Seam Welded Piping

April 2013

Background

There have been several catastrophic failures in the United States involving seam welded piping. Each of these failures involved pipe ruptures and resulted in significant damage to the utilities involved. These failures also have resulted in deaths and personal injuries.

Seam welded piping for installation in critical power plant piping systems has been produced since the early 1940's by about ten different manufacturers of this pipe, including M. W. Kellogg, Grinnell and ITT Grinnell, Tube Turns, National Annealing Box, Taylor Forge, Teledyne-Irby, and others.

In addition, elbows and other fittings for installation into the same piping systems have also been produced as clam shells by seam welding two half sections together. Failures resulting in steam leaks have also occurred in these types of seam welded fittings.

Variations in Manufacturing Processes

Each manufacturer of seam welded pipe or seam welded fittings has followed somewhat different procedures in the welding and manufacture of these products.

For example, even though the pipe may have involved a *1-1/4* Cr - 1/2 Mo or *2-1/4* Cr - 1 Mo low-alloy steel material, the welding performed may have utilized alloy steel wires with unalloyed fluxes or alloy steel fluxes if submerged-arc welding was utilized or may have involved carbon steel wires with fluxes alloyed with chromium and molybdenum. Significant variations in properties can result from these variations with respect to metallurgical composition as a result of variations in welding current, voltage, preheat and interpass temperature, travel speed, etc. Variations also depend on the type of distribution of the alloying elements incorporated into the flux or into the welding wire.

In addition, variations in properties can result from specific flux formulations depending on fluxes that are either considered acidic or basic.

Although these variations may represent 'fine' variations that are not obvious to the industry in general, they nevertheless can significantly affect the long-term performance of the seam welded pipe and fitting materials involved.

Very few metallurgists have the expertise to detect and differentiate the various effects of these conditions.

Variations also result from the size of weld cross sections where variations in performance, creep properties, life of piping, and failure mode, can also depend on the welding techniques and welding processes, procedures and techniques followed.

For example, some pipe manufacturers perform the root pass by one process, such as gas metal-arc (short-arc welding), while others perform the root pass by submerged-arc welding.

Other variations in the characteristics and performance depend on the heat treatments performed, including the preheat treatment, the maintenance of interpass temperature and the postheat treatments. Although many pipe manufacturers specified an interpass temperature of 300°F or 400°F minimum, which can vary from manufacturer to manufacturer, the actual weld quality depends on the controls applied by the manufacturer to be certain that the minimum interpass temperature is checked and followed. There have been instances where the interpass temperature actually applied was less than 200°F, which resulted in weld cracking in the as-welded condition. Since radiographic examinations are not performed prior to postweld heat treatment, such cracks or fissures in many instances were not detected in the seam welded piping that has been installed in various power plant piping systems.

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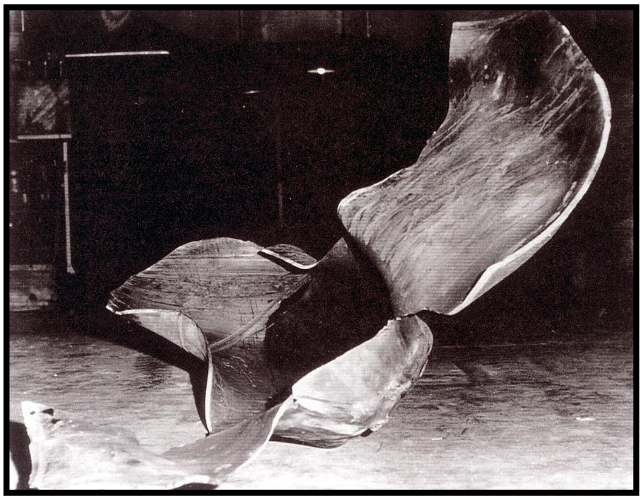
Variations in service behavior can also occur as a result of the type of postheat treatment used, which may have been a stress-relief heat treatment, a normalizing and tempering heat treatment, or an annealing heat treatment.



Rupture of 12” OD Elbow on Hot Reheat Pipe Bend

Where seam-welded pipes have been subsequently bent by a pipe fabricator, even greater variations in properties can occur as a result of the heating of the straight pipe prior to hot bending to temperatures ranging somewhere between 1600°F and 2100°F. The pipe subsequent to the hot bending may again have received different heat treatments, such as a stress relief heat treatment or a normalizing and tempering heat treatment or an annealing heat treatment. Again, variations in properties may have resulted.

Failure Causes and Considerations

The catastrophic and leak-type failures that have developed in critical piping systems are associated primarily with materials engineering considerations.

Some of the catastrophic failures that have occurred actually developed at low-stress locations in the hot reheat and main steam piping systems involved. In every instance, the failure analyses confirmed that the problems were associated with the piping materials, including the manufacture of the piping, the fabrication of the piping, the procedures used in seam welding of the piping, the effects of preheat and post-heat treatments of the piping, and the erection of the piping. In addition, the effects of the service environments, particularly involving service temperatures, have also, to some degree, affected the conditions and severity of the failures that have occurred.

Thielsch Engineering’s Experience and Services

As a result of extensive tests, experiences, metallurgical evaluations, mechanical test evaluations, etc. on seam welded piping and fittings, Thielsch Engineering has available what is probably the largest data base on these types of materials that are extensively utilized in various critical piping systems in power plant installations.

We were involved as experts in materials and welding engineering in the failure analyses of the ruptured hot reheat pipe sections at the Mohave Station and the Monroe Station, and are fully familiar with these particular failure incidences. Thielsch Engineering was also involved previously in the catastrophic rupture of the hot reheat pipe section at the Canal Station of Commonwealth Electric and is familiar with the various conditions involved in the hot reheat pipe rupture at the Sabine River Station. A number of catastrophic girth weld ruptures have also been examined by us during the past 35 years.

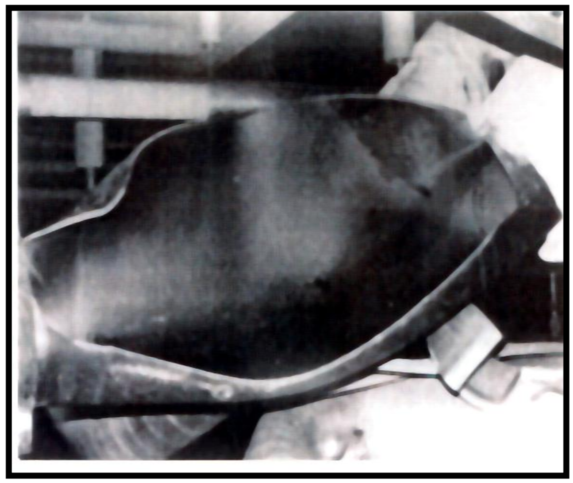
In addition, we have been involved in the evaluation of failures of girth welds and seam welds involving over 200 instances where the failures resulted in steam leaks and not in ruptures. With respect to headers, we have frequently been asked to reevaluate headers which have been rejected or condemned by the original equipment manufacturer. In other instances, we have used a variety of specifically developed nondestructive examination techniques to fully assess the current operating integrity of these boiler components.

We have performed analyses of over 2500 piping systems and boiler components, including seam welded hot reheat piping, and have detected various minor, as well as major, defect conditions, including cracking. For example, some hot reheat pipes had been welded and developed transverse cracks in the seam welds. These cracks were not discovered at the time when these welds were originally radiographed. Subsequent to the pipe manufacture and radiography, the seam welded pipe sections were hot bent by pipe fabricators such as Dravo, Power Piping, Grinnell, B.F. Shaw, and others. This caused slight widening of the cracks. We have now discovered these types of conditions during our field inspection and integrity analysis evaluations.

This included ultrasonic examinations, radiographic examinations, wet fluorescent magnetic particle examinations and borescopic inspections with photographic and video recording techniques. Detailed evaluations of weld probe samples removed from the pipe sections have been performed also. In some instances we also prepared the repair welding procedures and supervised the final weld repairs performed.

These unique experiences are also extensively utilized by various utilities, as well as insurance underwriters who have contracted with Thielsch Engineering to perform specific failure analyses and to determine insurability, as well as reliability and suitability for continued service of piping systems and components.

In the performance of an integrity analysis, it is equally as important to detect all conditions in girth and seam welds and branch connections which can result in catastrophic occurrences of thruwall cracking, interrupting power plant operations, as it is to recognize other conditions frequently noted in piping systems which may be totally non-injurious to the systems' integrity and will not result in pipe failures. There have been many instances where entirely safe and sound piping components have been rejected because of misunderstood material performance characteristics resulting in a high cost to the utilities involved.



To provide maximum benefits to a utility, insuring on one hand confirmation of safe piping systems and on the other, minimum interruptions to power plant operations, Thielsch Engineering personnel provide the following unique experiences:

I. Have examined critical piping and piping components in over 500 power plant units over the past 40 years.

II. Fully familiar with all aspects of manufacture and production of critical piping for main steam, hot reheat, cold reheat and auxiliary systems, and various conditions and defects that have occurred and can occur in piping materials and particularly in seam welds.

III. Have inspected and witnessed pipe manufacturing, including seam welding, in every pipe manufacturing plant, such as Taylor Forge, Tube Turns, National Annealing Box, Ladish, ITT Grinnell, Teledyne, etc.

IV. Have examined over 200 conditions of thru-wall cracks resulting in steam leaks and over 10 ruptures in critical high-temperature steam piping in steam power plants.

V. Have prepared procedures for repair welding and have supervised repairs by welding of over 100 thru-wall cracks in critical steam piping.

VI. Have given over *35* in-house training programs of one to three full days in duration for utility personnel on pipe failures, failure prevention, inspection, integrity, and repairs.

VII. Have presented over 100 one- to three-day seminars on failures, failure prevention and repairs of pressure vessels, piping, boilers, and rotating machinery, and life-extension considerations under sponsorship of the American Society of Mechanical Engineers, American Society for Metals, American Welding Society, Texas A&M University, and others.

VIII. Have investigated pipe ruptures at Mojave, Monroe, Sabine, Canal, Allegheny Power, and are familiar with conditions causing ruptures.

IX. Have performed over 200 failure analyses and integrity analyses for insurance underwriters such as Factory Mutual, Hartford Steam Boiler, Commercial Union, Kemper, etc.

Thielsch Engineering personnel have also been extensively involved in performing failure analyses, integrity analyses, and remaining-life determinations of various other components and equipment in power plants, including boilers, drums, headers, turbines, fans, deaerators, flash tanks, etc. Some of this equipment has also been subject to catastrophic failures, which have subsequently been evaluated by Thielsch Engineering personnel.