Event

On June 29th, 2014, TC2 was removed from service due to issues with the turbine EHC system. The 2A main steam stop valve (MSV) had failed to re-open the previous morning following a valve test. After I/E performed trouble shooting and replacement of the MSV servo, it was discovered that a TCS 'master reset' had to be initiated to send a 4-20 mA control signal output to it. It was decided to wait and perform the master reset while the unit was down for scheduled deslag. The TCS was 'master reset' successfully and control current was re-established to the servo, but the valve still remained closed. The fast acting solenoid (FAS) located on the valve appeared to be dumping the actuator hydraulic supply based on the valve hydraulic drain line temperature. The decision was made to remove the unit from service to allow replacement of the FAS.

While decreasing load to come offline, the 2A CV was not closing as expected, and it stopped closing partially open. The 2B CV was fully closed. At 80 MW, the turbine tripped and an auto shutdown was executed. The 2B CV and both the 2A and 2B intercept valves (ICV) closed; however, the 2A reheat valve, 2B reheat valve, and 2B MSV remained fully open. The 2A CV remained partially open.

A successful sequential trip of the generator requires all steam paths to the turbine to be blocked until the generator "motorizes." When a reverse power relay confirms that the generator is motorizing for three seconds at -4% of the generator power (MVA) rating and all steam paths are blocked, the line breakers open islanding the turbine from the grid. If the generator motorizes for ten seconds the line breaker is opened even if all steam paths are not blocked. Since all steams paths were not blocked, the synchronizing breaker was not automatically opened. The generator line breaker remained closed and the unit stayed at 3600 rpm. Operations kept the line breaker closed to prevent an overspeed. The unit remained online for several minutes until the generator motorized for ten seconds. The generator reverse power 2 relay picked up and tripped the line breakers, opening them automatically. Turbine speed began to decay on the machine with the turbine HP and LP bypass valves closed and dropped to 3150 rpm. The LP bypass valve opened up as normal following a turbine trip, but with the 2B MSV open along with the 2B CV open, a path for steam flow through the HP turbine to the condenser was established without load being generated (i.e. the line breaker open). This flow path, coupled with the 2B MSV's inability to close, resulted in the turbine picking up speed. The EHC pumps were tripped from service, the boiler MFT'd and the 2A PORV was opened. The Manual trip handles on the master trip solenoid valves equipped on the hydraulic fluid tank were operated, but nothing happened. Turbine speed reached 3969 rpm before I/E personnel manually actuated the 2B MSV FAS with a hammer and punch causing the valve to go closed. EHC trip pressure was slow to decay and was at 1300 psi when the valve closed. It began to re-open when the FAS was released, and the FAS had to be manually held open until EHC trip pressure was bled off.

Root Cause Failure Analysis

Since original unit startup, the TC2 EHC system has had a history of particulate and varnish contamination issues. In the spring of 2011, a high velocity flush was performed to eliminate particulate. In the spring of 2012, a chemical flush was conducted to remove varnish within the system. Because of parts issues, jumpers were installed at the emergency trip valve manifold and it was not flushed. Fluid sample data indicated no issues with the EHC fluid at the time of the TC2 Spring 2014 burner outage. However, because there had been issues reported from Operations with testing the master trip solenoid valves, I/E changed the master trip solenoid valves and pilot-operated valves on the trip block during this outage.

Leading up to the event on June 29th, 2014, there was a known issue with water contamination in the EHC system that had first become apparent to plant personnel on Friday, June 20th. A vacuum dehydrator was brought in on Saturday, June 21st, and removed approximately 2.5 gallons of water over the course of several days. Although the water was removed from the system, the components throughout the system had been contaminated, so the decision was made to conduct a complete flush on the EHC system.

EHC fluid analysis from January 6th, 2014 indicates that the fluid was in good condition with water content of 0.08% (800 ppm) before coming off-line for the 15+ week burner outage in February, 2014. However, the first sample taken after the outage on June 17th indicated that there was 0.45% (4500 ppm) of water in the fluid. According to the fluid supplier, water in the EHC fluid can act as a solvent breaking up and releasing contaminants that may be in the system. Therefore, any varnish that may have been in the system could have been released by the water.

The potential sources of water were investigated to determine the root cause of the water contamination. A leak in the coolers seemed to be the most likely source of water of this magnitude, so they were pressure tested on-site with nitrogen and water. Both EHC Coolers were pressure tested at 80 psig of air for 1 hour with no noticeable depreciation of pressure observed. These coolers were pressurized again to 120 psig of water. One cooler held pressure for approximately 12 hours and the other for approximately 6 hours. However, to avoid the risk, the decision was made to replace the EHC coolers with temporary coolers until a new heating/cooling system was in place.

After the outage, the coolers were sent out and tested by National Heat Exchange Cleaning Corporation in Youngstown, Ohio. Both coolers passed hydro tests on both the shell and tube side at the OEM's test pressures indicating no leaks in either cooler.

According to MD&A, another source of water into the EHC system could be during start up when the Main Stop and Re-Heat Stop Valve stems are not back seated. These drain lines and pans were inspected and cleaned, and the stem bushings below the valves were verified to be free of obstructions to prevent water from backing up on top of the actuators. During the start-up, the drain lines were blown out and debris was removed from the collection channel at each valve to confirm that all drain lines were clear to prevent standing water from collecting on top of the valve actuators.

During the planned 2014 spring TC2 outage, the EHC tank was drained and that EHC fluid was stored in plastic totes for several weeks. When the TC2 outage was near completion, the EHC tank was refilled with some of the EHC fluid that had been stored in the totes. While refilling the EHC tank with the used EHC fluid, the mechanics noticed that there was visible quantity water floating on top of the fluid in the tote. Assuming that the fluid below the visible water would be sufficiently water-free to reuse it, an unknown quantity of the used EHC fluid was pumped from the bottom of the tote back into the EHC tank, and then the mechanics used new fluid to finish topping off the EHC tank. Although the used EHC fluid that was stored in the totes was not sampled and tested before it was put back in the EHC tank, it is assumed now that the fluid was contaminated with water while stored in the totes, and that this is the most likely source of the EHC fluid water contamination problem that was revealed after the unit was put back online.

Since the TC2 EHC system flush was completed and the unit returned to service in early July, an experiment has been underway to determine how much moisture EHC fluid can absorb from the air. New EHC fluid was put into a small jug, with the cap installed on the jug in a loose, non-air tight manner, similar to a tote. The jug was placed near the location where the totes of fluid were stored during the TC2 outage. The water content of the fluid increased from 252 ppm to 1246 ppm over a 3 week duration.

Follow-up Actions/Recommendations

- All personnel at the plant have been tailgated about the proper handling and storage of EHC fluid.
    - The mechanics have received training on EHC handling procedures and the proper way to add or remove EHC fluid from the tanks and drums.
    - Used EHC fluid is no longer reused and only clean, new containers are used to hold or transport EHC fluid.
    - Only fluid in unopened EHC drums is used to fill EHC tanks. Once a drum of EHC fluid is opened, any unused fluid remaining in the drum is discarded.
    - The pump used to transfer new EHC fluid into the EHC tanks is clearly labeled to be used for EHC fluid only, and is stored in a secure location that is only accessible by personnel who are trained to handle EHC fluid, the EHC pumps, and associated equipment.
- More training is being planned as well.
- Maintenance PMs have been created to inspect each turbine valve actuator's condensation collection channel, remove any debris from the channel, and blow out the drain lines to ensure that it is clear so that no standing water collects on top of the valve actuators.

On July 8,2014, Hydra-Lube Inc. was asked to attend the 8:00am meeting at Trimble County Station. The meeting was called to discuss the problems with the EHC system on unit 2. After arriving at site and reviewing all the data presented. The things that concerned Hydra -Lube were the FME found in the trip circuit manifold. Also that once the FME was removed the turbine protective system could not be reset and tripped in the necessary time to assure there was no catastrophic failure to the Turbine generator. Hydralube started investigating were the FME came from. After reviewing the trip circuit, there is a .031 orifice on the fluid trip supply before entering the trip manifold. There was no FME found in the orfice therefore the FME was left in the manifold during disassembly.

Concerns:

1. How much FME was in the manifold and how much was discharged into the ETS (emergency trip supply) fluid lines.

2. Why is the trip circuit not resetting and tripping in necessary time?

To shoot trouble on the system HL requested pressure gauges on the test ports of MXA- pressure on X port of pilot valve A, MXB- pressure on X port of pilot valve B, and MB- pressure on ETS fluid supply line. After starting the system and observing the pressures during a reset and a trip the following was found.

1. MXA, MXB would pressure up to 2260psi during reset.

2. MB would pressure up to 2260 but would take 2-5 minutes to do so.

3. During a trip test MXA and MXB would drop to "0" on a 3000psi gauge.

4. MB (ETS) would not drop pressure and would take 1-3 minutes to decay pressure. Normal operation is .3-.5 seconds.

Hydralube requested the A, B pilot operated main valves to be removed for inspection. Once main pilot valves were removed, they were disassembled and inspected. There was slight scaring on the valve spool and some sticking. Plant representative was asked if there were any other valves and informed HL they had received 2 rebuilt valves. HL inspected the rebuilt valves and noticed the main valve spool was in a different position than the valves removed from system. With the different spools it was

determined that the problem was the pilot valve main stage. The rebuilt valves were installed and the test process was performed.

1. MXA, MXB pressured up to 2260psi as expected

2. MB was pressured up to 2260psi.

3. Time to pressure MB decreased to 20-30 seconds.

4. MB was tripped and ETS pressure dropped in .5 seconds

5. MXA, MXB pressure also dropped in .5 seconds.

The circuit was then tested multiple times and the trip times were consistent.

The next concern was contamination in the system; fluid samples were taken at the reservoir, MXA and MXB locations and the samples showed a NAS 5 was the highest reading. The lowest sample was a NAS 1. There were more samples taken after all the valve actuators were exercised and the samples confirm the system did not have Major FME in the system. The last sample decreased to a class 4.

During the testing process the pilot valve main stage valves were disassembled and compared to new valves, the main stage spool was installed backwards. This was the reason the trip test could not be done properly. The FME found in the pilot valves seemed to be material from a scotch bright pad along with some elastomer material.

After reviewing the circuit a concern was identified with the valve test. The solenoid valves have limit switches that confirm solenoid valve spool travel. But the main stage pilot valve does not have any identification of valve spool travel. Therefore the turbine protective system could not be proven to operate when a problem occurred. (over speed of turbine etc.). After reviewing pictures of the pilot valve main stage there was oxidation and varnishing that caused the spool to be frozen in the valve body. Although the solenoid valves were sending pressure to the main stage spool the ETS pressure could not be dumped to shut down the turbine.

It is recommended that the main stage spool have verification of travel. Also due to the operation of the main stage spool not being observed, the logic from DCS should include the Fast Acting Solenoid valves to be tripped at each actuator to ensure the ETS is dumped during a major trip.

Thank you for the opportunity to serve LG&E,

Gary Williams

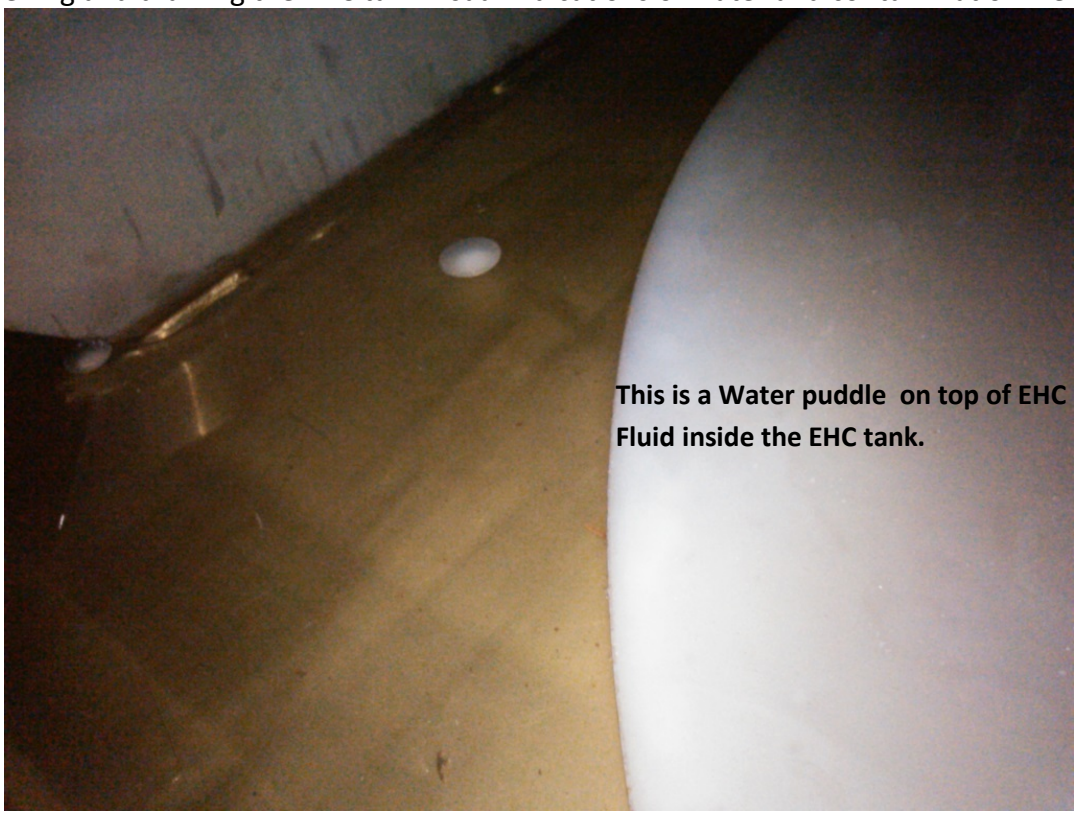
Hydra-Lube Inc.

Per Mike Kurn – MD&A

The "A" MSV was closed during a planned valve closure test and failed to re-open. Unit load was reduced and an auto shutdown was executed once the unit load reached 80 MW, the turbine tripped on reverse current and the "B" CV and both ICVs closed. The "B" MSV and the "A" CV remained open. The turbine speed increased to a peak speed of 3969 once the Hot Reheat (HRH) Bypass Valves opened following the line breaker being opened, a flow path was established through the turbine without load being generated (line breaker open). This flow path, coupled with the "B" MSV's inability to close, resulted in the turbine over speed condition. The "B" MSV was manually closed when the fast acting solenoid spool was punched. The "B" MSV decreased from 99% to 5%, with a rate of roughly 9.5 %/sec over a ten second period. The Manual trip handles on Master trip solenoid valve equipped on Hydraulic fluid tank were operated, but nothing happened.

Fyrquel representative made an onsite visit and stated water in the EHC fluid can act as a solvent breaking up and releasing contaminants. Trimble County Unit #2 EHC fluid sample date June 04, 2014 Water Content- WT% 0.43. ~ Water percentages of this magnitude typically are representative of a cooler leak. Suspect some of the contamination may be residual from unit storage/layup prior to instillation and start up.

Upon opening and draining the EHC tank visual indications of water and contamination were found.



This is a Water puddle on top of EHC Fluid inside the EHC tank.

Trip Block assembly was removed from the EHC skid and shipped to Rexroth in Pennsylvania. Rexroth disassembled cleaned and is inspected the Emergency Trip Device/Master trip Solenoid Block. Photos below provided by Rexroth show water, varnish and oxidation. Some components were found in a stuck or sluggish condition. The trip valves were reported to not be functioning at all. Rexroth recommended removal of valve actuators for inspection.

Spool and trip valve showing oxidation as well as varnishing.

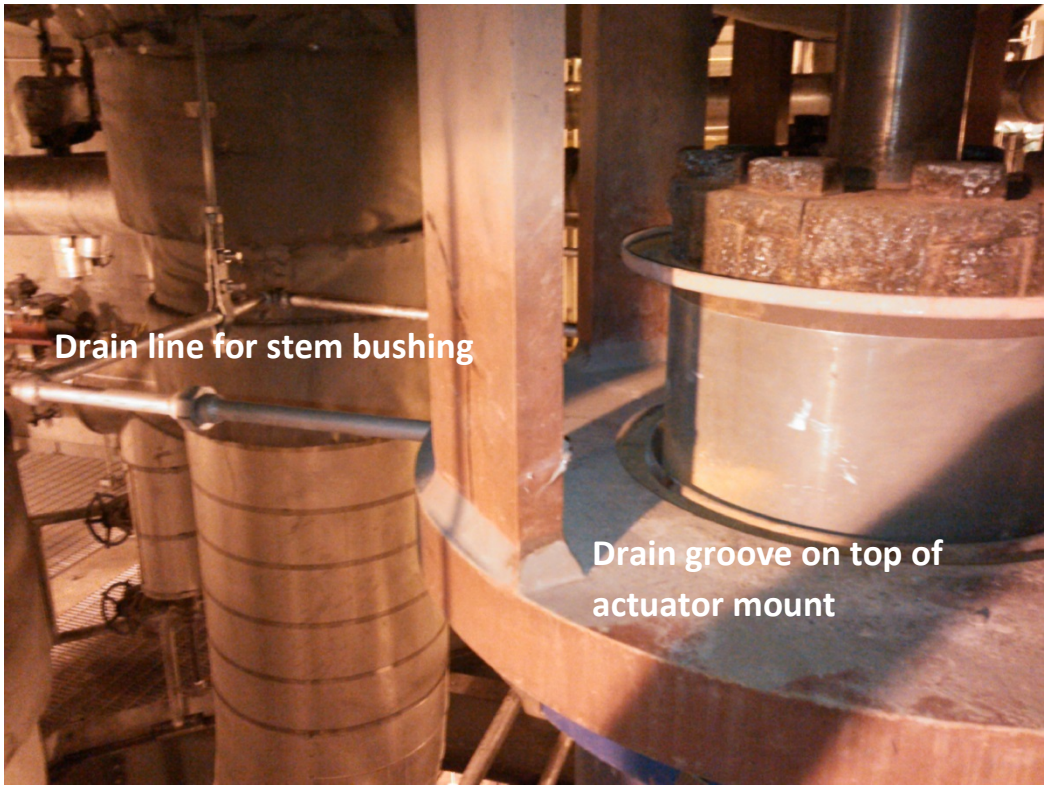
HydraLube provided EHC flushing services. EHC tank was cleaned between flushing steps. Flushing was conducted with a cleaning agent additive in new Fyrquel EHC fluid. All valves were stroked during flushing and the Emergency Trip System EHC fluid was dumped enabling valves to trip during the flushing process. DCS trends were observed to inspect for valve actuator sticking issues. Due to pressure limitations of the flushing pump only 2 valves were able to trip simultaneously and the DCS trends illustrated these pairs of valves closed closely together, (Mk VI should be observed for more accurate timing). Valve actuators were not disassembled and inspected at this time. It is recommended at the next Maintenance interval of the unit when enough time is allotted to remove All the EHC actuators and ship these to a qualified facility for disassembling and inspection.

All Accumulators were disassembled cleaned and inspected by Hydralube. Accumulators were valved out during the flushing process. All as found pre-charges on the accumulators were found within recommended pressures.

All new Servos and Solenoids were installed.

Both EHC Coolers were pressure tested at 80 psig of air for 1 hour with no noticeable depreciation of pressure observed. Again these coolers were later pressurized to 120 psig of water at the bottom-(u tubes were not evacuated of gas at the top of the coolers). Reportedly 1 cooler held pressure for approximately 12 hours and the other for approximately 6 hours. As the EHC fluid tested positive for the closed cooling water corrosion inhibitor the decision was made to replace the EHC coolers. Temporary coolers were provided by Hydralube until LG&E procures and installs new replacement coolers.

A source of water into the EHC system could be during start up when the Main Stop and Re-Heat Stop Valve stems are not back seated. These drain line from the stem bushings below the valves should be ensured free of obstructions to prevent water from backing up on top of the actuators. Observe this and ensure lines are clear and no stand water is on top of these actuators during the next start up.



Document Number: 25-LA-0005
Document Title: Technical Service Report
Document Version: 2-940125
ISSUED BY: AAJ

ICL Industrial PRODUCTS

TECHNICAL SERVICE LABORATORY
GALLIPOLIS FERRY, WV

- ADDRESSEE -

LOUISVILLE GAS & ELECTRIC CO.
TRIMBLE COUNTY STATION
487 CORN CREEK ROAD
BEDFORD, KY 40006
ATTN: MR. GARY DUNLAP

Dist No: 1-767

Technical Service - Fluid Analysis Report

LOUISVILLE GAS & ELECTRIC CO.
TRIMBLE COUNTY STATION
487 CORN CREEK ROAD
BEDFORD, KY 40006

Sample Kit Contact: ATTN: MR. GARY DUNLAP
Tel. No: 502-627-6192 Ext:
Fax No: 502-217-2045 Ext:
E-mail: Laura.mohn@lge-ku.com;gary.dunlap@lge-ku.com;mitch.slaughter@lge-ku.com;Jeff.Simpson@lge-ku.com

Product Name: FYRQUEL EHC PLUS
Unit No: 2
Turbine OEM: HITACHI
Sample No: E2438
Customer No: 1-767
Date Sampled: 06/17/2014
Date Received: 06/23/2014
Date Reported: 06/24/2014

Report Values

		OEM Recommended Limits		
Standard Test Properties	**Results**	**Min**	**Max**	
ACIDITY, MG KOH/G	**0.01**		0.20	
VISCOSITY, SUS, 100 ° F	**203**	200	230	
WATER CONTENT, WT%	**0.45**		0.20	**
NON-SAPONIFIABLE CONTENT, WT%	**0.10**		3.0	
PARTICLE COUNT/100 ml	**-**		-	
SIZE (Microns)	**-**		-	
5-10	**CLDY.****		9700	
RESISTIVITY, G-Ohm-cm	**16**	5		
CHLORIDES CONTENT, ppm	**5**		100	

Comment: **** ONE (1) OR MORE SPECIFICATIONS HAVE EXCEEDED LIMITS. PLEASE CONTACT YOUR ACCOUNT MANAGER.**

Visit www.fyrquel.com to review Frequently Asked Questions about fluid analysis, product handling, fluid maintenance, new improved Fyrquel® product choices and other subjects.

We recommend switching to the improved next generation Fyrquel® EHC Plus product. It's OEM approved and fully compatible with prior generation Fyrquel® fluids. Contact your Account Manager.

Stacy Barnes Pierotti

QA/QC SUPERVISOR

Account Manager: PAUL W. HARTSUCH (630)208-8036 Fax: (630)208-8037
Technical Service: FLUID ANALYSIS INFORMATION (304) 675-1150 Ext: 471 Fax: (304) 675-7698

Hydrotech®
Motion Control Solutions

Service & Repair Department
10052 Commerce Park Drive
Cincinnati, OH 45246
Phone: 513.881.7000 Fax: 513.682.7890

QF-7.5.1-R - Service and Repair Inspection Report – Rev.0 – 5/3/11

RA Number:	Qty:	Customer Ref:	
Customer: L8176 - Louisville Gas and Electrice		Contact: Trent Henderson / Marci Park	
Customer PO Number: 908370		PO Number Issue Date: 7/2/2014	Initial: dat

Component Information

Model Code: Service Call		
Part Number:	Serial Number:	Manufactured Date:

Probable Cause(s) of Failure Determined By Our Inspections

☐ Normal Wear	☐ Lack Of Lubrication	☐ Out Of Adjustment	☐ Contamination
☐ Heat Related	☐ Cavitation	☐ Electrical Related	☐ Cannot Be Determined
☐ Excessive Case Leakage	☐ Misalignment	☐ Improper Startup/Install	☐ Over Pressurization

Inspection Notes

Please see the attached detailed inspection report for the service call performed by Tyler Buck.

Your cost for the services performed is below.

Cost of Repair

☐ Not Economically Repairable	☒ $19439.29	Estimated Delivery: Completed

Payment terms to be determined upon credit approval.

For Internal Use:

Sales Order Number: 623816	Sales Order Date: 7/2/2014	Bin Location:	Date: 7/30/14
PO:		PO:	
PO:		PO:	

Prepared By: Dave Tengler – dtengler@hydrotech.com

The Drive & Control Company Rexroth Bosch Group

FIELD SERVICE
CALL REPORT

GENERAL INFORMATION			
Service Order	4256778	Customer PO	513165
Site Name & Address	LG&E 487 Corn Crreek Road Bedford KY 4006	Customer Name & Address	Hydrotech
Site Contact Information	Trent Henderson Laura Shufflet	Customer Contact Information	

Brief description of work to be performed:
Rebuild of steam turbine control system.

ASSIGNED TECHNICIAN(S)		BILLING LEVEL (1, 2, 3E, 3M, Training)
LEAD TECHNICIAN	Tyler Buck	3
TECHNICIAN 2		
TECHNICIAN 3		

TRAVEL

☐ Air ☐ Rental Car ☐ Company Vehicle _____ (Miles) ☐ Other (Specify)

Travel Date 1	7/4/14	Departure Time	14:00	Arrival Time	23:00
Travel Date 2	7/10/14	Departure Time	03:30	Arrival Time	12:00
Travel Date 3		Departure Time		Arrival Time	
Travel Date 4		Departure Time		Arrival Time	

OPEN ITEMS

FUTURE BUSINESS

The Drive & Control Company Rexroth Bosch Group

DAILY LOG

DATE of COMPLETED WORK	Start Time	Stop Time	Start Time	Stop Time
7/5/14	06:30	**00:00**		

REPORT: **NON-WORK (BREAK) HOURS:**

I arrived on site and met with everyone. They said the flushing contractors were still on the unit and a few other things needed to get accomplished before I could get to it. In the mean time, I did some explanations of the system to some of the LG&E crew. Once they were ready, I started up the unit using the pump that was replaced. I lowered the pressure settings so to check for leaks, then slowly increased the pressure and did a pressure check on the system. When it was up and running and everything was set, they wanted to do control tests, so I was done for the day.

DAILY LOG

DATE of COMPLETED WORK	Start Time	Stop Time	Start Time	Stop Time
7/6/14	**0730**	**2230**		

REPORT: **NON-WORK (BREAK) HOURS:**

I arrived in the morning to find that they were having trouble with their control tests from the night before. Hand trip valve B wasn't working so I traced through that circuit and blew air to hopefully clean any obstructions out. That appeared to help although it didn't last very long. Although, the ability to dump ETS pressure electronically was unable to occur, using the hand valves had more success even thought B side worked intermittently. Continuing work on that, I pulled the pilot valve off to check for any obstructions. Had the hand valves working pretty consistently so I went to work on having the solenoid poppet valves work. Didn't have any luck so pulled off those valves, checked but didn't find anything but they had 4 new ones in stock so we put them on to rule them out. Tested with them and nothing changed and still acted like there was debris inside the block. Decision was made to pull the block back off and clean it at their service center in Louisville.

DAILY LOG

DATE of COMPLETED WORK	Start Time	Stop Time	Start Time	Stop Time
7/7/14	**0800**	**2100**		

REPORT: **NON-WORK (BREAK) HOURS:**

Started the day out by heading to their service center to disassemble and clean the manifold block. Once there, I pulled all everything apart I could, flushing with alcohol and blowing through with air. Found debris (attached picture) as I was cleaning, double checked everything and reassembled. I function tested the poppet solenoid valves with air, making sure they shifted and sealed off the desired ports. Everything arrived back at the plant and I pre-lubed the pilot operated valves before the block was mounted again. Went back to testing and the hand operated valves worked great each and every time. The poppet solenoid valves worked better than before but after 2 tries, their effectiveness declined and everything went back to functioning very slowly. At that point, it was decided to call it a night and regroup in the morning about everything.

The Drive & Control Company

DAILY LOG				
DATE of COMPLETED WORK **7/8/14**	Start Time **0730**	Stop Time **1730**	Start Time	Stop Time

REPORT: **NON-WORK (BREAK) HOURS: .5**

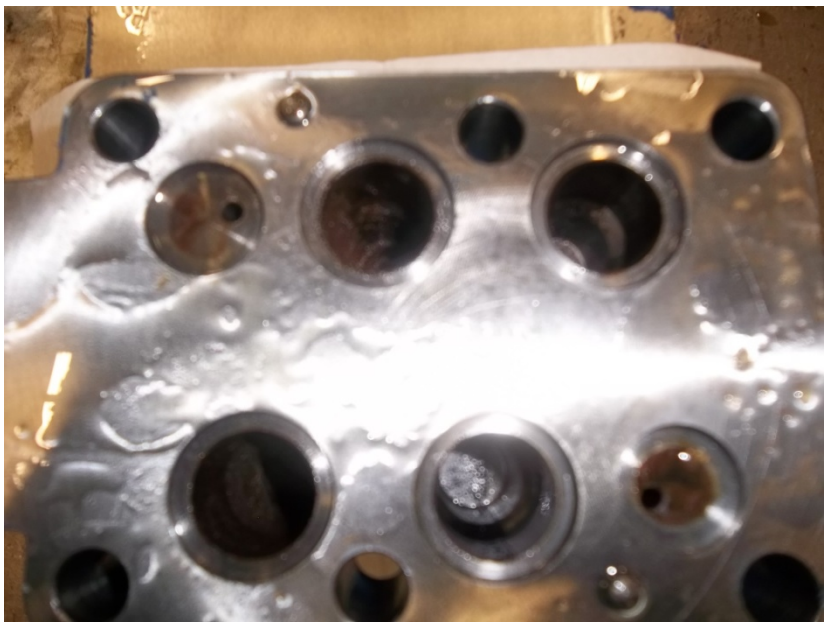
I arrived and everyone had a meeting to discuss what was going on. Laura had some fluid samples that did not look so good and raised the question about cleanliness again. Decision was made to take fluid samples and possibly flush depending on their findings. Went back to the system and did a recheck on pressure and everything. Hand valves worked fine, shift them and ETS pressure would dump just about instantaneous. Tried doing it electronically but had no success. Did, however, prove that the poppet solenoid valves were shifting as desired cause the pilot pressure would drop off. That left the pilot operated valves. They said they had some refurbished ones coming in a little later so we pulled the old ones off and compared when they showed up. Without digging too deep, could visibly see a difference in spool gaps between the two. Decided to put the refurbished onto the system and they said they'd do that over night.

DAILY LOG				
DATE of COMPLETED WORK **7/9/14**	Start Time **0630**	Stop Time **1600**	Start Time	Stop Time

REPORT: **NON-WORK (BREAK) HOURS: .5**

Arrived today to find the refurbished pilot operated valves installed. In a morning meeting, it was agreed upon to have the transducer lines flushed and check the orifices again for precautionary purposes. Once that was accomplished, we went ahead and tested the system with and had success with all the functions working. They went ahead and started performing their systems tests. During that time frame, brand new pilot operated valves arrived so I went and partially disassembled one and compared it to an original. Found the originals had the spool in backwards. After some time running, fluid samples were taken at the reservoir and put to rest any idea of contamination issues. They were content and released me then.

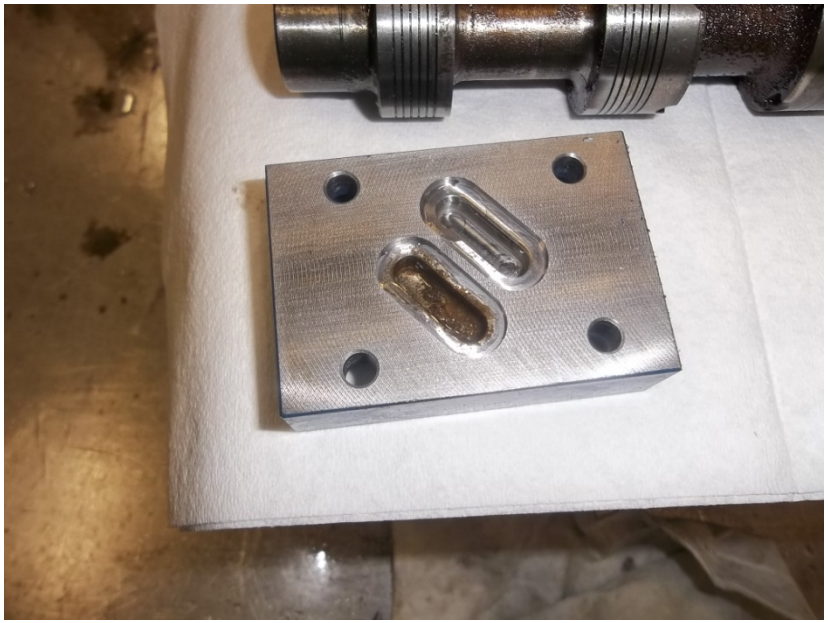
Trip Valve – 4WH 22 shows oxidation in ports



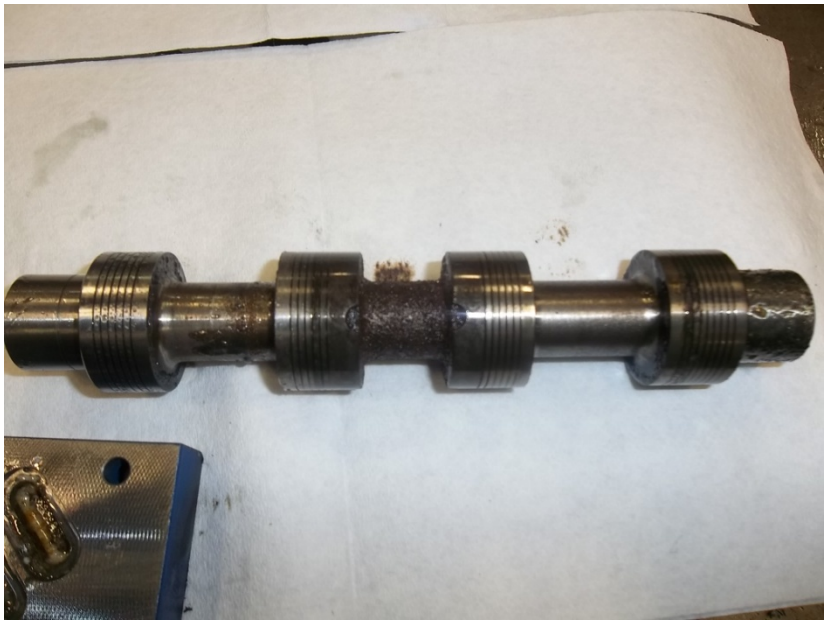
Trip Valve – 4WH 22 shows oxidation in ports

Trip Valve - 4WMM 6 shows varnish and oxidation

Varnish and debris in pressure port



Spool shows oxidation as well as varnish



Major oxidation can been seen within the valve

Water and oxidation shown

Varnish and oxidation