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Efficiently Maintaining Carbon Regeneration through Classical RCM at

Greater Cincinnati Water Works

Alex Schmitz, Sam Paske, Anthony "Mac" Smith and Tim Allen

In August of 2011, Greater Cincinnati Water Works (GCWW) initiated a pilot reliability centered maintenance (RCM) project on its carbon regeneration system under the guidance of AMS Associates. This was GCWW's first RCM effort and it was initiated as a result of a favorable RCM experience at a sister utility – Metropolitan Sewer District of Greater Cincinnati (MSDGC). (See Uptime Magazine, Oct/Nov 2011)

GCWW dates back to 1839 and is one of the country's oldest municipal water suppliers. Today, it serves approximately 1.1 million customers in several southwest Ohio counties and one Kentucky county, and provides, on average, 136 million gallons per day (mgd) of water over a 3,000-mile distribution network.

SYSTEM SELECTION

The carbon regeneration process was chosen for the RCM study based on 2009 and 2010 reactive and corrective maintenance data that showed this system to be the most costly. AMS Associates advocates the 80/20 rule for prioritizing system selections for RCM analysis. As seen in Figure 1, the carbon regeneration process has the highest maintenance costs in 2009 and 2010.

CARBON REGENERATION

Adsorption to remove a broad spectrum of organic substances is achieved by passing sand-filtered water through 12 contactors, each containing approximately 600,000 pounds of carbon at a bed depth of over 11 feet. Contact time between the water and carbon is about 20 minutes at average water production rates. The irregular shape of carbon granules – derived from coal - with its many voids provides a large surface area for the adsorption of impurities. Once the voids in the granules adsorb as many compounds as possible, the carbon becomes "spent" and must be replaced. Rather than use more expensive new carbon, GCWW recycles its spent carbon by passing it through a multiple hearth furnace to burn off the impurities.

BECAUSE RCM IS A TOP-DOWN METHODOLOGY DESIGNED TO PRESERVE THE INHERENT USER'S NEEDS OF THE SYSTEM, THE TEAM SET OUT AND DOCUMENTED EIGHT SYSTEM FUNCTIONS AND 17 FUNCTIONAL FAILURES.

Multiple Hearth Furnace

An RCM team, consisting of GCWW maintenance and operational personnel, was assembled to perform the RCM analysis.

GCWW RCM team members (left to right) Randy Schmidt, Paul Anderson, Gary Carr, Alex Schmitz and Phil Ressler

The team consisted of Randy Schmidt (Operations), Paul Anderson (Mechanical), Gary Carr (Instrumentation), Alex Schmitz (Maintenance Engineering) and Phil Ressler (Electrical). The group was guided by Mac Smith of AMS Associates and Sam Paske of Brown and Caldwell, and facilitated by Tim Allen of AMS Associates.

Because carbon regeneration is an extensive process, the team decided to focus on a manageable subsystem for the four-week pilot project. The team assembled a functional block diagram (Figure 2), which identifies the inputs and outputs of each of the six subsystems. The multiple hearth furnace, which is the most complex subsystem, was chosen. The system has two of these furnaces.

Spent carbon is pumped from the contactors as a slurry via the carbon transfer subsystem. This slurry then enters a carbon spent tank where it is metered into a dewatering screw. The dewatered slurry enters the top of the furnace and then proceeds through six brick oven hearths, guided by turning rabble arms affixed to a hollow, air-cooled center shaft. The bottom three hearths have natural gas burners – the hottest hearth reaches a temperature of 1600°F. The objective is to "bake-off" the impurities, not ignite them. The reactivation process takes 45 minutes. Upon leaving the furnace, the hot reactivated carbon is quenched in a water tank and then pumped back to the contactors. Additional components include a wide assortment of process control and protective instruments to ensure a safe, efficient and quality process.

RELIABILITY REQUIREMENTS

GCWW operates the furnaces during the spring, summer and fall months, with summer being the peak water demand season. The furnaces are shut down for maintenance during the winter months when natural gas prices are typically higher, and a reserve supply of regenerated carbon is stored. While dual operation of the furnaces is not always required, they both are needed at peak demand where they combine to produce 80,000 pounds of regenerated carbon per day. If the carbon is unable to sufficiently regenerate, the carbon adsorption of water will suffer and may require GCWW to increase

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chlorine and/or initiate additional treatment, which is not desirable. Because carbon regeneration furnaces operate using extreme temperatures, maintenance can be challenging. It takes days to heat up a furnace to be used for regeneration and then days again to cool it off for maintenance. As a result, unexpected downtimes are costly. Each heating and cooling cycle of the furnace ages the material condition of the hearth bricks and increases subsequent maintenance costs.

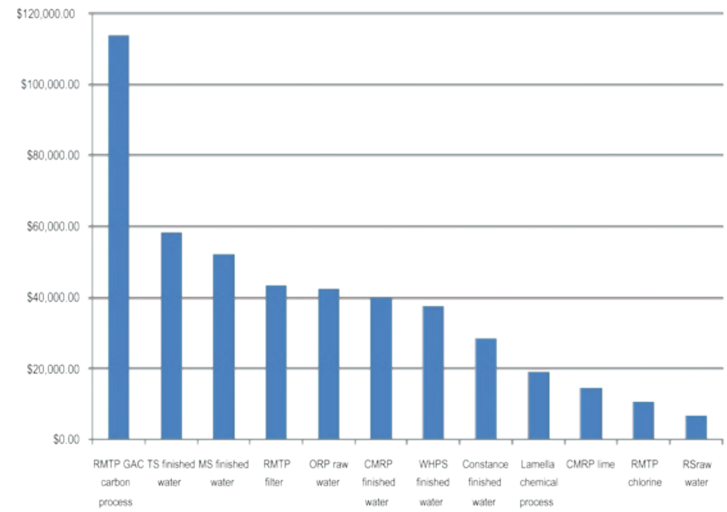


Figure 1: Reactive and corrective maintenance costs by process

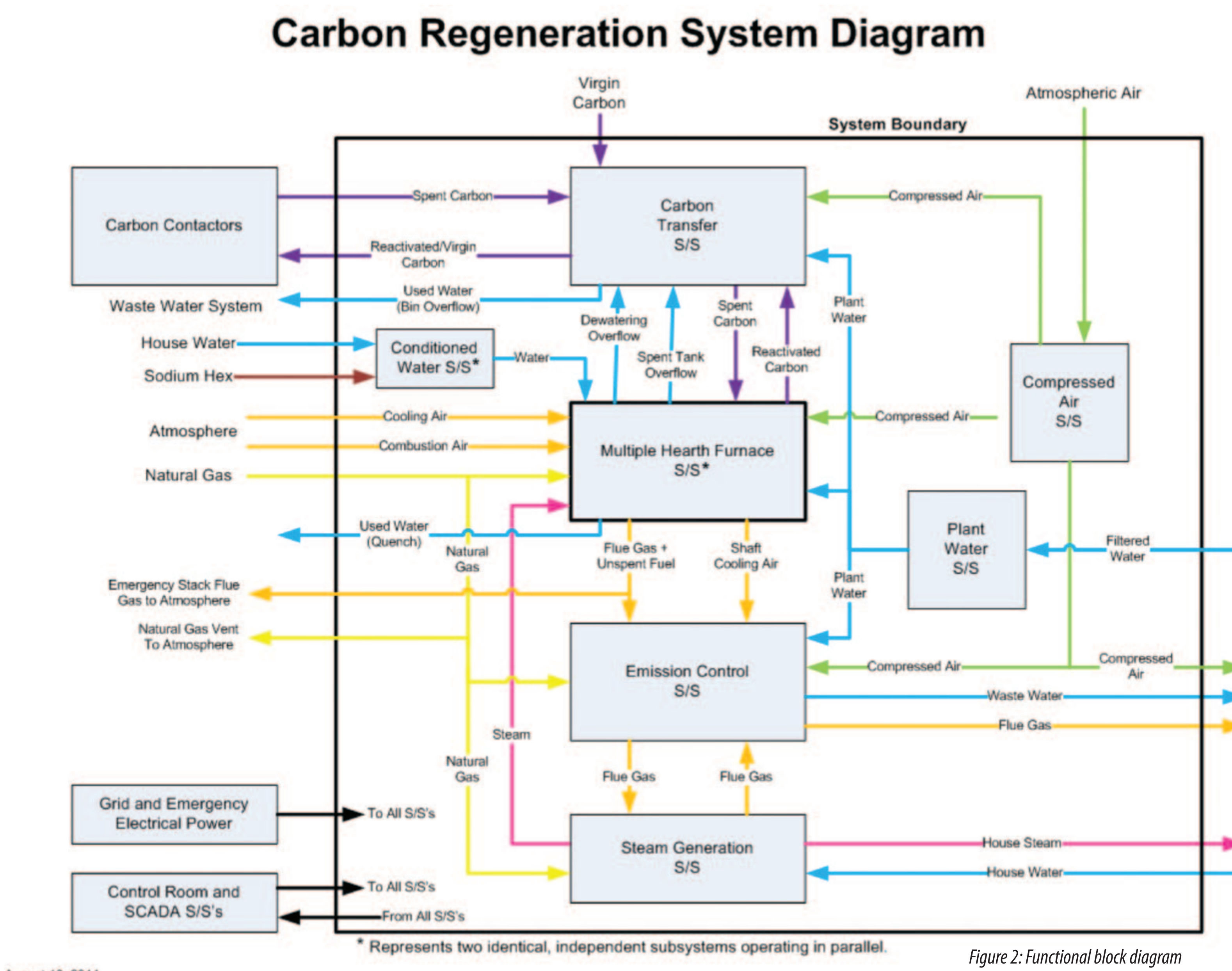


Figure 2: Functional block diagram

RCM ANALYSIS PROCESS

After two days of training, the team commenced evaluation of the furnace with Mac Smith's classical RCM process using JMS Software's RCM WorkSaver™ application. After bounding and describing the system, the team itemized the furnace subsystem into 52 specific components.

Because RCM is a top-down methodology designed to preserve the inherent user's needs of the system, the team set out and documented eight system functions and 17 functional failures.

The primary functions of the furnace are to economically:

- Reactivate spent carbon by removing organics and volatiles within regulatory and GCWW's water quality standards.
- Maintain a nominal carbon feed rate of 40,000 pounds per day per furnace.

The associated functional failures for the primary functions were identified as follows:

- Does not meet GCWW's apparent density and iodine standards.
- Does not reactivate the nominal carbon feed rate of 40,000 pounds of carbon per day.
- Excessive reactivated carbon loss.
- Excessive gas use.

Next, the team associated each functional failure with a system component that could cause or contribute toward the functional failure. The resulting association is displayed in Figure 4.

This unique feature of Mac Smith's classical RCM process maps the cause and effect relationship between each component and the higher level "business requirements" of the system.

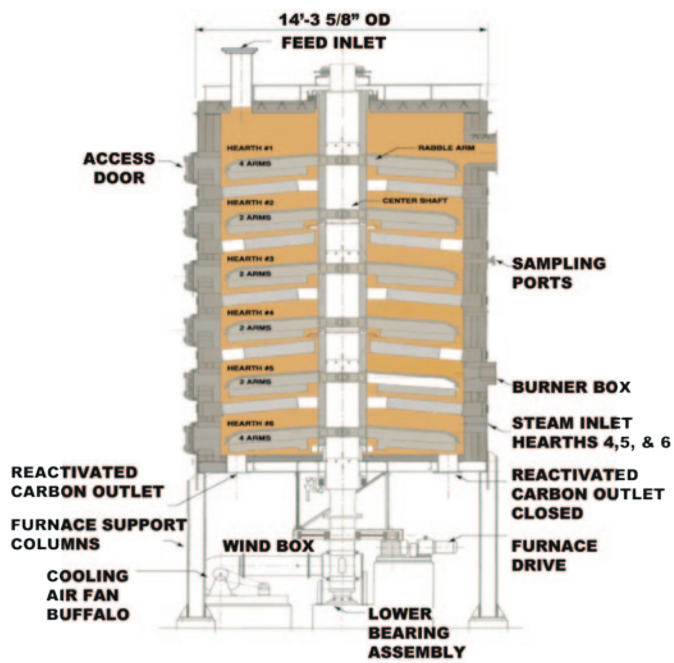


Figure 3: Multiple hearth furnace diagram

FAILURE MODES AND EFFECTS

During the four-week period, the GCWW RCM team evaluated 511 individual failure modes. A failure mode is an unsatisfactory piece, part, or material condition that prevents the equipment from functioning as required. Each failure mode had a failure cause attributed to it and the effects of failure were described at three levels: local, system and plant. It should be noted that although this process is time consuming, major discoveries are always made as part of the analytics. Moreover, the detailed documentation from the experienced maintainers and operators preserves valuable corporate knowledge for the future.

CRITICALITY ANALYSIS

Those failure modes with a safety, system, or plant level effect were carried to the next step for logic tree criticality analysis. Failures having safety consequences are ranked highest (Category A). Failures that cause a system outage, or degrade system performance or quality requirements, are ranked second (Category B). Those failures that do not contribute toward downtime, but have economic consequences due to corrective parts and labor costs are ranked third (Category C). Lastly, although not part of the ranking, each failure mode is designated as either hidden or evident to operations during their normal rounds and duties.

Of the 511 failure modes analyzed for the furnace subsystem, 462 (90%) had the possibility of safety or downtime consequences.

TASK SELECTION

The RCM team then evaluated each critical failure mode for the prescription of planned maintenance tasks. In accordance with traditional RCM methodology, the team sought out condition-based or predictive maintenance tasks in preference to intrusive time-based tasks where possible. It is fair to say that advanced predictive technologies had not been routinely utilized by the assembled team members, but they were willing to think outside the box to develop new strategies. Numerous failure finding tasks were developed as well.

RCM RECOMMENDATIONS

The RCM analysis generated a significant number of preventive maintenance tasks that were not in place at the time of the analysis. In all, 554 failure mode specific preventive maintenance (PM) tasks were recommended. It is important to point out that the 554 tasks were not all unique and were efficiently bundled into far fewer PM work orders. For example, the team identified four identical tasks to test a high-level probe in the carbon spent tank that applied to four individual failure modes: relay coil failure, dirty or worn contacts, burnt solenoid and loose wire connections.

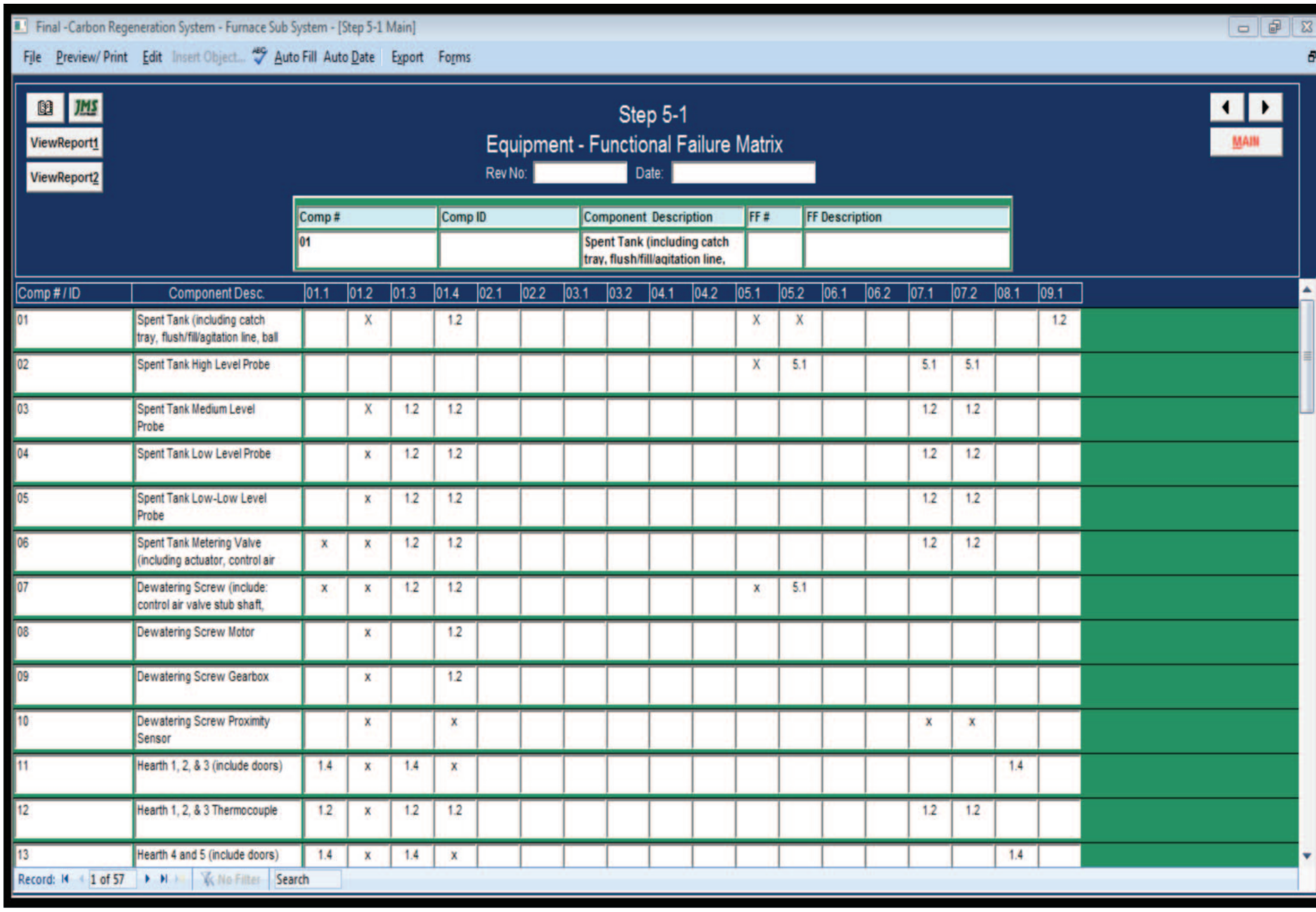
Touching the probe with a device will activate a high-level alarm and verify that the four specific failure modes have not functionally occurred. Not testing the probe could allow a hidden failure, and coupled with some blockage in the carbon flow, would result in a significant spill of carbon slurry from the top of the tank onto below equipment, damaging equipment and causing unsafe working conditions. This excellent example of a failure finding task is similar to many of the other tasks developed. In all, 51 percent of the developed tasks were failure finding tasks, which discovered failures that may have occurred and are lying in wait because no one knows about them. Testing of the burner fire eye relay is another example of a failure finding task that shall be showcased herein.

BURNER FIRE EYE RELAY TEST

The team developed a test to verify that the blocking valve effectively shuts to stop natural gas flow to the furnace when the burner pilot light goes out. The fire eye senses the light of the flame and through photovoltaics generates a permissive signal to keep a gas blocking valve open. Upon loss of that permissive, multiple relays in the burner control panel will disengage and interrupt the permissive to the blocking valve, which will thereby spring closed. If the relays were to be mechanically bound or the contacts welded, they would not open up to actuate valve closing. Granted, this would be a rare occurrence, but testing the functionality by temporarily removing the fire eye helps ensure that protection will be there if ever needed. The team also recommended installing new relays with an LED indicator to verify the open or close position.

IMPLEMENTATION RESULTS

The study was completed just as the furnaces were being brought down for winter shutdown. There was concern from team members and management that there would not be enough time during the shutdown to complete all the tasks identified in the study.



Final -Carbon Regeneration System - Furnace Sub System - [Step 5-1 Main]

File Preview/ Print Edit Insert Object... Auto Fill Auto Date Export Forms

ViewReport1

ViewReport2

Step 5-1

Equipment - Functional Failure Matrix

Rev No: Date:

MAIN

Comp #	Comp ID	Component Description	FF #	FF Description
01		Spent Tank (including catch tray, flush/fill/agitation line,		

Comp # / ID	Component Desc.	01.1	01.2	01.3	01.4	02.1	02.2	03.1	03.2	04.1	04.2	05.1	05.2	06.1	06.2	07.1	07.2	08.1	09.1
01	Spent Tank (including catch tray, flush/fill/agitation line, ball		X		1.2							X	X						1.2
02	Spent Tank High Level Probe											X	5.1			5.1	5.1		
03	Spent Tank Medium Level Probe		X	1.2	1.2											1.2	1.2		
04	Spent Tank Low Level Probe		x	1.2	1.2											1.2	1.2		
05	Spent Tank Low-Low Level Probe		x	1.2	1.2											1.2	1.2		
06	Spent Tank Metering Valve (including actuator, control air	x	x	1.2	1.2											1.2	1.2		
07	Dewatering Screw (include: control air valve stub shaft,	x	x	1.2	1.2							x	5.1						
08	Dewatering Screw Motor		x		1.2														
09	Dewatering Screw Gearbox		x		1.2														
10	Dewatering Screw Proximity Sensor		x		x											x	x		
11	Hearth 1, 2, & 3 (include doors)	1.4	x	1.4	x													1.4	
12	Hearth 1, 2, & 3 Thermocouple	1.2	x	1.2	1.2											1.2	1.2		
13	Hearth 4 and 5 (include doors)	1.4	x	1.4	x													1.4	

Record: 1 of 57 No Filter Search

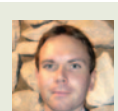
Figure 4: Step 5-1 functional failure matrix

With time being of the essence, RCM team members knew that work had to begin immediately. The team opted to distribute hard copies to each maintenance shop that listed the RCM tasks to be completed during the shutdown. Monthly meetings were established with RCM team members to track the task completion status and ensure the furnace startup would not be delayed. After months of hard work and collaboration between GCWW's maintenance and operations staff, the RCM strategy for the winter shutdown was complete. The furnace started up one day ahead of schedule and the regeneration season began.

FAILURES HAVING SAFETY CONSEQUENCES ARE RANKED HIGHEST (CATEGORY A). FAILURES THAT CAUSE A SYSTEM OUTAGE, OR DEGRADE SYSTEM PERFORMANCE OR QUALITY REQUIREMENTS, ARE RANKED SECOND (CATEGORY B). THOSE FAILURES THAT DO NOT CONTRIBUTE TOWARD DOWNTIME, BUT HAVE ECONOMIC CONSEQUENCES DUE TO CORRECTIVE PARTS AND LABOR COSTS ARE RANKED THIRD (CATEGORY C).

The end of the winter shutdown was just the start of the continuous improvement effort with the RCM strategy. RCM tasks were converted into GCWW's CMMS and reports were created to track failure modes associated with each reactive maintenance work order. The RCM team continues to meet monthly where the failure modes are reviewed and linked back to the RCM strategy. They determine why the failure mode occurred and update the RCM strategy accordingly.

Thus far, it is clear that the commitment to the RCM program has paid off. The furnace did not experience any of the functional failures identified by the RCM team. The furnaces have regenerated 40,000 pounds of carbon each day and meet all of GCWW's apparent density and iodine standards. Excessive natural gas usage has been avoided and remains consistent to the average. The carbon loss has improved from a 7.7 percent loss in 2011 to a 7.3 percent loss in 2012. Furthermore, going full circle as to why the carbon regeneration process was chosen for the RCM study, GCWW's 2012 reactive and corrective maintenance costs have been reduced by 50 percent on the equipment analyzed in the RCM study.



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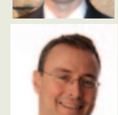

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Anthony "Mac" Smith has over 50 years of engineering experience, including 24 years with General Electric in aerospace, jet engines and nuclear power. He has personally facilitated over 75 RCM studies and has authored/co-authored two books on RCM. www.jmssoft.com

Tim Allen joined Mac in 2005 after a 20-year career with the US Navy's Submarine Maintenance Engineering Planning and Procurement Activity (SUBMEPP). During his tenure, Tim was one of the principals in developing the submarine group's RCM process. www.jmssoft.com