UNIVERSITY OF MICHIGAN HOSPITALS AND HEALTH CENTERS
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MEMORANDUM

TO: Bob Harris, PE
Director, UMH Facilities Planning and Development

FROM: Adam Desmarais, PE
Manager, Mechanical Engineering, UMH FPD

DATE: 6/9/11

SUBJECT: Domestic Water Analysis- Premature Failures in UMH Domestic Hot Water Systems

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This memo attempts to consolidate the efforts to date in understanding the ongoing premature failures in our UMH domestic hot water systems. Primarily this effort has focused on problems in facilities on the main hospital campus served by Central Power Plant (CPP) domestic hot water, which is in turn supplied by the City of Ann Arbor water service.

Maintenance has numerous examples of failed components used in our domestic water systems. These problems to a large extent are most prevalent in our domestic hot water and domestic high temperature hot water systems. Pictures and numerous samples of failed components have documented a long-standing, ongoing problem with corrosion, excessive scale/ deposit formations, pitting and etching of various materials used in our domestic hot water system. The most common problems are with the failure of EPDM gaskets (primarily those used in grooved “Victaulic/ Grinnell” style couplings) which appear to be disintegrating in the hot water system, pitting of copper and brass components and corrosion of brass and stainless steel components, primarily underneath scale/ plating deposits that have formed on these materials. These various means of failure have been witnessed in our older plumbing systems as well as systems in use for less than 2 years.

UMH FPD has worked closely with the UMH Plumbing Shop, our water treatment contractor, Rochester Midland, campus Utilities and the CPP resident chemist, Merrill Willett at identifying the mechanisms at play in causing these failures.

The City of Ann Arbor water service is a mix of surface water and well water that exhibits high ph (8-9), high conductivity (500-700 uS) and medium hardness (~140 mg/L). The City of Ann Arbor uses chlorimines as a domestic water disinfectant, which, in concert with the high conductivity and hardness characteristics, is believed to be the mechanism responsible for our premature failure problems. In addition, conductivity values fluctuate seasonally, with higher values seen in winter and lower values seen in summer. It is generally believed that these high conductance values exacerbate the corrosion, material degradation and pitting problems we witness. Raising the temperature of the water increases the corrosive potential of the water (~corrosion rates double for every 10 degree temperature rise), which explains why these failure problems are primarily seen in our domestic hot water systems and not our domestic cold water systems.

The group discussed the various means of counteracting/ pretreating our domestic hot water systems. Water softening was discussed but ruled out because of its limited ability at controlling corrosion and pitting and the high maintenance costs associated with the large amounts of salt replenishment. Carbon filtration/ chloramine removal was discussed and ruled out because of the need to re-treat/ disinfect the water and the inherent water treatment licensing issues that would be required. Partial reverse osmosis (RO) pre-treatment was discussed as a viable option, but involves high maintenance/ operating costs as well as high first time installation costs, in addition to the complexities involved at maintaining an acceptable balance of blended water. Based on the recommendation of Rochester Midland, the group decided to explore polyphosphate chemical injection and careful material selections used in our domestic hot water systems.

Rochester Midland pursued 60 day and 90 corrosion coupon tests to document the corrosion/ pitting problems and benefits of polyphosphate injection. Admiralty brass was chosen as the coupon material because of its suspected corrosion/ pitting problems in our domestic hot water systems. Coupon racks were installed in University Hospital and CVC. In addition, a polyphosphate chemical injection system was installed in the CVC hot water system. UH was used as a benchmark to document the benefits of polyphosphate injection seen in the CVC facility. Attached are the results and a report from Rochester Midland. In general, the use of polyphosphate in the hot water system was found to reduce corrosion and pitting rates by over 50%. As a secondary benefit (yet unmeasured), the use of polyphosphate is expected to prevent the formation of calcium carbonate deposits (which will in turn form benign calcium phosphate). First time installation costs for polyphosphate injection are minimal (injection pumps, analyzer and chemical tanks) as well as operating costs are expected to be minimal (the CVC site used approx. 3 gallons of polyphosphate per month, valued at approx. $700 for the 3 month test).

Simultaneously CPP conducted a corrator probe test of the hot water delivered out of CPP. This test studied the effects untreated domestic hot water has on various materials common in our domestic hot water system. This study looked at corrosion and imbalance values (indicative of pitting problems) for 304 SS, 316 SS and admiralty brass for a 3 month period. Attached are the results from this test. In summary, this test indicated that 304 SS and 316 SS show little if any corrosion and/or pitting problems. In contrast, admiralty brass exhibited poor corrosion rates (>0.5 mpy) and poor pitting potential (>6uA IMB). In addition, this study looked at the relationship amongst corrosion potential, pitting potential and conductance of the water. In general, higher conductance values were shown to increase corrosion rates and increase pitting potential.

RECOMMENDATIONS

The group recommends the following:

- Careful material selection of metals that are resistant to the corrosive effects of the domestic hot water system. In general, of the common materials used in our domestic hot water system, installations should focus on the use of stainless steel (either 304 or 316) and copper. Brass should be limited as much as possible. Mild steel should not be used at all.
- In so much as possible, limit the use of EPDM in the domestic hot water system. The campus tunnel group reports good success with the use of peroxide-cured EPDM as a viable alternative. This special treatment, available as an option for grooved piping installations, exhibits a closed cell structure that is more resistive to the corrosive effect of the hot water system. Recent updates to the UM masterspec now require the use of peroxide-cured gaskets on all grooved piping installations used in hot water systems.
- Brass and EPDM are used extensively in a multitude of plumbing fixtures and choices are limited on alternative material selection. In addition to the above material selection choices, the group also recommends the use of polyphosphate injection on our domestic hot water systems. The use of polyphosphate is expected to decrease corrosion and pitting problems, as well as decrease scale formation.
- Continued follow-up with the City of Ann Arbor on their efforts at modifying their water treatment process. Preliminary discussions with the city have indicated that the city plans on implementing a revised water treatment method to help even out the seasonal fluctuations of conductivity. Domestic water from the City of Ann Arbor is anticipated to be kept at low summer-time conductivity levels (400-500 uS) year-round, which should have a significant benefit in reducing corrosion and pitting problems.

FOLLOW-UP

1. Continued discussions with the campus design guidelines/ specifications committees at exploring means to limit brass and untreated EPDM in our domestic hot water system. Significant advancements have been made lately with the addition of peroxide-cured EPDM gaskets and all SS butterfly valves specified for use in our domestic hot water systems. Tim Smith will follow this effort in his involvement in the campus design guideline committee.
2. The implementation of a polyphosphate injection system. Ideally this effort would be conducted out of CPP so that all of the university facilities provided with CPP hot water would benefit. While the hospital campus is the largest user of CPP hot water, problems are believed to prevalent throughout campus. Adam Desmarais to follow-up with Mike Swanson on the means/ ability to implement this out of CPP.

3. Follow-up with the city on their plans and timeline for the above described treatment modifications. Adam Desmarais to follow-up with Mike Swanson on his contact with the city.
4. UMH FPD will continue working with RMC for continued polyphosphate injection in CVC for an additional 120 day period. The group agreed further analysis on the benefits of this pretreatment would be beneficial. The group will meet again in October to review progress on this issue.

CC: Mike Swanson (UM Utilities)
Merrill Willett (UM CPP)
Jim Brinker (UMH Plumbing Shop)
Tim Smith (UMH FPD)
Tom Girard (UM AEC)
Dennis Kretin (UM Utilities)
Tom Jensen (UMH Maintenance)
Jim Lingenfelter (UMH Maintenance)
Joe Stchur (UMH Facilities Operations)

Attachments: Central Power Plant Corrosion Study
Rochester Midland Co. Corrosion Study

Summary of 60 and 90 Day Coupons at UH and CVC

Admiralty Brass coupons were installed at UH and CVC domestic water systems. The CVC system was treated with a Potable approved domestic water corrosion treatment. Treatment was maintained at 2 – 3 ppm. Usage was approx. 3 gallons per month. One set of coupons was removed after 60 days. The second set was removed after 90 days. The corrosion rates were determined, and the reports are attached.

The goal of the analysis was to determine if Potable Treatment would reduce the corrosion rates and to determine if chemical treatment is a viable method to reduce failures in UM domestic water systems.

Discussion

UH – Both sets of coupons showed poor results in respect to corrosion. 60 day rate was .70 mpy. 90 day rate was .51 mpy. Of particular note and concern was the significant amount of pitting on the coupons. Localized pitting magnifies corrosion rates and leads to premature, localized failure of system piping – this type of failure is typical of what is seen at the hospitals. Pitting also contributes corrosion products to the system which can lead to deposition/plating on other metal surfaces. This deposition can lead to additional pitting and failure other system metallurgy.

CVC – Both sets of coupons showed good to very good results with respect to corrosion rates. 60 day - .32 mpy. 90 day - .24 mpy. No pitting was noted.

The addition of the potable inhibitor reduced corrosion rates and metal loss by more than 50%. More significantly, the inhibitor greatly reduced the level of pitting on the coupons. Pitting, as noted above is a greater concern than general corrosion because of the potential for localized failure and corrosion product contribution.

Recommendations

Metallurgy - Utilization of corrosion resistant metallurgy where ever possible is the most important factor. Stainless 304/316 should be used where possible. Copper should be used where stainless is not an option or is too costly. This includes clamps and saddles if contact with water will take place.

Chemistry – The results at CVC show some promise especially in respect to pitting. Treatment at UH for a 60 and 90 day period with coupons should be undertaken. A 30 gallon drum of PT112 should be sufficient for a 90 day period.

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CORROSION COUPON ANALYSIS REPORT

Univ. of Michigan

Date Received: 5/17/2011
Date Finished: 5/19/2011
Analyst: Andrew Wozniak
Log No. 999 **Sales Rep:** Mike Miller

Coupon Number	483	481	489	490				
Coupon Type	Brass 443	Brass 443	Brass 443	Brass 443				
Coupon Location	UH		CVC					
Days Exposed	60	90	90	60				
Initial Mass (grams)	12.6275	12.5250	12.6314	12.5586				
Final Mass (grams)	12.5796	12.4662	12.6068	12.5338				
Mass Loss (grams)	0.0479	0.0588	0.0246	0.0248				
Corrosion Rate (MPY) in scientific notation	6.97E-01	5.07E-01	2.38E-01	3.21E-01				
Corrosion Rate (MPY)	0.70	0.51	0.24	0.32				
Corrosion Rating	Poor	Poor	Very Good	Good				

The corrosion rating is not available if the type of system is not given.

Open Recirculating Cooling Water Systems (also used for Condensate Systems)			
RATING	**MILD STEEL 1010**	**COPPER 110**	**ADMIRALTY BRASS 443**
Excellent	0.00-1.00 mpy	0.00-0.15 mpy	0.00-0.15 mpy
Very Good	1.01-3.00 mpy	0.16-0.25 mpy	0.16-0.25 mpy
Good	3.01-5.00 mpy	0.26-0.35 mpy	0.26-0.35 mpy
Acceptable	5.01-8.00 mpy	0.36-0.50 mpy	0.36-0.50 mpy
Poor	8.01-10.00 mpy	0.51-1.00 mpy	0.51-1.00 mpy
Unacceptable	≥ 10.00 mpy	≥ 1.01 mpy	≥ 1.01 mpy
PLEASE NOTE: CUT MILD STEEL RANGE IN HALF FOR GALVANIZED STEEL COUPONS.			

Closed Recirculating Cooling Water Systems			
RATING	**MILD STEEL 1010**	**COPPER 110**	**ADMIRALTY BRASS 443**
Excellent	0.00-0.20 mpy	0.00-0.10 mpy	0.00-0.10 mpy
Very Good	0.21-0.50 mpy	0.11-0.25 mpy	0.11-0.25 mpy
Good	0.51-0.80 mpy	0.26-0.35 mpy	0.26-0.35 mpy
Acceptable	0.81-1.00 mpy	0.36-0.50 mpy	0.36-0.50 mpy
Poor	≥ 1.01 mpy	≥ 0.51 mpy	≥ 1.01 mpy
PLEASE NOTE: CUT MILD STEEL RANGE IN HALF FOR GALVANIZED STEEL COUPONS.			

Physical Description	**Coupon Number**		**Coupon Location**
Before Cleaning:	**483**	Ad. Brass 443	**UH 60 Day**

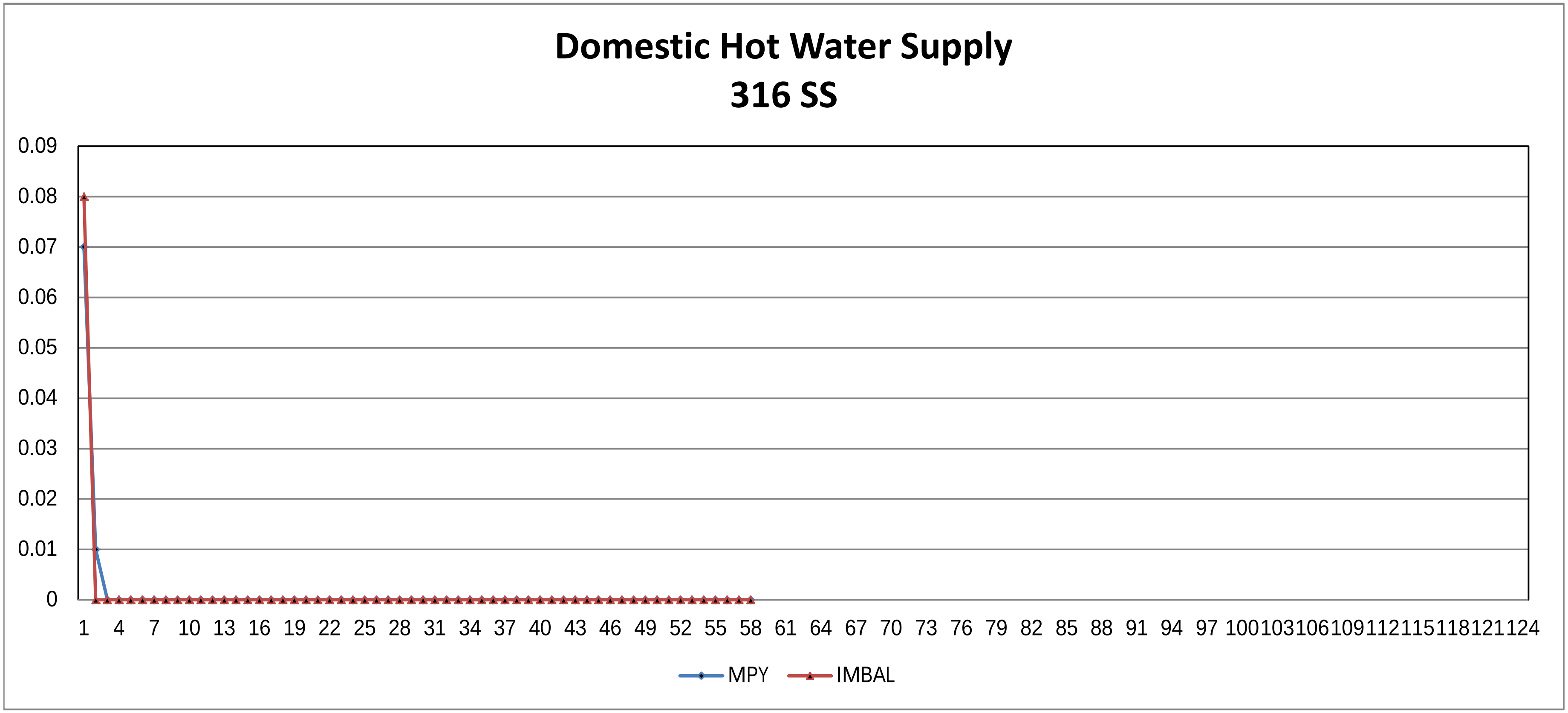
This coupon appeared dark gray in color with spots of lighter gray, mainly on the trailing end of the coupon. There is no metal loss visible			
After Cleaning:			
This coupons has many tiny pits on the surface of the coupon. It also has some discoloring around the edges. These spots are not the Dark gold of Brass but are more of a copper/brown.			
Before Cleaning:	**481**	Ad. Brass 443	**UH 90 Day**
This coupon appeared dark gray in color is tiny white spots visible, mainly on the trailing end of the coupon. There is no metal loss visible			
After Cleaning:			
This coupons has many tiny pits on the surface of the coupon. It also has some discoloring around the edges. These spots are not the Dark gold of Brass but are more of a copper/brown.			
Before Cleaning:	**489**	Ad. Brass 443	**CVC 90 Day**
This coupon appeared a dull gray in color with tiny white spots visible, mainly on the surface near on the trailing half of the coupon. There is no metal loss visible			
After Cleaning:			
The dull gray coating and the white spots were removed during cleaning. The color is present but darker then normal especially on the ends and edges of the coupon. There are a few tiny pits visible on the coupon.			
Before Cleaning:	**490**	Ad. Brass 443	**CVC 60 Day**
This coupon appeared a dull gray color with a patch of white/green near the center of the coupon. There is no metal loss visible.			
After Cleaning:			
The dull gray coating and the green/white patches were removed during cleaning. The color is present but darker then normal especially on the ends and edges of the coupon.			

Coupons Before Cleaning

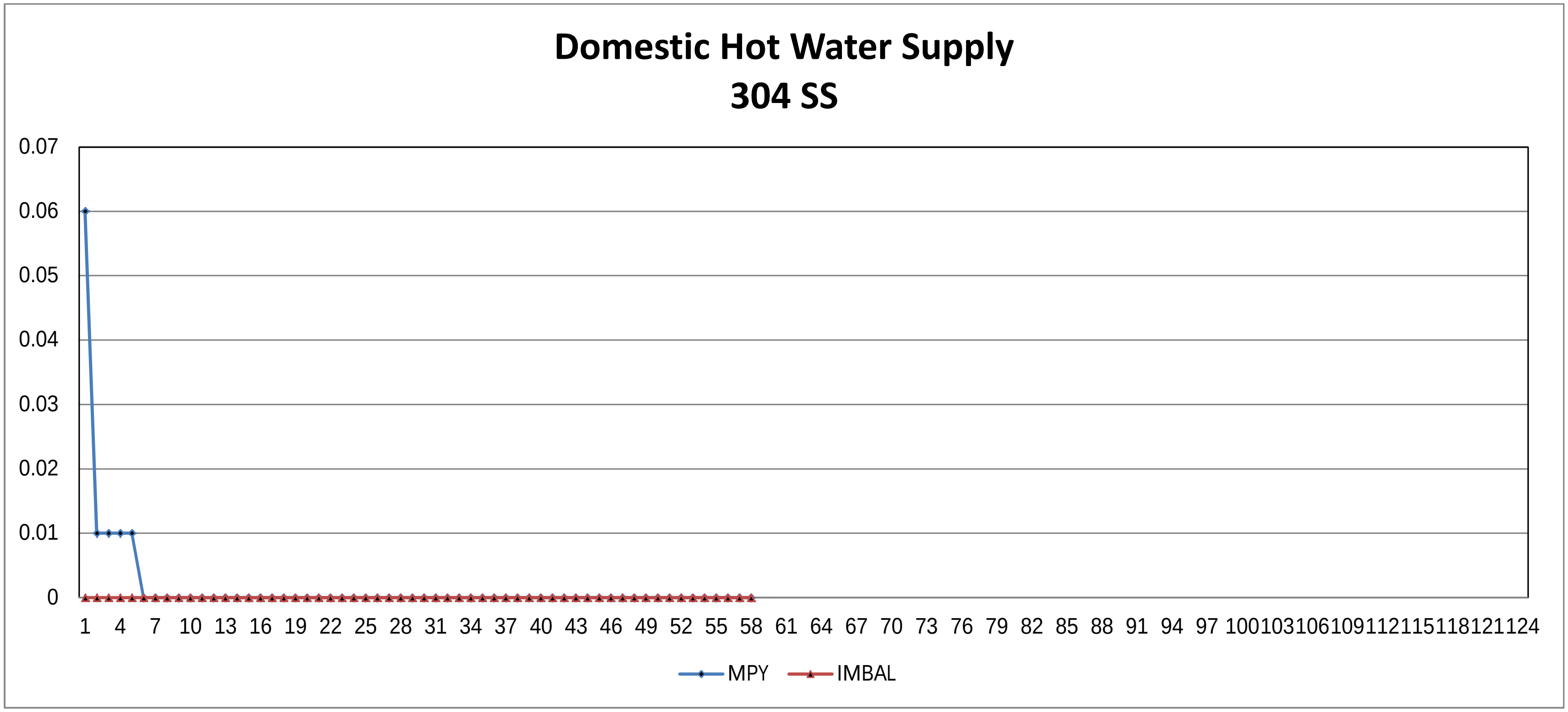
Coupons After Cleaning

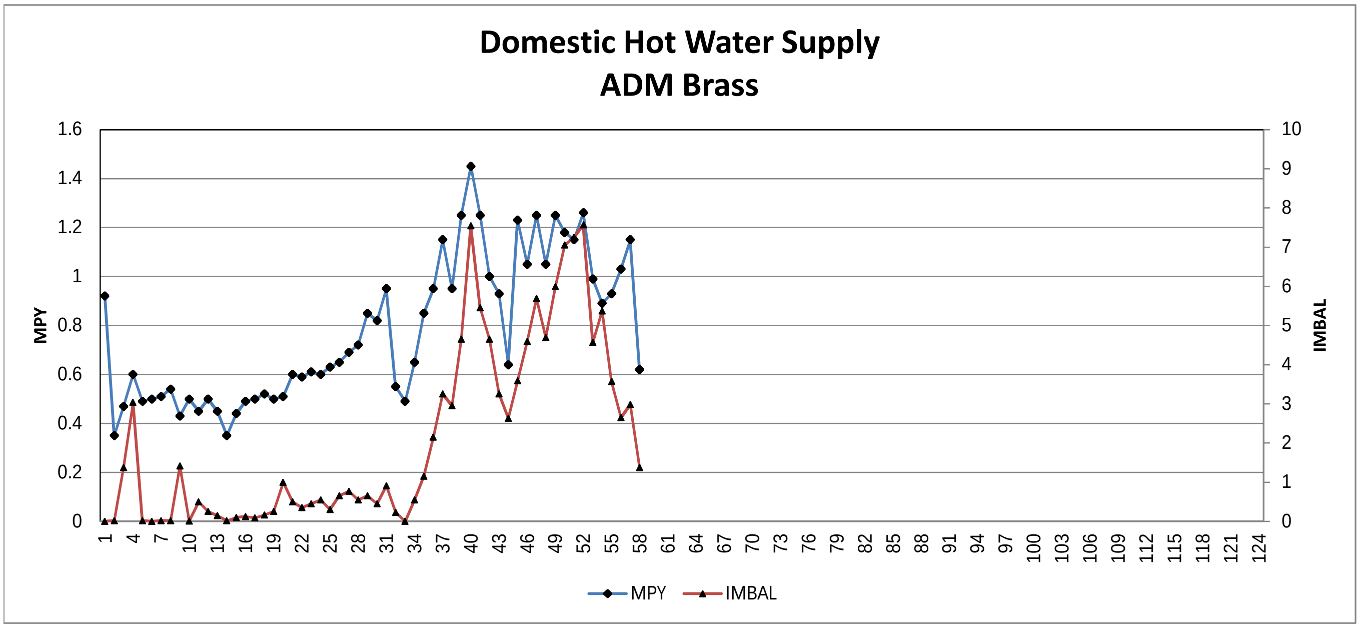
Date Printed: 5/20/2011

CPP Corrosion Study



CPP Corrosion Study

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ADM Brass
MPY
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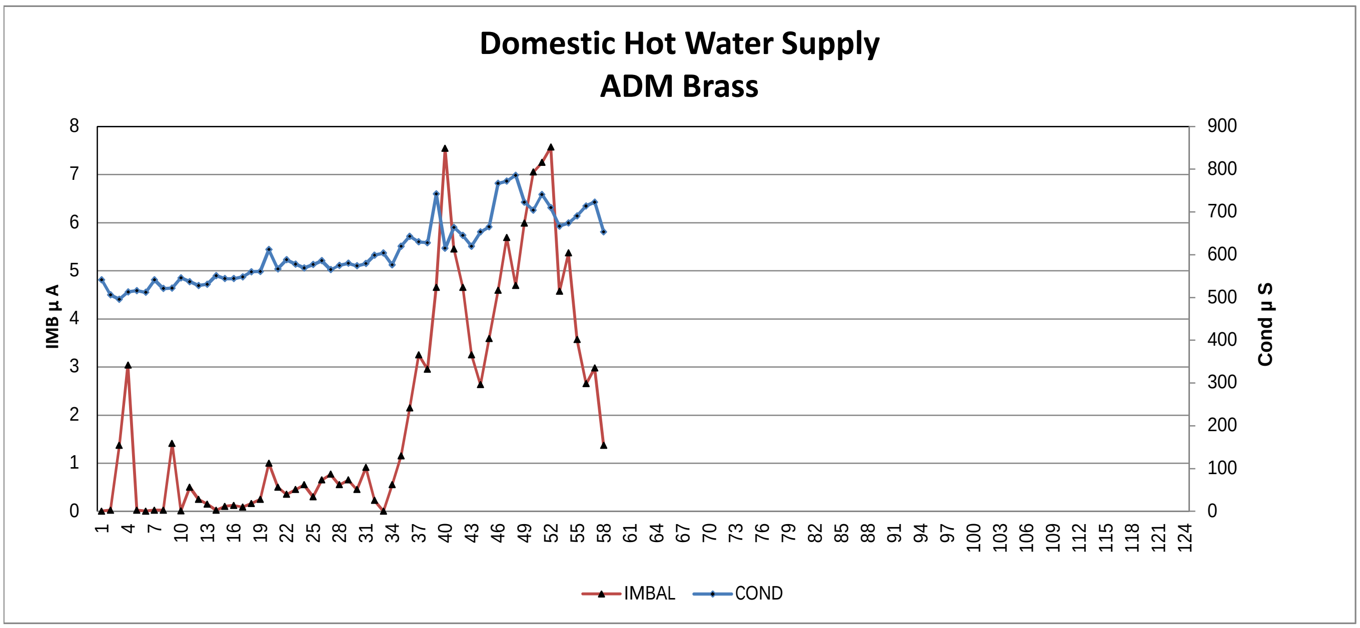
MPY
IMBAL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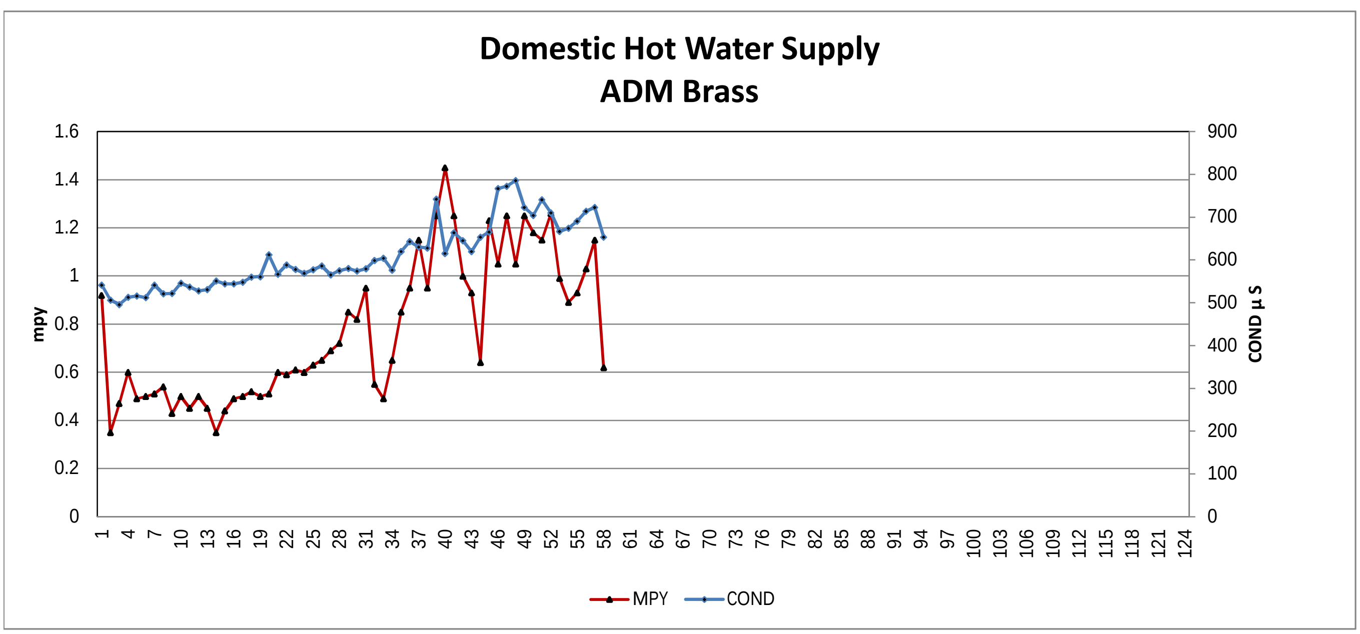
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