



the Conduit



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High Energy Piping Evaluation, Part 1 of 3

By Jonathan D. McFarlen

Often, high-energy piping systems within a plant or mill are overlooked and assumed to be in serviceable condition. While major planned outages are reserved for inspecting pressure vessels, storage tanks, boilers, turbines, and other critical components within a plant or mill, rarely are routine inspections carried out for high-energy piping systems. This is particularly alarming in regard to main steam lines. If rupture were to occur, serious damage and personnel injury may result. As plants and mills age, monitoring and evaluation of the main steam line and other high-energy piping systems should be emphasized.

In this article (and the two subsequent installments to follow) an evaluation program to assess piping systems and their supports will be discussed as well as some piping and support basics. The second installment will provide a detailed evaluation approach while the third article will discuss damage mechanisms and conditions for susceptibility. By the end of this series, it is hoped that plant and mill personnel can apply this information and incorporate the piping evaluation programs thus monitoring a systems-readiness program for continued service.

Power Piping and High Energy Piping (HEP)

Power piping, as defined by ASME B31.1, is roughly defined as piping connected and external to a boiler. This could include a large utility boiler located at a power plant, a recovery boiler at a pulp mill, or even a small package boiler used as a steam generator. Examples of power piping systems associated with these boilers include but are not limited to main steam systems, hot reheat and cold reheat systems, boiler feed lines, blow-off lines, drain lines, and vent lines.

Although not formally defined, HEP generally refers to main steam, hot reheat, and cold reheat piping systems. High-pressure

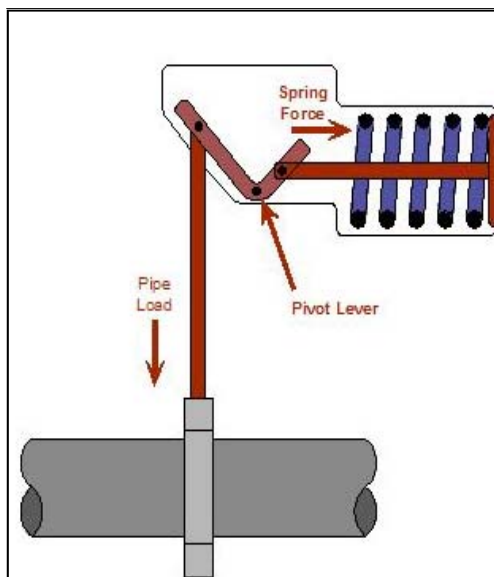


Figure 1. This diagram illustrates a cross-sectional view of a constant support hanger.

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boiler feedwater piping is also considered HEP by some. Depending on the size of a unit and its application, a reheat system may not be used. Regardless, there should be general concern for any high temperature and/or high-pressure system where a sudden release could result in damage and personnel injury.

Piping Support Basics

Piping supports can be divided into two basic categories including flexible hangers and rigid hangers. Flexible hangers are used when vertical travel due to thermal expansion of a piping section is required. This can be accomplished by using either constant support hangers or variable spring hangers.

Constant support hangers provide a “relatively” constant supporting force on the pipe section throughout the full range of vertical thermal expansion and contraction. Constant support hangers do this by using a helical coil spring attached to a pivot lever (Figure 1). As a general rule, constant supports are used for critical piping systems or critical areas of piping where a

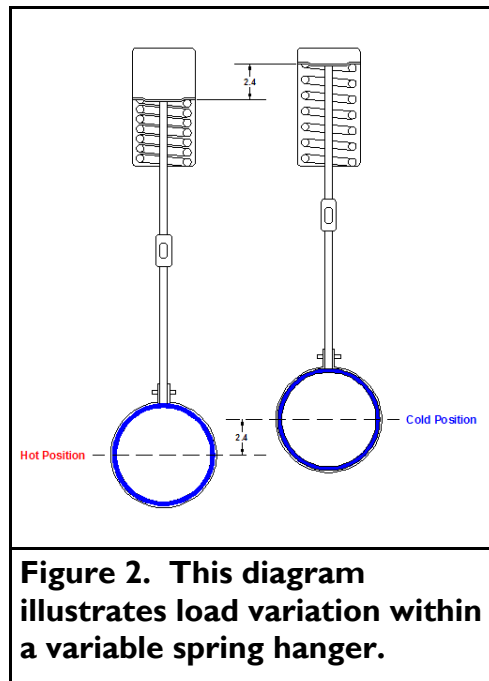
(Continued on page 2)

deviation in the support load is not acceptable (i.e., boiler or turbine terminations).

Variable spring hangers are typically used in circumstances where constant supports are not required, making the primary benefit of variable spring hangers a cost-saving advantage. With a variable spring hanger, the support effort is the product of the deflection and the spring constant (k). Referring to Figure 2, given a spring constant of $k = 1,500 \text{ lb/in}$, the difference between the hot load and cold load is 3,600 lbs with a total vertical displacement of 2.4-inches. Since the weight of the pipe segment is constant, the variation that the hanger provides (due to thermal excursions) can create excessive stress in adjacent areas. This can be a problem for variable spring hanger placement near critical equipment. Furthermore, variable spring hangers are not used where large vertical displacements are expected due to their load variation.

Rigid hangers can be categorized into hangers that allow axial growth and those that do not. Rod hangers, stanchions, and structural steel supports used in conjunction with pipe lugs are examples of rigid hangers. Supports that do allow axial growth include rollers, spider guides, slide plates, and travelers. Rigid hangers are used to support the piping in areas where axial and/or transverse expansion is negligible or at locations where the piping is to be fixed.

Another type of piping support in a category of its own is a Snubber. Snubbers act like a “shock



absorber” and are used to arrest dynamic loads such as seismic loading or water hammer events. Snubbers, for the most part, are not considered a pipe support as they do not provide any static supporting effort. Nevertheless, snubbers should be inspected routinely to ensure they are working properly in arresting dynamic loading.

Reading Hangers

With any piping evaluation program, understanding how to read hangers and interpret the reading is essential. Reading constant support hangers and variable spring hangers is rather straightforward. Referencing Figure 3, it can be seen that constant support hangers utilize a scale and an indicator to allow determination of a hanger’s position. The hanger scale will usually have ten divisions and often the hot and cold set points are marked or stamped directly onto the hanger scale (red and white indicators). Hanger readings just past “L” (i.e., 0) or “H” (i.e., 10) indicate a hanger is bottomed or topped out.

Hanger position readings on a variable spring hanger are read and interpreted somewhat differently. Like constant support hangers, variable spring hangers also utilize a scale. However, the scale is divided into increments of travel, as shown in Figure 4, with the hot and cold set points often stamped on the scale. On some hanger scales, the supporting load of the hanger at that position will also be displayed, as shown in Figure 5. If not, then the support loads corresponding to the hot and cold set points can be obtained from the hanger data plate (Figure 6). From there, the actual load at the current hanger position can be linearly interpolated. That being said, determining corresponding loads at the current hanger position is not a necessity. After all, the main point of recording hanger readings is to ensure that they are traveling without bottoming or topping out and that they are within range of the original set points. However, should subsequent stress analysis be required, the load at the hot and cold position will be needed. Therefore, it is a good idea to determine the hot and cold loads while taking the hanger readings.



Figure 3. An exemplar constant support hanger scale.

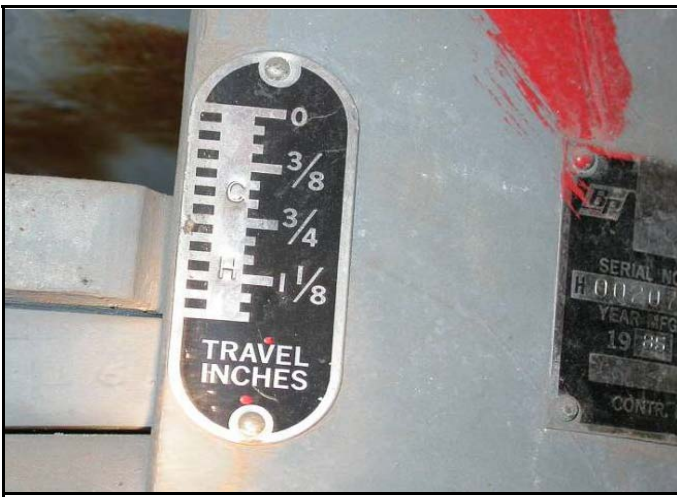


Figure 4. An exemplar variable support hanger scale showing only travel.



Figure 5. An exemplar variable support hanger scale showing travel and supporting load.



Figure 6. Exemplar variable support data travel and supporting load.

Seminars and Workshops Attended

Boiler Feedwater Corrosion Issues: David Daniels of M&M Engineering Associates, Inc. presented a discussion on the fundamentals of Flow Accelerated Corrosion at the MidWest Utility Chemistry Conference held in Overland Park, KS, a suburb of Kansas City. There were over 130 attendees from various utilities in the Midwest.

The Second International Conference on the Interaction of Organics and Organic Cycle Treatment Chemicals with Water, Steam, and Materials was held November 4-6 in Lucerne, Switzerland. The conference was sponsored by EPRI and Power Plant Chemistry, GmbH. Approximately 80 attendees from throughout Europe, South America, the Middle East and Africa attended the 3-day conference. David Daniels represented M&M Engineering. Conference topics included organics in makeup water, the effects of organic breakdown products on steam turbine materials, organic boiler treatments, and cation conductivity and TOC monitoring. Highlights of this conference will be the subject of a future **Conduit** article.

The International Water Conference was held in San Antonio, Texas, October 27-29 and was attended by approximately 200 from around the US and many foreign countries. Following the conference, David Daniels held a seminar on boiler water chemistry for high pressure (>1200-psig) boilers. The class was well attended with over 20 participants. The next IWC will be held in Orlando, Florida in October of next year.

News and Upcoming Events

Save the Dates:

- ⇒ **HRSO Users Group Annual Meeting**-- Hyatt Regency Jacksonville Riverfront in Jacksonville, Florida, April 6-8, 2009. See www.hrsogusers.org for more details.
- ⇒ TAPPI and API will be con-sponsoring the **2009 API Inspector Summit** in Galveston, Texas, January 27-30, 2009. Ron Lansing, P.E., of M&M Engineering will be presenting a discussion on Metallurgy and Nondestructive Examination.

Cooling Water Chemistry: Check out the article in September's Power magazine on cooling water chemistry written by M&M Engineering's David Daniels <http://www.powermag.com/issues/features/1347.html>

Forensic Investigation of a Gas Turbine Event

Part I of 3

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

Reprinted from the *COMBINED CYCLE
Journal*, 3Q/2007

(This is the beginning 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.)

Gas turbines (GTs) truly are
engineering marvels. Their
sophisticated design, materials,
and operation challenge the limits
of modern technology. When one
of these machines “breaks”,
understanding *what* happened and
why is a demanding exercise
requiring the participation of
experts in equipment forensics.
This article, and the articles to
come in future editions of the
Conduit, discusses the many facets
of the investigation into the failure
of one of these machines.

When a major failure occurs to
any equipment, the immediate
concern is for the welfare of the
employees. Dangerous conditions
must be eliminated and personnel
safety assured. It is important to
isolate energy sources (lock out
and tag out), but also to assure
structural stability of the
compromised equipment. Large
dynamic forces and fires can
weaken structures which could
lead to collapse. The remaining
equipment in the quarantined area
must be protected from the
environment to prevent further
damage. It is likely that most
equipment will be inoperable for
an extended time while repairs

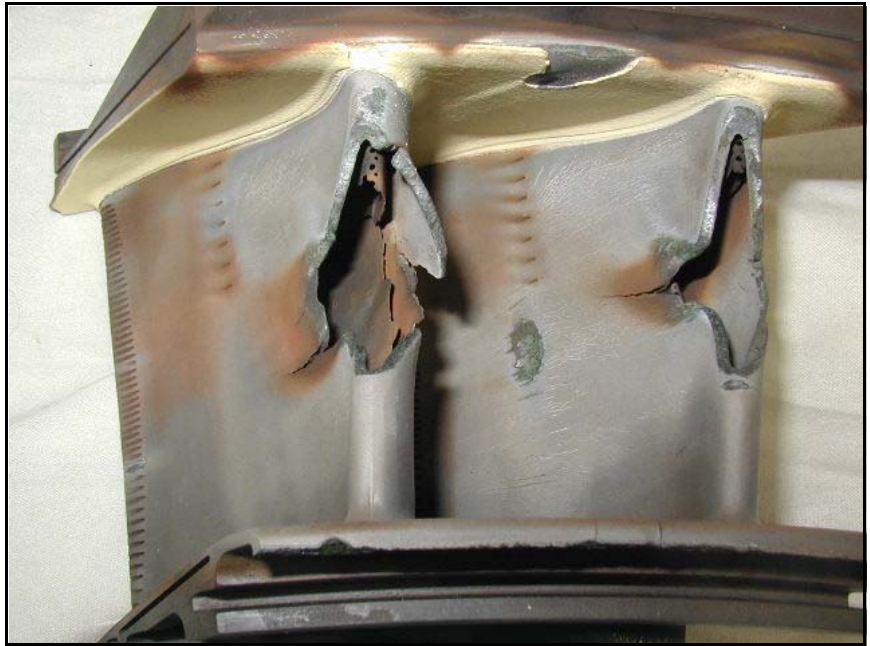


Figure 1. Loss of cooling caused this vane segment to fail. Cooling passages were plugged with debris from inadequate air filtration.

are made, thus lay-up procedures
are appropriate. Immediate
actions after the event do have an
impact on the future success of
the failure investigation to follow.

There is not a set “protocol” for
each of the first steps to follow
after a large event. The best
advice is to Document,
Document, Document. Recording

the scene either with video or
digital photographs is essential.
Photograph everything—even
things that appear normal.
Photograph all control equipment
settings. Several months after the
event, the memory will fade but
photographs are available for
review indefinitely.

One item of extreme importance



Figure 2. Long-term aging and metallurgical deterioration were the underlying causes of a turbine wheel-post failure that allowed a blade to release into the flow path.

is to make a projectile map. Tag and label each projected piece and its relative position to the equipment of origin. Talk to your first responders—ask them what they moved or disturbed during their initial damage control efforts. Talk to the operators. Ask them what was reset or turned off immediately after the failure. Talk to them as soon as possible after the event while their memories are fresh. The tone and demeanor of the investigators during the initial visit is very important. Be causal and do not state your opinions. Listen carefully to statements by operators and personnel involved in the event. Record what everyone says. The validity of the statements can be judged at a later date. It is important early on to accurately record, but not pre-judge what is said. Talk to plant maintenance people about the equipment. Discuss with them recent maintenance work and observations they made during those maintenance projects. Talk to operators about observed trends, anomalies, or procedural changes prior to the failure event.

If there was a fire, it is recommended you retain a cause and origin professional early in the recovery project. Details of a fire will deteriorate quickly with time.

Once all personnel are all

accounted for, the equipment is rendered safe and the environmental issues around the GT workspace resolved, it is time to begin the investigation into *what* happened.

Until the investigation team is onsite, it is important to protect the equipment from the environment. The equipment should be protected from precipitation with tarps and enclosures. The equipment must also be secured from “souvenir hunters.” Broken components can be sought after for nostalgic purposes but pieces critical to the investigation can be lost if not secured for the investigation.

In addition to the hardware, it is important to secure the electronic “remains” such as equipment data loggers, DCS systems and any other form of electronic data storage. In addition to the data during the event, it is useful to recover data from at least six months prior to the event to look for trends that may explain the failure. Often, a step or trend in something such as vibration or lube oil temperature (which is considered insignificant before the failure) is critical data afterwards. Even data that is within normal limits should be noted because “exclusion” is very important to establishing root cause.

In-Place Metallography and Replication

By Ronald E. Munson, PE

M&M Engineering Associates, Inc. is often asked to nondestructively evaluate components such as steam drums, boiler tubes, turbine disks, generator retaining rings, piping and paper machine suction rolls in the field in order to analyze failures or assess metallurgical integrity. In-place metallography and replication (IMR) are the tools M&M Engineering uses for these evaluations. IMR takes the laboratory to the hardware when the hardware cannot be taken to the laboratory. Overheating mechanisms such as creep, spheroidization, and graphitization, as well as cracking mechanisms such as stress corrosion cracking and fatigue, can be identified by IMR. The general metallurgical condition of the component can also be determined and documented. IMR is a very useful tool that can be used for loss control (e.g., damage assessment of a boiler after a low water condition) and loss prevention (e.g., examination of cracks discovered during an outage).

Selected areas are lightly ground, polished, and etched for examination at high magnification. Heavy oxides are first removed with a handheld surface grinder. The ground areas are then polished with successfully finer polishing media. Adhesive-backed polishing disks are used with a handheld Dremel® tool. Initial polishing typically includes 60, 120, 240, 320, 400, and 600 grit disks.

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Final polishing is accomplished with felt disks and 9-, 6-, and 1-micron diamond paste. The result is a mirror-like finish on the metal. The prepared areas may be inspected in the as-polished (unetched) condition, especially if cracks or porosity are visible, but most areas are etched to reveal the microstructure. Etching is the application of a mild acid that selectively attacks the structure of the metal to show grain size, segregation, phase distribution, and inclusions. For example, etching will show whether cracks are transgranular (propagate through the grain) or intergranular (propagate around the grain). The grinding, polishing, and etching procedures typically remove a few

mils of material. Therefore, the in-place metallography and replication are useful only for surface examinations. IMR cannot evaluate subsurface material. For example, the surfaces of some hot-formed components do not represent bulk, through-wall conditions due to the presence of a decarburized surface layer from manufacturing.

A prepared surface is replicated by dousing the polished and etched areas with acetone and applying a strip of acetate replicating tape. The acetone softens the tape, allowing the surface topography of the metal to be imprinted on the tape. This produces a “fingerprint” image of the selected area. The back side of the replica is blackened

(made opaque) to enhance reflected light microscopy. A portable light microscope may be used for onsite verification of the quality of both the metallographically prepared surface and the finished replica, and for preliminary evaluation. Replicas are examined and photographed at high magnification in the laboratory. When area location and component geometry permit, a microscope equipped with a camera can be used to take photographs of microstructures onsite. Replication is an especially important part of IMR when accessibility or component geometry prohibits the use of a portable microscope to examine an area in the field.

New Employees Join M&M Engineering

Daniela Lowry joined the M&M Engineering Associates, Inc. staff this summer as a Metallurgical Technician.



Ms. Lowry's experience includes weld inspection of orbital tube welds in Class One Clean Room and performing laboratory examinations, including failure analysis, metallography, hardness testing, and materials analyses associated with component failures and operational problems.

Test equipment applied in these analyses include metallurgical microscopes, hardness testers, metallography equipment, non-destructive testing and photography.

Also included in Ms. Lowry's experience is in-place metallography, replication, hardness testing of high-energy piping, rotors, and blades in power plants and auxiliary equipment in Utilities.



Gene Holland joined the M&M Engineering Associates, Inc. staff this summer.

Mr. Holland, although relatively new to the metallurgy field, has an extensive aviation physics and science background as well as

recent quality assurance/quality control experience in a clean room environment.

Mr. Holland's knowledge in weld inspection via pneumatic testing in a sensitive, controlled environment has created an interest and passion for failure analysis. Both Rockwell and Struers microhardness testing along with field metallography and other field inspections involving litigation cases are only a few of Mr. Holland's skills utilized at M&M Engineering.

Other proficiencies include photography, some computer networking and peripheral management, replication, sample polishing and etching.

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