Holding Manufacturers Accountable with Plant Data

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U.S. Geothermal San Emidio Project
Renewable Independent Power Producer
San Emidio Project - Nevada

Online May 2012

9 net MW (annual average)
• Water Cooled

San Emidio was acquired in April 2008 – an existing Ormat facility. The Ormat facility was retired in December of 2011.

Construction on the replacement facility began in the Fall of 2010. New facility was commercial in May of 2012.

San Emidio Availability currently operating at 98.6%
Concerns

Proper data collection using multiple disciplines

Setting yourself up for success by not relying on a single discipline

• Real time data collection using Historian or similar SCADA data collection system as well as in situ vibration data collection

• Periodic data collection using grease analysis, oil analysis, vibration analysis, SDT Ultrasound, PdMA and IR

By using multiple disciplines you can show an event via the historian or in situ vibration analysis and then back up the effects of the event by the other disciplines.

Similarly you can show that an indicator under periodic data collection can be attributed to a manufacturers defect, design flaw or error by the lack of indication of an event that would be the cause of such an indicator. For example if there were burnt motor windings you could show that there was never an overheating moment on the motor windings as indicated by the historian.
Challenges
We Need to Monitor Assets - But We Don’t Have An Unlimited Budget

Personnel and Financial Challenges:
• Having personnel trained in monitoring the data that is collected and understanding it well enough to flag concerns.
• Establishing the proper instrumentation for the equipment on site to bring the data back to a central data collecting system.

Potential Solutions:
• Establishing a mentoring program with analysts to teach personnel how to properly implement and monitor the data collection systems. You can further utilize them as experts when site personnel are unable to properly assess an issue that was noted.
• Being engaged during the design process.
• Addition of equipment monitoring over time as finances allow.
• Using a rounds collection system with alarm triggers if historian is not a viable option.
Achieving Our Objectives
Data Collection

It was recognized that a maintenance management program was needed to organize and track assets, work orders, parts and personnel. However we also wanted:

• To use these tools and technologies using a multi-disciplinary approach to monitor equipment health and have accountability during startup of a facility or when implementing new equipment.
• To make as much use of our operational staff to collect information on our assets as possible.
• To take advantage of predictive maintenance tools and technologies within the constraints of our budgets.
Data Collection
Across Multiple Disciplines

We are currently utilizing:
• Operations / PM Inspection Rounds
• Oil analysis
• Vibration Analysis
• Ultra sound analysis
• Grease analysis
• In house thermography

We are currently implementing:
• on-line/off-line motor testing
The historian allows data to be trended over time to look for subtle changes. The data can be shared with other industry experts to allow for mentoring or analysis as needed.
MMS Data Collection
Testing Equipment Used at SE

- An Intermec Handheld Computer is used to collect data on a multitude of multiple devices throughout the facility.

- All equipment information, instruments, gauges, PIT’s, TIT’s, Liquid Levels along with any reading considered relevant to the operation of the site are collected. The device will instantly notify the operator if one of his readings are out of the predetermined parameters.

- The information is then uploaded into the CMMS system where it will be reviewed by the system. The information will generate work orders automatically if warranted. All of this is able to be reviewed by the O&M Manager the instant he logs into the CMMS system.

- This also allows nearly all of the site equipment to be visually inspected twice daily, in the event of any discrepancies, i.e. oil or air leaks on the equipment, being found they also can be entered into the device adding another layer of data collection. “Visual Inspections.”
• Oil sampling is completed quarterly at the facility and sent in to LubeWatch Laboratories.

• Once they have completed their analysis the results are sent back to the facility and reviewed by an O&M Technician then uploaded into our CMMS.

• The reports are then generated and sent to the O&M Manager for review.
A baseline was initially set up at the commissioning of the equipment, and is the point of reference going forward.

- The alarms set points for all of the vibration monitoring devices were set up cross-referencing the manufacturers recommendations along with information gathered from reputable vibration analysis groups.
- A caution alarm will alert the maintenance team that there might be an issue and the equipment will be monitored further.
- At that point we further investigate the issue through an Emonitor analysis and a review of the historical data to determine if further action needs to be taken.
Rockwell Automation E-Monitor Software
SDT Sound Analysis was implemented into our Predictive Maintenance and has allowed us another channel in which to gather different information than the vibration equipment.
A baseline reading is initially set up and is the point of reference going forward.

- The SE site uses a 10% increase in decidable output to trigger a caution alarm.

- A caution alarm will alert the maintenance team that there might be an issue and the equipment will be monitored further. (Sound analysis can be effected by environmental conditions.)

- A 15% increase in decidable output to trigger an Alarm.

- At that point we further investigate the issue with vibration analysis and a review of the historical data to determine if further action needs to be taken.
Grease Analysis

- Grease sampling is completed bi-annually at the facility and sent in to Oil Analysis Labs.

- Once they have completed their analysis the results are sent back to the facility and reviewed by an O&M Technician.

- The reports are then sent to the O&M Manager for review.
Our facilities previously had IR scans performed annually. An example of early detection and preventing material and operational losses at San Emidio:

• Two years in a row an electrical connection was found reading in excess of 300 deg. F. A failure with the possibility of fire or other material damage was narrowly avoided each time.

• Had the thermography program been implemented during this time, we could have eliminated the risk associated with waiting for the next annual scan.

• With scans performed quarterly in house, the chance of costly electrical system fires will be minimized.

• Additionally, it will identify other issues such as heat stress due to motor misalignment, surveys of overhead power lines and disconnects, motor lead connections, etc.

The purchase of the Fluke Thermal Imager / IR Detector not only has allowed us to monitor the health of the equipment, but is also used at our site as part of our Weekly Fugitive Leak Detection program in seeking out possible refrigerant leaks.

Fluke Thermal Imager / IR Detector
Having the ability to generate the IR Reports on site has enabled us to immediately have access to them and address any issues that we may have with the equipment or their controllers.

- All of our sites have sent personnel out for Inferred Training.
- The cost saving was nearly $5.5k per year versus the hiring of an outside entity to have this done.
- The ability to instantly check and determine if a piece of equipment, wiring or its controller has an issue has an enormous value in allowing for immediate action to be taken.
SE – Fan Motors – (Vibe versus Grease Analysis)

- At our Nevada facility the results of scheduled vibration readings taken on the fan motors showed no indication of a bearing issue. By utilizing multiple disciplines of predictive maintenance we were able to ascertain that the bearings would not meet their expected life through a grease analysis program. Similar readings were seen across the array of fan motors that were still under the manufacturer's warranty. By capturing complete work, inspection, sampling and vibration history we were able to make a warranty claim against the manufacturer that could not be disputed. They had the motors rebuilt. The value of the claim was $65,000 for the six motors.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

NHS – Fan Motors – (Vibe versus Grease Analysis)

At our Oregon facility the same program resulted in similar results. The manufacturer failed to properly set up the VFD’s which allowed the motors windings to run in excess of 300 degrees. After data was pulled from the historian to demonstrate this, grease analysis was also performed and the manufacturer had little choice but to warrant the motors. They are currently rewinding and replacing the bearings in 28 of the 30 motors installed at the facility.
Holding Manufacturers Accountable with Plant Data

Warranty Claims

US Geothermal Nevada

HF Refrigeration Pump vibration readings

High Pressure Feed Pump

Original Pump (Feb 3 2016 to Apr 3 2016)
Holding Manufacturers Accountable with Plant Data
Warranty Claims

- The original pump ran from plant commissioning in 2012 until it was replaced with an upgraded more efficiently designed pump and newly designed mechanical seal.

- The spectrum analysis pictured was typical of the original pump.

The vibration trend had been stable for the past year (April 2015 to April 2016).

No warning events triggered over the last year.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

- The pump was replaced and upon restarting the plant there was an event causing the plant and equipment to shake violently, upon seeing this the pump technician stated that the pump may have been damaged.

- After 23 days of being online and operating at full speed a single significant vibration spike occurred on both of the motor bearings and it was reviewed but there was no reoccurring event.

- 24 hours later another single significant vibration spike occurred.

- The maintenance team immediately analyzed the data at the Emonitor station and collected data using the handheld vibration analyzer. It was determined to be whirl instability in the pump bearings / bushings by the site Vibration Tech.

- The information was sent to a third party vibration analysis specialist, who confirmed the initial finding of the sites Vibration Tech.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

• Within two days of the initial vibration spikes the pump tripped the plant off line.

• It was determined that the plant would be operated while waiting for the original pump to be rebuilt and shipped back to the site for install.

• Upon restart the plant had to be run at a significantly reduced speed to minimize further damage to the pump, while waiting for the rebuilt one.

• The plant was operated at approximately half output for 30 days.
While waiting for the replacement pump, the manufacturer started indicating that unusual startup conditions were probably the cause of the failure. Of course we disagreed.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

• We supplied the manufacturer with all of the vibration data and the reports from the third party vibration analysis experts for the whole period from startup of the pump through its failure.

• We argued that there was nothing in the data during the run-up to the pumps failure that would indicate that the pump had ever suffered any damage.

• So far we have not been invoiced for the rebuild. Probable savings of close to $100k.

High Pressure Feed Pump
Holding Manufacturers Accountable with Plant Data Warrantee Claims

• As mentioned before visual inspections are of major importance in early detection of issues that may be undetectable with all of our advanced technology.

• In this particular instance it was noticed that the generators air house had oil starting to show up on the outside around the seams and access areas.

• An inspection of the of the DE and NDE showed that during the commissioning of the generator that the valves that allow equalization of the pressure across the bearing housing had never been adjusted.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

- A warranty claim was initiated that initially the generator manufacturer pushed back on, eventually, shown the pictures in conjunction with all data proving that the vacuum on the lube oil skid had been functioning properly, along with and the condition of the generators interior they agreed to a complete teardown and cleaning of the generator three years in advance of what would be normally expected, at their cost. This included everything from the crane service to the extra manpower that was hired locally.

- Of course once we discovered this at the San Emidio site it was immediately decided to open and inspect the generators at Neal Hot Springs facility. The same issue was also discovered there.

- The manufacturer scheduled and cleaned those also. At a cost in excess of $20k each.
Holding Manufacturers Accountable with Plant Data Warrantee Claims

• While we have had great successes with the data collection and warrantee claim process it should be noted that the SE facility was under construction and commissioning as a prototype plant for a longer period of time than was initially contracted.

• It was during this period that the site personnel with the help of the services group as a team developed and deployed a lot of what is now common across all of the US Geothermal facilities.

• Once the original data base was built into the San Emidio CMMS it was easily exported to the Neal Hot Spring facility’s data base where they were able to quickly cross-reference, build and utilize during most of their construction and commissioning. This allowed them to capture and record an enormous amount of information that was used in the settlement in the closing out of the commissioning, that was not as readily accessible at San Emidio.
### Work Order

**USG Oregon LLC**  
Neal Hot Springs

<table>
<thead>
<tr>
<th>Parts Description</th>
<th>QTY</th>
<th>Cost Each</th>
<th>Cost Center</th>
<th>Priority</th>
<th>W.O. # WO-16177</th>
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<tr>
<td>Expansion Joint</td>
<td>1</td>
<td>130.89</td>
<td>350</td>
<td></td>
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</table>

**General Instructions:** Unit 2 expansion joint leak-deterioration of tube on cooler.

**Due:** 12/6/2013

**Procedure:**
- **Work Order:** 12/6/13 - PS. During outage for Unit 2 found an air leak on expansion joint on the remnant plating downstream of the oil cooler. Pulled cover off and found a broken expansion joint with one that was replaced during the May 9 - 11 outage.

**Operator Notes:**

**Actual time required to complete Task:** 

**Tools required to complete Task:**

<table>
<thead>
<tr>
<th>Misc</th>
<th>Qty</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight on Expansion Joint</td>
<td>1</td>
<td>419.88</td>
</tr>
</tbody>
</table>

**Total Parts Cost:** $130.55  
**Total Pers Cost:** $56  
**Cont. Cost:** $1,170.4  
**Total Misc Cost:** $420  
**Total WO Cost:** $2,523.5
Holding Manufacturers Accountable with Plant Data Warrantee Claims

Using Integrated Records to provide supporting documentation for warrantee claims:

NHS – Design, Construction and Manufacturer warrantee claims (integrated system records)

During the commissioning phase and first year of this new plant, significant issues with project design, construction methods, materials and equipment suitability were uncovered. Having our maintenance and reliability system set up and implemented before the facility went commercial we were able to track time and parts used on warranty work performed by the staff, as well as the contractors costs to support them, in relation to the warrantee claims:

• 202 work orders captured the value of the plant deficiencies associated with warranty claims.
• This was used to formalize our request for reimbursement in regards to warranty issues.
• Maintenance system also tracked the days outstanding for each item along with any progress that was made.
• 82 work orders tracked the value in parts, labor and contractor costs spent by the USG on warranty repairs
• $52k in labor costs that would have been absorbed by the company had we not used work orders.
• $157k in parts costs and XX parts pulled from inventory, installed and reordered.
• $196k in vendor and contractor costs.
Plant Data Collection
Not all Gains are in Warrant Claims

The following are a few examples of cost saving associated with having the types of data collection devices on site and are not necessarily associated to warrantee claims but have saved us untold thousands in what could have been significant losses due to equipment failure or lost output.
Plant Data Collection
Not all Gains are in Warrantee Claims

SE – Motor Rebuild

The new handheld UT unit was used the first day in service on a pump motor. An inexperienced, new employee was able to utilize the technology to determine that there was arcing at the terminal connection box on the side of the motor.

By having this early detection, they were able to avoid the necessity of rewinding the motor saving $8000. Not to mention the losses in revenue due to what could have been a significant reduction in output to the grid, as this particular motor supplies a majority of the brine through the plant.
Not all Gains are in Warrantee Claims

A small leak from a cracked pipe was found that had the potential to turn into a piping failure.

- Lost generation costs
- Potential safety hazard from the high pressure refrigerant leak.
- Mitigated environmental contamination issues from large refrigerant release to the atmosphere.
- This could have resulted in the complete loss of the plant refrigerant charge - $3.50/lb at 20,000 lbs
Plant Data Collection  
Not all Gains are in Warrantee Claims

Again, having the ability to generate the IR Reports on site has enabled us to immediately have access to them and address any issues that we may have with the equipment or their controllers.

- The ability to instantly check and determine if a piece of equipment, wiring or its controller, has an issue has an enormous value in allowing for immediate action to be taken.

- We have added IR Camera windows to all of our major equipment's switchgear cabinets to allow for online evaluations quarterly and before annual outages.
Using Predictive Maintenance to extend maintenance intervals beyond manufacturer’s recommendations:

Raft River Plant – Turbine/Generator Overhaul extension - 7 yrs. vs. 5 yrs. (Oil and Vibration analysis)

By using predictive maintenance, vibration monitoring and oil analysis, we have extended the manufacturers recommended interval for turbine and generator overhauls from 5 years to 7 years. Over the life of the plant, 25 years, this has reduced the number of turbine and generator overhauls by one.

This will realize a savings of $300,000, or $12,000 a year, over the life of the plant.
Plant Data Collection
Not all Gains are in Warrantee Claims

Using Integrated Records to provide supporting documentation to insurance companies and regulatory agencies.

By utilizing integrated records to manage regulatory requirements such as sampling, reporting, inspections or permit renewals we can further mitigate our risk.

• We can show when work was performed via the reporting functions during regulatory inspections. Having this information at our fingertips often lends itself towards our credibility and reduces the amount of time needed on site for the inspectors.

• Equally important is the ability to quickly pull data during an insurance audit. Having these comprehensive reports readily available builds confidence that we are effectively managing our maintenance programs.

• Utilizing all of the tools in our maintenance solution has allowed us the opportunity to demonstrate the efforts made in minimizing risk and has reduced our overall insurance costs by 20%, or $120,311 per year enterprise wide.
<table>
<thead>
<tr>
<th>Description</th>
<th>Initial or Immediate Savings</th>
<th>10 yr NPV (25 yrs Turbine)</th>
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</thead>
<tbody>
<tr>
<td>SE Motor Rebuild – Arcing</td>
<td>$8K</td>
<td>$300K</td>
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<tr>
<td>NHS Warrantee – Staff work</td>
<td>$406K</td>
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</tr>
<tr>
<td>NHS Warrantee – Deficiencies</td>
<td>$1,400K</td>
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<tr>
<td>Turbine/Generator Overhaul Extensions</td>
<td>$12K</td>
<td>$191K</td>
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<tr>
<td>Additional Revenue</td>
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<tr>
<td>Oil Change Intervals (3 Plants)</td>
<td>$14K</td>
<td>$140K</td>
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<tr>
<td>Generator Cleaning X 4</td>
<td>$80K</td>
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<tr>
<td>HP Feed Pump Rebuild</td>
<td>$100K</td>
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<tr>
<td>SE Fan Motor Warrantee</td>
<td>$65K</td>
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<tr>
<td>NHS Fan Warrantee</td>
<td>$400K</td>
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<tr>
<td>Property Insurance Savings</td>
<td>$120K</td>
<td>$1,200K</td>
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<tr>
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<td>$2.605M</td>
<td>$1.831M</td>
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</tbody>
</table>
Some of the pitfalls

- Although we have had some great results there are always some minor and not so minor issues.
- Data bases crashing or becoming full, inoperable or not backing up correctly. Costing thousands to recover if they can be recovered at all.
- Training has to kept up.
- Employees have to be kept apprised and trained on the newest versions of the software and changes in the programing.
- Due to the location of all of our facilities the classes have to be set up offsite most of the time if not out of state, costing lost man-hours at the facility in addition to the overtime worked by the personnel covering for the personnel at training.
- Due to the location of all of our facilities personnel often leave for jobs closer to home taking with them all of the training they have been provided, leaving your team to start over with another employee. Although this is common everywhere, try retaining crews with a one way hour and a half drive to your site.
- Cross training of additional personnel is a must, along with the additional cost associated to it.
- Most of the items mentioned are more of a nuisance and in no way outweigh the benefits in the collection of as much data as possible when dealing with manufactures and the warranty process.