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In this Issue

High Energy Piping Evaluation, Part 2 of 3

By Jonathan D McFarlen

The full article can be seen in the COMBINED CYCLE Journal, 1Q/2009.

As previously stated, high-energy piping systems within a plant or mill are often overlooked and assumed to be in serviceable condition. This can be a terrible mistake since considerable damage and potential personnel injury could result if rupture were to occur.

In the last installment, a basic understanding of hangers, their functionality, and reading hangers was discussed. In this series, an evaluation program to assess piping systems and their supports is discussed. We will conclude with a discussion about the evaluation process.

Piping System Evaluation

The first step in a piping system evaluation is to perform a systematic visual inspection along with a hanger survey. The inspection should include hot and cold walk downs of the piping system in which the hanger positions are recorded. Photographic documentation, as well as, written documentation should be used to record hot and cold hanger readings. These records should be stored in an accessible location for future system surveys. It is also necessary to note the physical conditions of the hangers.

Figure 1. Constant Support Hanger Fouled by Nesting Birds

Figure 2. Closer View of Constant Support Hanger Fouled by Nesting Birds

Figure 3. Variable Support Hanger Displaying Severe Corrosion

Any unusual observations of the piping system such as areas of uplift or sag, interference of adjacent piping, components, or structural members, and wetted or visually corroded areas should be noted. Wetted areas or areas displaying oxide staining may need to have insulation stripped to determine if external corrosion has occurred. Pitting in particular, can serve to nucleate cracking in areas of elevated stress.

Although flexible pipe supports are generally reliable, they can be prone to internal mechanical problems such as contamination by fly ash, coal dust, corrosion products, or even nesting birds. Such contaminants can foul the spring within the support and arrest its motion. As an example, Figure 1 and Figure 2 show a constant support hanger fouled by nesting birds causing limited and irregular hanger functionality. Piping systems close to seawater or in paper mills are particularly prone to corrosion due to the ambient corrosive environment. As a result, this can cause load deviations or limited functionality of supports that have been severely corroded (Figure 3).

Rigid supports are also susceptible to degradation. Corrosion

(Continued on page 2)

between contacting surfaces can impede axial movement. With some rigid supports, an intermediate material may be used between contacting surfaces. The sliding pad may become liberated, as shown in Figure 4, thus causing increased resistance to axial movement.

Figure 4. Slide Plate Displays a Dislodged HDPE Pad

During the hanger survey, readings from flexible hangers in their hot and cold positions should be recorded during the piping system walk down. For constant support hangers, it is recommended that readings be recorded numerically (i.e. try not to use descriptive readings such as midway, near cold set, etc.). This will facilitate their comparison to the hot and cold set points and evaluating the amount of actual travel by the hanger.

The following table serves as an exemplar hanger survey record. Note that the "rated load", "total travel, and "design travel" should be included and can be obtained from the hanger data plate. The hot and cold set points should be included in the record as well. Current hanger readings, past hanger readings, and any pertinent comments should also be included in the record. It is also recommended that the actual travel be calculated and compared to the design travel. This will allow comparison of a hanger's movement to the design travel.

Corrective Measures

Depending on observation from the visual walk down and hanger survey, corrective measures may be required. Topped out or bottomed out hangers identified during the survey may require adjustment. However, before making any adjustments, consideration should be given to adjacent supports and how they may be influencing a bottomed or topped out hanger. It should also be mentioned that hangers that do not reach their hot or cold set points but do exhibit their anticipated amount of travel do not require adjustment, particularly if the hanger is not

Example of a Hanger Survey Record

Support Number	Support Type	Rated Load	Total Travel	Design Travel	Cold Set	Hot Set	Cold May, 03	Hot July, 03	Actual Travel	Comments	Cold Feb, 04	Hot Apr, 04	Actual Travel	Comments
MS-1	CS-BH	1450	3.5"	2.13" UP	2	8	7.5	10+	1.05" UP	BO	2	8	2.1" UP	Adjusted
MS-2	CS	1990	3"	1.81" UP	9	3	9	6.5	0.75" UP	Less Travel	9	3.5	1.65" UP	
MS-3N	CS	1245	1.5"	0.38" UP	9.5	7	9	10+	0.225" DN	BO - Travel Reverse, Tested & Adjusted	9	6.5	0.375" UP	
MS-3S	CS	1245	1.5"	0.38" UP	9.5	7	9	10+	0.225" DN	BO - Travel Reverse, Tested & Adjusted	9	6.5	0.375" UP	
MS-4	CS	2430	1.5"	0.25" DN	1	2.5	1	7.5	0.975" DN	Extra Travel	1	3	0.3" DN	
MS-5	RIGID	2935	--	0"	--	-	-	-	-	-	-	-	-	-
MH-6	CS	2640	2"	0.94" DN	1	6	2	2	0.0"	No Travel	2	7	1.0" DN	Cleared Debris & Load Test
MS-7	CS	1885	2.5"	1.5" DN	1	7	1	1	0.0"	No Travel	0.5	7	1.625" DN	Cleared Debris & Load Test
MS-8N	CS	1435	2.5"	1.38" DN	1	6.5	1	2	0.25" DN	Less Travel	1	6.5	1.375" DN	Cleared Debris & Load Test
MS-8S	CS	1435	2.5"	1.38" DN	1	6.5	0.5	1.5	0.25" DN	Less Travel	0.5	6	1.375" DN	Cleared Debris & Load Test
MS-9	VS	-	2"	0.375" DN	4.75" 2027#	5.125" 2087#	4.875" 2047#	5.25" 2107#	0.375" DN		4.875" 2047#	5.25" 2107#	0.375" DN	
MS-10E	CS	3621	2"	0.6" DN	3.5	6.5	3	7	0.8" DN		3	6	0.6" DN	
MS-10W	CS	3621	2"	0.6" DN	3.5	6.5	3	7	0.8" DN		3	6	0.6" DN	

easily assessable. Piping systems will tend to settle or relax after a period of operation and hanger positions will likely change. If adjustments are made, the amount of adjustment should be recorded.

Hangers exhibiting less than expected travel (i.e. less than their design travel) may require load testing to ensure their functionality. Load testing requires releasing the hanger from pipe, which has been temporarily supported by other means. Often, load testing of a hanger can be done with the hanger in place. Cycling a hanger through its full range of travel during load testing has been known improve its functionality as cycling tends to remove debris that impedes the hanger's travel.

If problematic hangers have been identified during the hanger survey, a stress analysis of the system should be pursued. Non-functional hangers (i.e. do not exhibit any travel) or hangers with limited functionality (i.e. hangers exhibit travel but either top out or bottom out) can be modeled using pipe stress analysis software. The analysis can help determine if the system was over-stressed by the problematic hangers and can locate areas of concern for subsequent non-destructive testing.

Areas determined to have been over-stressed should be further inspected using non-destructive testing. The same applies for sections of pipe and associated structural supports or hanger components that display deformation. Key areas for testing in over-stressed areas include circumferential welds, hanger attachment lugs, as well as, welds between a hanger and the structural steel to which it is attached.

Non-destructive techniques will be discussed further in the third installment of this series along with a discussion of damage mechanisms.

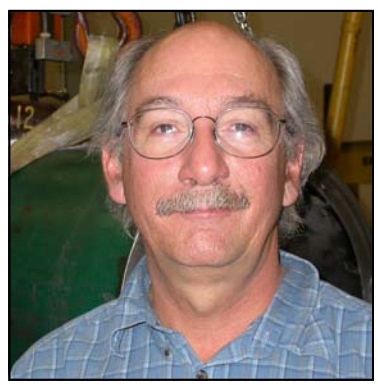
New Employees Join M&M Engineering

Catherine Noble joined the M&M Engineering Associates, Inc. Staff at the beginning of the year as a Senior Engineer.

Mrs. Noble's experience includes failure analysis, aerosol can technology, polymer coatings, FEA modeling, proposal writing, metallography, corrosion testing, SEM, customer service, mechanical testing, and photography.

She also conducted graduate research in titanium and cobalt superplasticity, as well as undergraduate research with carbon nanotube/polymer composites.

She will be involved in failure analysis examinations, including development of laboratory testing programs for parts received, supervision of laboratory work, interpretation of laboratory results, and issuance of reports.



Jerry Fowler joined the M&M Engineering Associates, Inc. staff this year as a Laboratory Technician.

Mr. Fowler has experience as a Senior EHS Technician, Senior Laboratory Analyst, Fire and Safety Technician, Environmental, Health and Safety Technician and as a Senior Laboratory Technician. In these areas he helped monitor safety, worked with OSHA standards for general industry and with OSHA 18001:1999. He has experience analyzing process emissions for airborne pollutants as required by MACT, providing technical training and oversight for process analysis staff, collecting emissions samples for analysis, visible emissions observation (Method 9) and Title V certifications.

Jerry is a Journeyman Bladesmith and a Certified Quality Auditor in the American Society for Quality. His experience will be a great asset to the M&M Engineering Laboratory in Austin, Texas.

Forensic Investigation of a Gas Turbine Event

Part 2 of 3

By Ron Munson, P.E. and John Molloy, P.E.

This is the second part of a multi-part article that will appear in upcoming issues of the Conduit. The full article can be seen in the COMBINED CYCLE Journal, 3Q/2007.

In the previous edition of the Conduit, the initial actions to take when investigating a combustion turbine event were discussed. Initial documentation, preferably in the form of photographs and video, as well as interviews with the operators and key personnel are important to the investigation. Preservation of the remains is also critical in determining the root cause of the event.

The next crucial step in investigating the cause of a gas turbine (GT) event is choosing the proper level of investigation. At the very early stages it is important to determine what one wants the failure investigation to ultimately achieve. There are three basic levels to investigations:

A **level one** investigation, which has a 75% to 99% certainty of being correct, is focused on the mechanistic level of damage. In this case, the investigation will determine the component(s) that failed first and the damage mechanism that led to this failure. Examples of possible damage mechanisms could include creep, thermo-mechanical fatigue, foreign object introduction (impact), incipient melting, among many others. Metallurgical investigation techniques and sound logic are your best tools at this level.

A **level two** investigation, which has a 50% to 90% certainty of being correct, is determination of cause. Generally, this level is easy to achieve once the mechanism is known. For example if a hot section is overheated, and a faulty exhaust gas thermocouple controller is identified, the mechanism (overheating) and cause (faulty thermocouple) are easily identified.

A **level three** investigation, the most difficult and costly to achieve, is the Root Cause level of analysis. It's certainty of success is always less than 100%. A **R**oot **C**ause **A**nalysis (RCA) is multi-disciplined, and should ultimately provide the root causes for the event. Notice the plural usage of the word "cause". A major CT loss event almost always has multiple causes, the cumulative effect of which leads to the failure.

The next step in the forensic investigation is composition of the RCA team. An appropriate way to conduct a root cause failure analysis of a GT loss is with a team of skilled and knowledgeable people. It is also important that the team work together and communicate effectively. The composition and size of that team is very critical. The team must be small enough to operate efficiently but have all technical areas covered. Typical team members should include the following:

- The Owner **-** obviously the owner must be represented on the team, but specifically who is chosen from the owner's staff is an important consideration. The person chosen should be one who knows the big picture of plant operation and equipment operation, and more

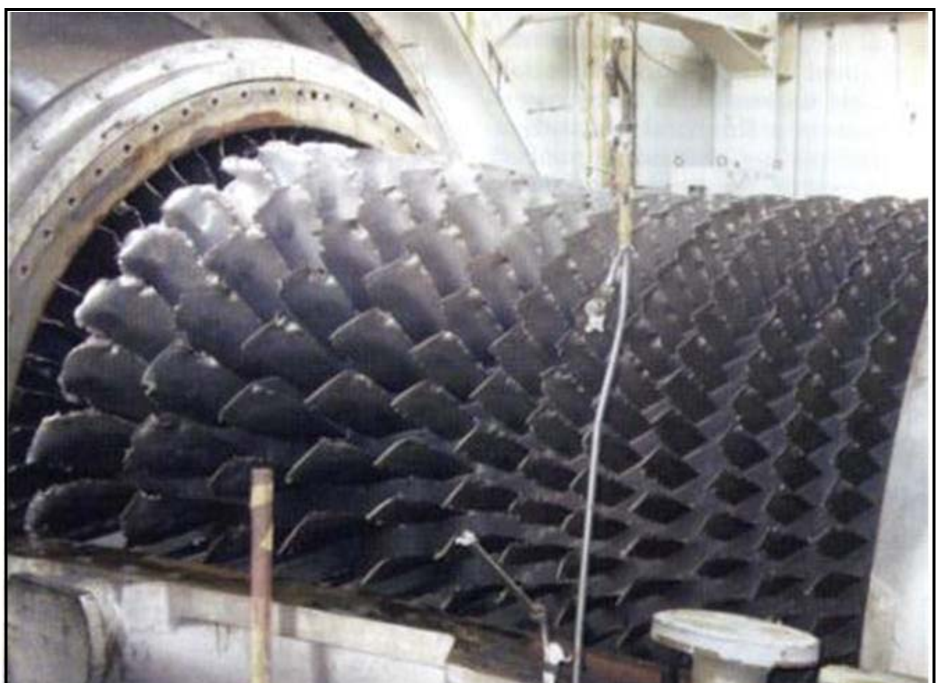


Figure 1. Failure of a first-row blade showing the damage to every stage of the compressor.

Figure 2. No bucket was left unscathed I this Frame 6 Turbine failure.

importantly, knows where to go for information and facts. That person must also be empowered with access to all sensitive information, because in an RCA effort the root cause may be controversial. A plant engineer or maintenance manager or both are usually involved. A real issue with owner participation is that the people who should be involved are likely fully occupied and focused on repair of the down unit. Understanding what happened is often secondary to restoring the cash flow for the plant.

- The OEM - The equipment manufacturer can be a key member of the RCA team. They understand the equipment design and details of construction. They have access to the details on construction materials, stress models, and dimensional details. The OEM also has historical information on the failed machine, as well as the entire fleet of similar machines. However, the OEM is usually not willing or able to share this information with the other team members because of confidentiality and proprietary information concerns. They are also cautious because of litigation/subrogation that could result from this event or similar events at other locations. Management of and the regulation of the OEM effort by the equipment owner is critical to the success of the RCA.
- Third Party Hired by Owner - in most cases the owner will hire a third party, either an individual or a company to represent them on the RCA team. These engagements usually occur even if the owner has employees on the team. Generally, the third party will have special expertise in either CT technology or experience in failure analysis that is not resident with the Owner.
- Third Party Hired by Insurance Carrier - Insurance contract coverage on modern GTs can be very complex. Typically many companies, each of which has a vested interest in the results of the investigation, share the risk. Generally, these insurance companies will hire an adjuster which, in turn, may hire a third party to help understand technical issues on the loss or recovery, or to provide the accounting to quantify the financial loss. In addition, the individual insurance companies will also hire (or jointly hire) an independent third party to protect their interests. The broker, who sold the policy, also has an interest to be sure any subsequent claim is fairly and accurately addressed. In many cases there is a financial institution that has a significant financial interest in the loss and recovery efforts.

The bottom line: For a major complex failure there can be many interested participants vying for a spot on the RCA team. Managing these diverse parties and their agendas can be challenging and often frustrating. Not all of these participants can be on the root cause team. The phrase "Too many cooks in the kitchen" certainly applies here. The owner usually has the final say on participation roles.

In most cases a suitable compromise position can be reached for all parties. All parties can share the findings of the RCA team, but only a limited number of qualified people should participate in the actual effort. In no case should any one participant ever have complete control of the RCA team. Such a team cannot be objective, candid, and thorough.

News and Upcoming Events

Dave Daniels of M&M Engineering Associates, Inc. will be presenting a paper on Innovative Lay-Up and Startup Methods at the EPRI International Conference on Cycle Chemistry in Fossil and Combined Cycle Plants in Boston, MA, June 30, 2009 through July 2, 2009.

HRSG Users Group Annual Meeting

Ron Lansing, P.E. of M&M Engineering, will be presenting a course on Non-Destructive Examination at the HRSG Users Group Annual Meeting to be held at the Hyatt Regency Jacksonville Riverfront in Jacksonville, Florida, April 6-8, 2009. See www.hrsgusers.org for more details.

Dave Daniels of M&M Engineering Associates, Inc. will be presenting a paper on Under-Deposit Corrosion Mechanisms and presenting training sessions on Boiler Water Chemistry following the regular conference sessions at the International Water Conference in Orlando, Florida, October 4, 2009 through October 8, 2009.

Daniela Lowry, Acting Laboratory Manager for M&M Engineering, recently passed the exam and met the requirements of the American Welding Society QC1, Standard for AWS Certification of Welding Inspectors.

Congratulations, Daniela !

Seminars and Workshops Attended

TAPPI and API co-sponsored the 2009 API Inspector Summit in Galveston, Texas, January 27-30, 2009. Ron Lansing, P.E., M&M Engineering, presented a discussion on Metallurgy and Non Destructive Examination.

John Molloy, P.E., M&M Engineering attended The 2009 WTUI Conference held at the Wyndham Palm Springs in Palm Springs, California March 15-18, 2009. He found the Session on the LM6000 very informative.

Check out Jon McFarlen's article in the current Combined Cycle Journal First Quarter of 2009

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