placing a low priority on, or deliberately reducing, PM expenditures can be a very expensive strategy.
4. Costs rise very quickly below 90% PM compliance.
5. Diligent compliance to an effective PM program has an excellent return.

Additional Benefits of the DCU Reliability Study

There were numerous additional benefits and lessons learned from the study as listed below:

- Highlighted several improvement areas in the site PM program
- Helped focus the reliability program's continuous improvement efforts
- Further refined the relationship between PM compliance and the total cost of repairs
- Quantified the relationships between the various maintenance cost components as shown above
- Demonstrated the validity of the Marsulex reliability philosophy

This exercise and successful development of a "diagnostic" maintenance planning model also reinforced the need for additional maintenance planning & execution systems such as**:**

- Computerized Maintenance Management System
- Condition Based Equipment Inspection & Life Cycle Analysis
- OEM Support Network & Expanded PM's
- Full Time Equivalent Analysis & PM Support Staffing
- Maintenance Window Planning & Scheduling
- Root Cause Analysis of Findings
- Critical Spare Parts Identification & Risk Management

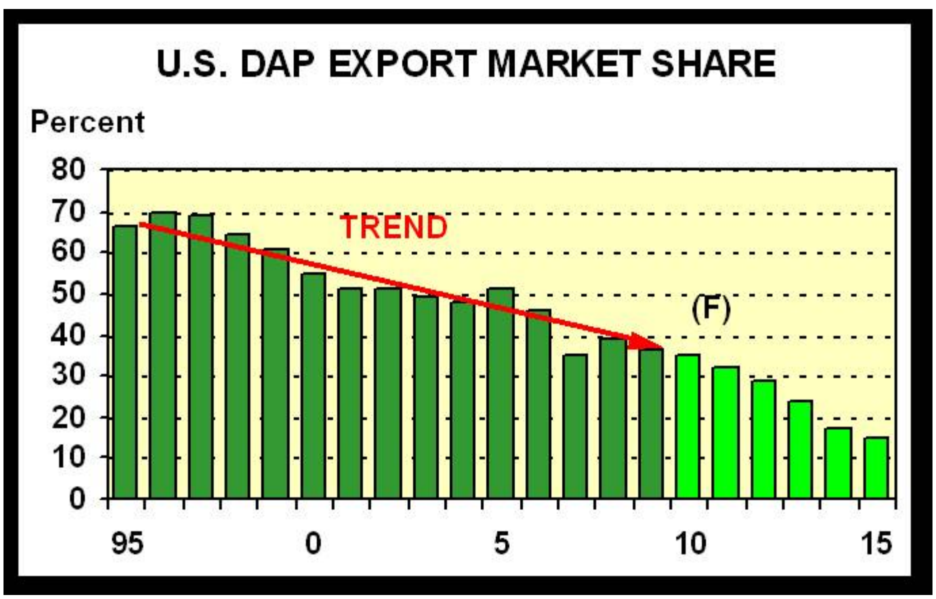
Conclusions for DCU Operators

<u>While planned operating costs on the DCU are fairly transparent and measureable, the ability to quantify the effectiveness of the total maintenance investment is much more difficult</u>. Challenges to identify the long term effects of maintenance resource investment exist whether a refiner self-performs or outsources these services. Given that the total maintenance investment is generally comparable to the investment in operating labor and materials, refiners can be tempted to scale back the maintenance investment to generate a short-term gain, again whether self-performing or outsourcing these services. The cost of this short-term focus can be extremely significant with the consequence of severely impacting refinery profitability. We encourage refiners to resist this cost reduction approach to maximize the long-term performance of one of the refinery's most critical assets.

APPLICATION OF MAINTENANCE-BASED RELIABILITY MODEL TO SULPHUR FORMING

Trends in Sulphur Movement and Market Dynamics

While sour gas production has generally waned in Western Canada over the past 10 years, it is expected that sulphur produced at Western Canadian and Western US upgraders and refineries will increase significantly over the next 10+ years as more bitumen is upgraded in existing and new upgraders, and additional sour syncrude is further processed at existing refineries. With most of the sulphur production used to produce sulphuric acid, which in turn is used in the production of ammonium phosphate fertilizers, it is expected that North American fertilizer exports will decrease as other countries utilize their stranded gas reserves (Middle East, Latin America and Russia) along with sulphur produced locally from new sour gas fields and/or new refineries. For example, the long awaited Ma'aden project located in Saudia Arabia will start production Q4, 2010 adding 10% to the world's phosphate production capacity with low cost economics of being basic in both sulphur and phosphate rock and as well being logistically low cost to key export markets of India, Pakistan and China. As a result, the long term trend for converting North American molten sulphur to solid (prill) sulphur, which is required for ocean transport, will increase significantly. Sulphur economics are generally dictated by logistics and we think the incentives to produce solid sulphur will be greatest in locations most remote from current centers of fertilizer production in Florida and Idaho or closest to points of sulphur export being Vancouver, US West Coast and on the US Gulf Coast (Texas, Louisiana).



Source: FRC

US Sulphur Balance

	2009	2010	2011	2012	2013	2015
DEMAND	11.23	10.9	11.4	11.9	12.4	12.6
- Cons.	8.81	9.0	9.2	9.3	9.3	9.0
- Exports	2.42	1.9	1.9	2.6	3.1	3.6
CA+	*1.05*	*1.1*	*1.1*	*1.1*	*1.1*	*1.1*
US Gulf	*1.37*	*0.8*	*0.8*	*1.5*	*2.0*	*2.5*
SUPPLY	10.70	11.2	11.4	11.9	12.4	12.6
- Recovered	8.51	8.5	9.0	9.3	10.0	10.4
Oil Refining	*7.37*	*7.5*	*8.0*	*8.3*	*9.0*	*9.4*
Gas Processing	*1.14*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*
- Imports	2.19	2.7	2.4	2.6	2.4	2.2
Canada	*1.44*	*2.0*	*1.5*	*1.7*	*1.4*	*1.2*
Mexico	*0.55*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*
Venezuela	*0.20*	*0.1*	*0.4*	*0.4*	*0.5*	*0.5*
Other	-	*0.1*	-	-	-	-
STOCK CHANGE	(0.53)	0.3	-0-	-0-	-0-	-0-

million tonnes

Source: ICIS PentaSul

Accordingly, Marsulex believes that many Western Canada and US refineries and upgraders will need to make investments to produce and transport solid sulphur. Since reliable processing and disposition of sulphur is required to allow upstream units to run at full throughputs, and with “blocking” of sulphur at ground level is increasingly being scrutinized, refiners will have to extend their operating expertise to these sulphur forming operations, or consider partnering with firms like Marsulex who do have this expertise.

Using our actual maintenance experience from our sulphur prilling facility in Mt. Vernon, Washington, coupled with the same modeling approach as developed for the delayed coker, we are developing the same optimal PM approaches and plans to deliver the lowest total cost of ownership to these operations as well.

Marsulex Mt. Vernon, Washington Sulphur Prilling Facility

We will briefly review the production of sulphur prill and then travel downstream through all the various logistical and solids handling solutions that may be considered for a safe, efficient and productive prilling operation.

Let's review the product flow chain and logistics to see how many mechanical systems are required to move sulphur from the refinery/upgrader to the ship bound for foreign export markets:

INBOUND MODE

There are various options for liquid sulfur receiving:

►Railcar

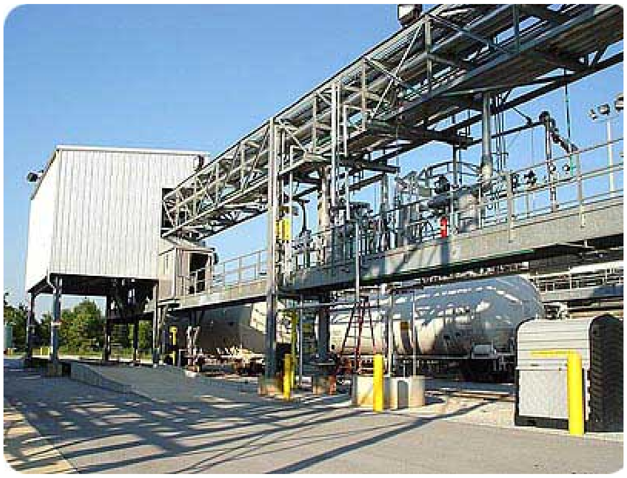
A well-designed facility should be designed to receive liquid sulpur primarily by rail car, but will have the capability to receive liquid sulphur by truck as well. The railcar yard will have dedicated track with steam, air, double wall sulfur receiving pipe, steam tracing, overhead railcar access via man ways from a central platform down the rail line, associated facility lighting and equipment required to receive the liquid sulphur by railcar.

Example of rail car overhead access platforms

The facility receiving system is designed to accommodate liquid sulphur railcars in the region's most extreme cold weather conditions. Under normal operating conditions a string of railcars will be turned back to the railroad for transit to the refinery in one day. In extreme cold weather, and accommodating delays in switching the railcars that causes the liquid sulphur to solidify more than normal, the system will have the heating capacity to turn railcars back over to the railroad on the second day from the date of receipt. The processing capability will increase as the volume increases, with expansions of the system performed as modular additions to the section(s) that already exist.

►Truck

The system will also be designed to receive liquid sulphur by truck. The railcar system will have tie-ins adapted to allow multiple trucks to transfer liquid sulfur adjacent to the rail track using the same receiving system as used for railcars.



Example of a railcar facility with a truck option on the side

Example of the stacking pattern for an extendable circular stacker

►Other

In the event that neither railcars nor trucks can be sent to the facility from the refinery a combination system may be used. If the refinery can load the liquid sulphur to barge a commercial liquid dock in the facility area will be contracted to transfer the liquid sulphur to truck for transit to the facility.

►Stockpiling

The prilled sulphur will transfer from the priller to a transfer conveyor. This transfer conveyor will move the prilled sulpur to the stacking conveyor where it is stockpiled in a conical pile. As the stockpile builds the stacking conveyor slews to allow the stockpile to be formed in a semi-circular pattern. As the pattern is filled from one side to the other the length of the stacker is shortened to allow another semi/circle to be formed inside the outer one. By overlapping the stockpiles the utilization of the storage area can be maximized.

OUTBOUND MODE

A well-designed facility may include any, or all of the following options for formed sulphur transport:

a) **Barge** (to ship or customer):

The normal movement of product will be to load barges at the facility in lots to match the arrival of an ocean going vessel for a West Coast port. The barges would be held at a fleeing area pending vessel arrival. The barge loading would be timed to match the vessel estimated time of arrival as close as possible.

The barge loading system will generally have a rated capacity of 750 long tons per hour.

Example – Panamax Class vessel being loaded by a mid stream operation in the lower Mississippi River

b) **Railcar:**

The rail facility will have a separate railcar loading station fed by a conveyor system from the storage yard. The conveyor will feed a transfer hopper over the railcar. The prilled sulphur will meter out of the hopper into the railcar and it passes under the load point. The loading will be a continuous process with the railcars moving slowly under the load point until a string of railcars is loaded. The loaded railcars will be switched out and additional empties spotted as necessary. The system is designed for 750 long tons per hours and will have a practical capacity for 7 railcars per hour. The railcar loading system will have a belt scale that could be upgraded to provide certified railcar weights on agreement with the line haul carrier if necessary.

Sulphur Unit Train Transporting Prill

c) **Truck:**

Trucks will be loaded using the railcar loading system. The flow rate will be reduced to compensate for the smaller cargo compartment in the truck bed. The truck will pull under the load point and then gradually move forward as the cargo bed is filled. The system capability will exceed the ability of the trucks to position under the spout. If significant truck traffic is expected a second loading arm can be installed to accommodate the higher volume. Weights will be by certified commercial truck scale in the area. If the truck loading volume warrants a certified truck scale can be installed on the property.

The railcar 750 long ton loading system will be slowed down for the trucks. Loading, including positioning at the load point of each truck, will be approximately 300 long tons per hour.

d) **Container:**

Depending on end markets or shipping container balances at the export port (backhaul economics), the option of loading shipping containers can be economically advantaged for a portion of the outbound sulphur. Containers will be loaded using a portable transfer conveyor. The tail of the conveyor will be located on the storage pad with the head outside the parameter. The truck with the container will back into position with the conveyor inside the open end of the container. The hopper will be started and as product fills the container the truck will move ahead slowly. When the product reaches the point that the container is full the loading will be stopped. The truck will move forward to allow the doors to be closed. As the truck moves through the facility to exit the cargo will settle within the container to allow uniform distribution throughout the bottom of the container.

The conveyor loading conveyor will be able to load one container per hour including positioning of the truck.

CONCLUSIONS

Petcoke and Sulphur are the two major by-products of bitumen and heavy oil refining. The volumes of these by-products are increasing rapidly and will continue to do so in the future. Safe, reliable disposition of these by-products is more critical than ever to ensure that upstream, capital-intensive refining operations can continue in an un-interrupted fashion. These solids-handling systems are complex and maintenance-intensive. Additionally they are operations with which refiners have limited experience. A well-designed maintenance planning and tracking tool is critical to the reliable operations of these units. Marsulex has developed a "diagnostic" tool to model these systems and their current Preventative Maintenance plans to determine if they are appropriate and sufficiently robust to deliver the performance expected.

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