A Long Term Study of Using Balanced Charge Agglomeration for Oil Purification on GE 7FA Turbines

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Introduction

Balanced Charge Agglomeration (BCA™) technology for oil purification has been in use for nearly twenty years as a means to remove submicron contaminants from oil. During that time, designers of this equipment discovered that these systems could also remove products of oil degradation (varnish) from the group 2 oils being used to lubricate machines of all types.

The power station in this study was constructed several decades ago as a coal fired, primary base load, plant. The decision was made to convert the station to natural gas using seven GE F7FA combustion turbines as primary firing and generating capacity and using the waste heat in a combined cycle to power the old, but serviceable steam turbines. The first three 7FA gas turbines were brought on line during the spring of 2002 and the plant was officially dedicated in April 2003 in a base load capacity.

Management & operations soon developed concerns about oil varnishing due to some incidents related to sticking servos and actuators. They expected that the frequency and severity of these varnish related issues would increase over time, because other members of the GE 7FA User Group had noted the appearance of varnish as early as 8,000 hours. Management presumed that the level of pre-varnish material was near saturation in the lubricating system and might cause a problem. As a result, management decided to implement lubricating oil purification and varnish reduction/removal technology.

After considerable study and review, management installed ISOPur Balanced Charge Agglomeration (BCA™) technology on one steam turbine, and on all seven GE 7FA Combustion Turbines. The ISOPur Model-HR (20 gpm 76 lpm) was installed on the steam turbine and one Model- MR (10 gpm, 38 lpm) was installed on each of the seven gas turbines, Figure 1. The ST installation was completed in November 2004, and the GT installations started simultaneously in January 2005 as the Series 1 GT's were approaching 10,000 hours. The systems have been running continuously since that point in time. The lube oil condition was monitored, first daily, then weekly, then bi weekly, and finally semiannually for the past 7 years.

Figure 1. MR installation on a GE 7FA Turbine Oil Sump

The oil is now nearly 10 years old, it is cleaner than new oil, and may last another 6 years or more. A thrust bearing inspection in November 2008 indicated a remarkable absence of varnish fouling on the internal surfaces. Unlike most power plants, there has not been an oil related unscheduled shutdown during this time period.

Varnish and additive depletion, generally, determine the life of oil. Remove varnish, products of oxidation, and submicron contamination and the oil could last forever. This is the long term goal of ISOPur, lubrication suppliers and government agencies around the world.

BCA™ Technology

Balanced Charge Agglomeration, BCA™, is one of the methods used to purify oil using electrostatic charge. BCA™ systems split oil flow into two paths in a charging section, one path is charged positive the other is charged negative with a regulated high voltage system. The two paths are recombined in a mixing section, allowing the charged particles to stick together due to the opposite charge on particles. The particles grow in size and are removed by a filter. This system agglomerates particles down to the 0.01 micron range, combining them with larger particles for removal from the oil. BCA™ and Electrostatic Precipitator systems were tested in the field for varnish removal, and recommended by GE in a Technical Information Letter (GE

TIL 1528-3). GE sells the ISOPur purification system to their customers and also recommends Electrostatic Purification using a precipitator approach. This technology attracts particles toward a charged plate that is covered with a filtering media.

Immediate Results of Oil Purification

The first BCA™ machines went online about February 2005. The operation and the effect of the purification machines on the oil were monitored quite closely for 19 weeks to document the results of its operation. Referring to Figure 1,

1. The initial oil particle count went up as particles were agglomerated from submicron levels to the four plus micron range of most particle counters.
2. As agglomeration took place the filtration system started to remove particles and clean the oil. The oil got very clean during the first week of operation.
3. Particle size and varnish potential then began to rise caused by the very clean oil becoming a solvent again and removing contamination and varnish from internal surfaces.
4. When the oil became saturated with contaminants, no more contamination could be removed by the oil from the system internal surfaces.

5. The BCA™ system started cleaning the saturated oil again, completing a cycle.
This up – down sequence continued for several cycles, becoming less pronounced each time.

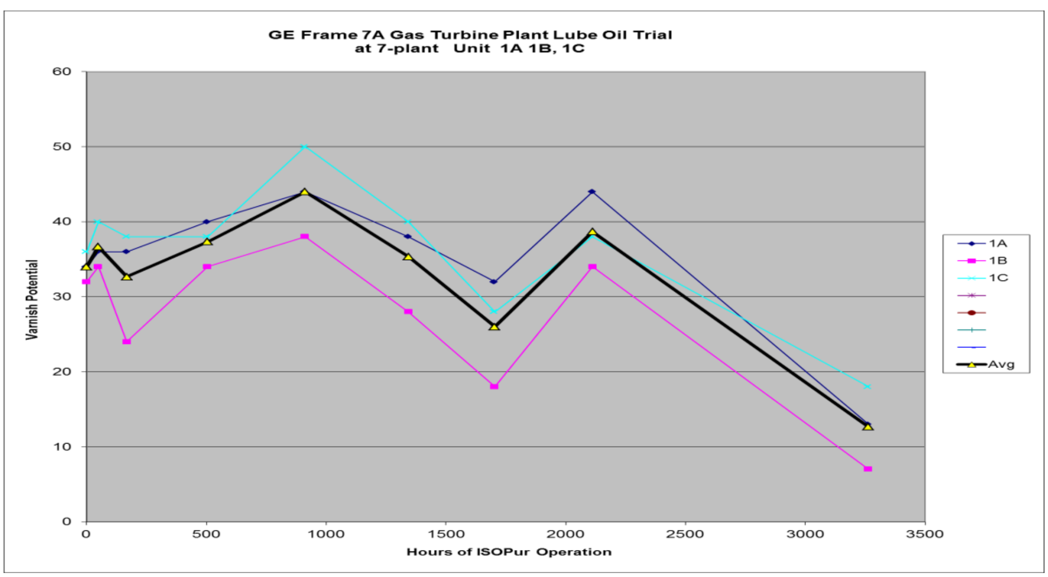

Figure 2. Preliminary Results of Oil Purification

Visual Results

Analysis indicated that varnish potential was decreasing and contamination levels were dropping. The oil itself looked cleaner. The surprise came when the tanks were opened. The internal surfaces were cleaned of any varnish. Previously, the maintenance people had been cleaning the tanks manually to reduce sludge, a two day shutdown and nasty working conditions

Figure 3. Oil tank internal inspection at 20 weeks after installation

Oil Life Enhancement

The high purity oil in this plant is free of submicron contaminants that act as a catalyst for oil degradation. The lack of degradation byproducts in the oil places no demand on the oxidation preventing additives, thus extending their useful life. In general, when antioxidant additives reach 25% of original oil, most plants condemn their oil. The level of additives as determined by RPVOT had remained above the 70% plus range on all seven turbines since the BCA™ machines were placed in service. After nearly 10 years of operation, there is no indication that this oil should be changed, because it passes every test required for new oil

Turbine	Varnish Potential	Gravimetric Patch mg/l	ISO Particle Count	RPVOT Minutes to 25%	RPVOT Remaining Life
New Oil	< 5	75	18/16/3*	1700	100%
Unit 1A	13	4	14/12/10	1216	72%
Unit 1B	9	20	13/12/9	1377	81%
Unit 1C	3	2	19/17/14	1228	72%
Unit 2A	3	16	17/14/10	1140	67%
Unit 2B	5	4	14/12/10	1324	77%
Unit 2C	5	16	14/12/9	1157	68%
Unit 2D	3	18	15/13/10	1275	75%

Figure 4. Oil Analysis at 9 Years vs. New Oil * Conoco Phillips Ultra Clean Turbine Oil

Figure 5. Latest Samples from the 7 GE 7FA Gas Turbines with 48,000 Run Hours

Turbine Bearing Life

During the month of April 2011, three turbines were opened for inspection to check bearings for wear, to clean any deposits from internal surfaces and access the general condition of the turbine. The main turbine shaft journal bearings were removed and inspected. They showed no sign of wear and no varnish buildup. The thrust bearings also showed no wear and no varnish buildup. All bearings were approved for continued operation.

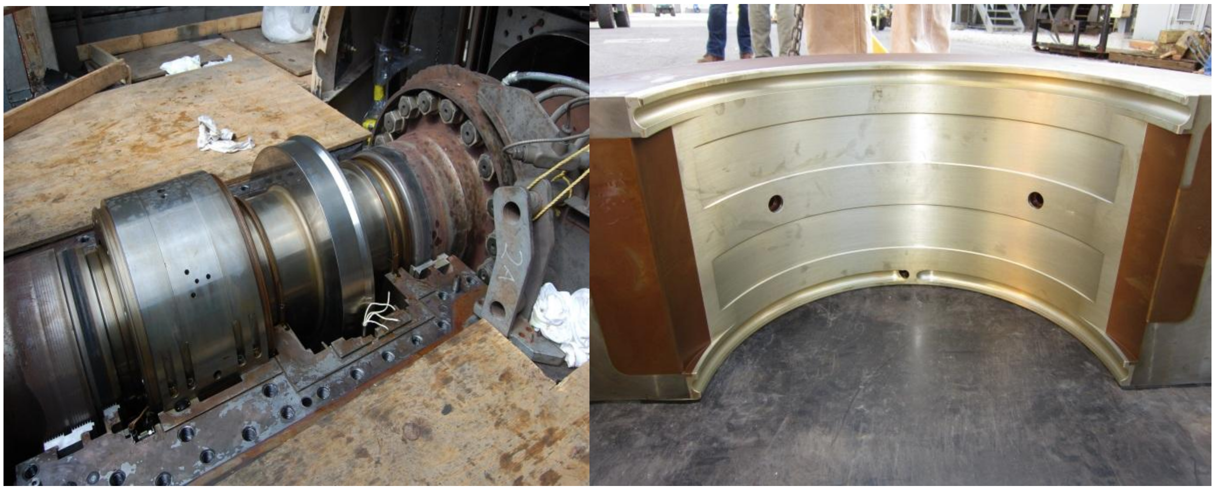

Figure 6. Thrust bearing at 8 Years and Journal at 9.5 years of Operation

Figure 7. 7FA Bearing at another plant with 4 Years of Operation without Purification.

Machine Internal Surfaces

The oil tank was drained and inspected. To everyone's surprise, two of the tanks showed a slight varnish buildup. The other tank was perfectly clean. Previous inspections showed no varnish, so the operations manager asked for assistance in determining the problem. An engineer from ISOPur tested the purification machinery and found two had failed. The failure was in an old version of the feed-thru for high voltage wiring into the technology vessel. The feed-thru had shorted out, causing the high voltage power supply to shut down. It was determined that the preventative maintenance on the machine that would have indicated a problem was not performed because there was no record of this PM.

On examining oil analysis reports for this plant, it was discovered that there was a slight upward reading in Varnish Potential and Gravimetric Patch in the past 6 months on some of the turbines. This increase in readings indicated that the supplies had recently failed, and this was the probable cause for the varnish seen in the tanks.

Figure 8. Oil Tank after Nine Years of Operation

Servo Valves

The components with the most impact on the plant are the servo-valves. These valves control speed of the turbine under varying loads to keep it constant. Varnish causes the valves to stick. The control system can determine if the valve is responding fast enough to control the turbine. If the valves slow down, or stick, the computer will shut down the plant. To ensure that servo valves don't stick, some plants have several sets of servo-valves. This allows them to have one set in operation and one set constantly out for repair. The servo-valves in this plant were starting to show signs of sticking at the beginning of the trial. Due to the cleanliness of the oil, and lack of varnish buildup, their performance improved and they did not stick during the remaining 7 years of operation. They were sent for normal preventive maintenance inspections for the first time during the ninth year in service.

Oil Replacement Savings When Using BCA™ Oil Purification

This power plant had been operating about 2 years when varnish began to show up in the tanks, which is typical for single tank machines like GE and Alstom. The initial load of oil will run approximately 5 years. At that point, the oil is changed and the lubrication and hydraulic systems are flushed with a high flow flushing rig and sometimes solvents to remove varnish and other contaminants. Subsequent oil changes occur in the three to five year range, along with more flushing of the lube oil and hydraulic system. If the system is not flushed, the oil does not last as long as expected, due to contamination in the system that was not removed by a flush.

This power plant had the choice of changing oil at 10,000 hours or investing in a new technology, electrostatic purification using Balanced Charge Agglomeration technology. They chose BCA™. The choice of BCA™ has resulted in nearly10 years of operation on the original oil, along with no oil related plant shutdowns.

Item	***Value***
A GE 7FA Turbine Oil Requirements in gallons	6,200
Average Cost per Gallon	$15
Cost Per Turbine of an Oil Change	$93,000
Cost of Varnish Removal Chemical Flush	$100,000
Cost per turbine for 2 Oil Changes	$286,000
Cost of Purification system, approximately	$25,000
Filter Replacement Cost with Labor for 10 Years	$8,000
Total Cost of a Purification System for 10 Years	$33,000
Savings Per Turbine Using a Purification System	**$353,000**
Savings for 7 Turbines from Avoiding 2 Oil Changes	**$2,417,000**
Savings for 7 Turbines from Avoiding 3 Oil Changes	**$4,053,000**

Figure 10. Savings in Oil Replacement Costs by Using Purification Systems

Savings in Operating Costs When Using Oil Purification

An unexpected turbine trip is often caused by control or servo valves not responding. It is difficult to estimate this cost, but most power companies reply over $100,000 when asked. This is just the direct cost of repairing the problem and getting the turbine back online. There are additional costs such as power grid fines, replacement of lost power to the power grid, and lost revenue.

To avoid plant trips, many plants purchase an extra set of servo valves. These valves are changed on a regular schedule and sent out for cleaning and calibration. The hydraulic servo valves in this report were sent out in their ninth year of operation for the first time. The servo did show some wear, but they were not sticking and varnish was not a problem.

Environmental Savings

The GE 7FA uses 6200 Gallons, 23,400 liters, for combined lubrication and hydraulic needs. The turbines in this report have saved 12,400 gallons, 46,800 liters, each during the first nine years of operation. There are about 1,000 turbines presently using ISOPur BCA™ technology to purify and extend the life of turbine oil. In a ten year period they will save a up to approximately twelve million gallons of lubricating oil. It is easy to see that there are tremendous environmental savings in crude oil, lubricating oil and the energy required to make, transport, and reprocess the oil at the end of its useful life.

Summary

The idea that oil should be used for a few years and disposed is going to have to change in the future. We often say, "Treat your oil like an asset and not a commodity". In the case of this plant, that's exactly what they are doing. Their oil has been an asset in keeping their turbines clean, preventing varnish and the problems associated with it. The cost of the initial load of oil, along with the cost of proper purification of the oil has paid them back several times more than the cost of that original oil. As the years go on and the oil continues to run, it is paying them back every day that they don't have to replace it, and every day without an oil related failure.

An investment of $33,000 paid the plant back $253,000 in real savings per turbine over the first ten years of operation for a total plant savings of $1,771,000. Since most accountants only see the initial dollar cost of a purification system, it is often difficult to get the funding to purchase a system. However, there are very few investments that can guaranty savings of this magnitude, $122return on every dollar spent. When the added savings on operational problems are added into the results, total plant savings could be nearly double the savings resulting from oil changes alone. A plant that can see these results would be foolish not to invest in oil purification.

India, China, and Southeast Asia are adding power plants at an incredible rate. If steps are not taken to control oil use, their demand for lubricants will exceed ability of refiners to supply group two and three turbine oil. The government in China is now taking steps to require that oil be capable of being used for a minimum amount of time. They know that China's need for oil will soon exceed the world's ability to supply new lubricating oil. When that happens, their power plants will stop and their economy will falter. They must invest in oil purification to meet their requirements for oil life.

The new turbine oil coming on the market now will have better varnish control characteristics than the oil used on the turbines in this study, but they will not be warrantied to reach more than 20,000 varnish-free hours of operation. The simple addition of a BCA based purification system can extend the life of turbine oil indefinitely. It is possible, using a good purification system and good oil, to have a lubricant that will last for the life of the machine. That is our goal!

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Definitions

Gravimetric Patch - Gravimetric analysis is a test method that measures the total amount of insoluble material in an oil sample that are greater than 0.3 microns. The test is performed by filtering the oil through either a 0.8 or 0.4 micron filter membrane and weighing the contaminants on the membrane. The results are reported as milligrams of contaminants per liter of oil (mg/l).

RPVOT ASTM standard test D2272 - (Rotary Pressure Vessel Oxidation Test) measures the oxidation stability of turbine oil. The sample is placed in a vessel that contains a polished copper coil. The vessel is then charged with oxygen then placed in a bath at a constant temperature of 150°C. Oxidation stability is expressed in terms of the time required to achieve a 25.4 psig pressure drop from maximum pressure.

Varnish Potential - the varnish potential rating used in this report is based on a varnish predictive technology called Quantitative Spectrophotometric Analysis or QSA®. This testing methodology identifies and measures the specific contaminants that promote the formation of varnish deposits in lubrication and hydraulic systems. The QSA® test is a proprietary testing method developed by Analysts, Inc. Los Angles, California.