ELECTRIC POWER RESEARCH INSTITUTE

Heat Recovery Steam Generator Repair Welding Technologies to Address FAC in Tube Bends

1012762

Heat Recovery Steam Generator Repair Welding Technologies to Address FAC in Tube Bends

1012762

Technical Update, March 2007

EPRI Project Manager

D. Gandy

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

ORGANIZATION(S) THAT PREPARED THIS DOCUMENT

Electric Power Research Institute (EPRI)

Encompass Machine, Inc

This is an EPRI Technical Update report. A Technical Update report is intended as an informal report of continuing research, a meeting, or a topical study. It is not a final EPRI technical report.

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or e-mail askepri@epri.com.

CITATIONS

This report was prepared by

Electric Power Research Institute (EPRI)
1300 W.T. Harris Boulevard
Charlotte, NC 28262

Principal Investigators
D. Gandy
K. Coleman

Encompass Machine, Inc.
661 Cel-River Road
Rock Hill, SC 29730

Principal Investigators
B. Powell
K. Spencer

This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

Heat Recovery Steam Generator Repair Welding Technologies to Address FAC in Tube Bends. EPRI, Palo Alto, CA: 2007. 1012762.

REPORT SUMMARY

Tube failures that occur in heat recovery steam generators (HRSGs) are often caused by thermal stress or thermal shock associated with cyclic plant operation or by flow-accelerated corrosion. Many premature failures occur along the length of finned tubes or at attachment locations where tubes are joined to the upper or lower header. Because of current tube repair practices and limited access for welding, reoccurring failures are common.

Background

In response to reoccurring failures of tube repairs, EPRI initiated the development of two new welding technologies specifically designed for tube repairs in HRSGs. One of these technologies addresses tube failures that occur along the length of the tube, and the other addresses damage to the tube-to-header attachment area. This report focuses on the latter and discusses developments for both straight and curved tube attachments. Tube-to-tube repairs were covered in EPRI report 1010441. The improved welding technologies are expected to reduce repeat failures and result in higher quality repair welds that will take less time and be more cost effective.

Objectives

- To design and develop repair methodologies to address costly damage observed in HRSG header-to-tube attachments.
- To expand existing technology for repair of straight tube attachments to also address curved tube (elbow) attachments where flow accelerated corrosion can cause concerns.

Approach

To address both HRSG areas that are subject to premature tube failures, EPRI planned for the development of two separate welding techniques and corresponding welding devices.

In April 2004, EPRI began to conceptualize an approach to the repair of HRSG tube-to-header attachments. This type of weld repair is typically more difficult than conventional tube repair because of limited access to the damaged area. The new repair approach involved repairing the tube attachment from “inside” the header as opposed to the conventional method in which welders cut into the tube bundle and repaired the cut tubes by welding their way back out. The development work began in mid-2004 when EPRI contracted with Encompass Machine, Inc., to assist in the development of a tube-to-header repair device. A detailed repair methodology and equipment were developed for straight-entry type tubing (1010441). The current report describes how this technology is now being extrapolated to address curved-entry (elbow) tube attachments.

Results

Throughout 2004 and 2005, EPRI has been involved in the development of new technologies and equipment to improve the welding process for repairing tube and attachment damage in HRSGs. A tube-to-header attachment repair methodology for straight-section tubes was devised, prototyped, and is now commercially available. During 2006, work began to modify the existing straight-tube attachment repair technology to address curved tube attachments. The curved-tube repair technology has now been conceptualized and various prototype pieces of equipment are in development. This report provides an update on the development of this equipment which is slated for introduction to the market in 2008.

EPRI Perspective

After recognizing the high number of failures in tubes and tube attachments in HRSG equipment, power plant owners turned to EPRI to assist in the development of improved welding methodologies and equipment. This report describes the newly developed welding technologies that can be used by power plant personnel, repair vendors, installers, and OEMs. These advances will lead to significant improvements in the repair of HRSG tube failures. Further, the improved repair methods, developed as part of this research, will result in significant cost reductions to power producers as they deal with repairs to damaged HRSG tubing.

Keywords

Heat recovery steam generators
Flow accelerated corrosion
Tube welding
Header attachments
Gas metal arc welding
Gas tungsten arc welding

ABSTRACT

Tube failures that occur in heat recovery steam generators (HRSGs) are often caused by thermal stress or thermal shock associated with cyclic plant operation or by flow-accelerated corrosion. Premature failures have been observed both along the length of finned tubes and at attachment locations where tubes are joined to the upper or lower header. Each type of failure is expensive to correct, normally requiring welders to cut their way into the tube bundle and weld their way back out. The welder's limited access and conventional repair practices (common with existing technologies) often resulted in reoccurrence of the tube failures.

This report describes welding technologies that are being developed to address tube-to-header failures primarily resulting from flow accelerated corrosion (FAC) damage to the elbow. The technology expands on the equipment and methodology developed for tube-to-header weld damage repairs which was introduced in early 2006 for straight tube designs. As before, a majority of the repair is accomplished from the inside diameter of the header; however, a new extended arm approach that is employed from outside of the tube bundle is also introduced. This report is intended to provide an update on the development work that was accomplished during 2006.

ACKNOWLEDGMENTS

The authors of this report would also like to acknowledge and thank the following individuals for their insight and diligence in the development of the tube-to-header repair equipment:

- L. Tellone and P. Troutman from Encompass Machine, Inc.

CONTENTS

LIST OF FIGURES

1
BACKGROUND

Finned tube repair in heat recovery steam generators (HRSGs) requires that the welder "cut their way" into the tube bundle to gain access to the damaged header-to-tube attachment region, repair the damaged header-to-tube weld, and then reweld (replace short sections) each tubes in the bundle as the welder moves their way back out to complete the final tube replacement. These time-consuming and costly repairs have a high rate of repeat failures as a result of both the welder's limited access to the damaged tube and the lack of available welding technologies specific to the task. Moreover, undamaged tubes also have to be severed to gain access to the damaged tube deep in the tube bundle.

EPRI was tasked by membership utilities to identify an improved technology for performing HRSG both tube and tube-to-header welds. An earlier EPRI report (1010441) covers the both types of repairs. However, for tube-to-header welds, only straight tubes (not elbow connections) were covered. The current report focuses on 2006 developments aimed a improving the existing straight section tube equipment and at modifying/developing equipment/approach to address the header-to-tube welds that include an elbow (curved tube).

2 INTRODUCTION

Concurrent with their development of the prototype welding device, EPRI began developing the report, *HRSG Material Selection and Repair Guidelines* (1004875) [1]. During the preparation of that report (and from working with several HRSG vendors), tubing repair was identified as an area that needed better welding equipment to improve the quality of installation and repair. Two types of tube repairs were identified: repairs on tubing away from the upper or lower headers and repairs at tubing-to-header attachments. These are described as follows:

- *Repairs on Tubing Away from the Upper or Lower Headers:* These repairs require welders to either cut their way in and weld their way out of a tube bundle or plug and abandon the tube. The result is often poor quality tube welds due to access limitations on the rear side of each tube. Mirror welding is commonly used on the back side of each tube; however, this repair technique requires a highly skilled welder and still often results in poor quality welds. Replacement sections (in which at least two OD welds are required) are commonly used.
- *Repairs at Tubing-to-Header Attachments:* These repairs require a similar approach in cutting in and welding back out. Another approach often used is to plug the tube from the inside of the header. This approach, however, reduces plant efficiency because the plugged tube is essentially removed from service.

As a follow-on to these guidelines, EPRI staff began to investigate ways to improve the welding technology to address these two forms of repair. Investigators believed that for tube welding applications, the ID Tube Welder window-welding device could, with a few slight modifications, be adapted for use with HRSG tube-to-tube welding applications (that is, applications replacing tube sections). During 2004, EPRI worked with Aggressive Equipment, Inc., to improve the existing window-welding device and to make incremental changes that would make the device useful for HRSG tubing applications. This equipment is described in EPRI Report 1010441 [2]. Additionally, off-the-shelf tube welding equipment from five different equipment manufacturers was examined and reviewed.

In April 2004, EPRI also began to conceptualize a method for repairing tubing-to-header attachments. A repair approach was identified, and a welding equipment vendor (Encompass Machine, Inc.) was selected to develop a second welding device. During the second half of 2004 and throughout 2005, EPRI and Encompass Machine worked to develop a prototype of the repair device. The final repair equipment was made available during the first quarter of 2006. The equipment and approach was also described in the earlier EPRI Report 1010441 [2].

Continued improvements to the repair approach/equipment were made throughout 2006 resulting in a commercialization of the equipment for straight section tube attachments. In conjunction with this development, EPRI/Encompass Machine began to further develop the technology to address curved tube section (elbow) attachments where FAC is often observed. This report describes the technology/methodology that is currently being developed for curved tube repairs. This technology will, like the straight tube repair approach, be able to be applied from the inside of the header, thus eliminating the "cutting your way in and welding your way out" need. It is anticipated the curved tube repair technology will be available by third quarter of 2007.

3
HEADER-TO-STUB TUBE DAMAGE REPAIR

One form of repair identified during the preparation of the EPRI report, *HRSG Material Selection and Repair Guidelines* (1004875), was tube-to-header attachment repair (see tube failure at header location in Figure 3-1). Due to limited access, this form of repair is often more difficult to perform than conventional tube repairs. A photograph of several tube-to-header attachments, shown in Figure 3-2, reveals the complexity and limited access of such repairs, particularly those that may be buried deep within the bundle. As a result of access limitations, tube failures are often left in place and simply plugged. Figure 3-3 provides an example of a plug-weld configuration. Plugging requires 1) removing a window within the header 180 deg away from the stub tube attachment location, 2) machining and inserting a plug into the damaged tube bore, 3) welding the plug into place, and 4) reinstalling the window.

Figure 3-1
Failed HRSG Tube at the Header Location

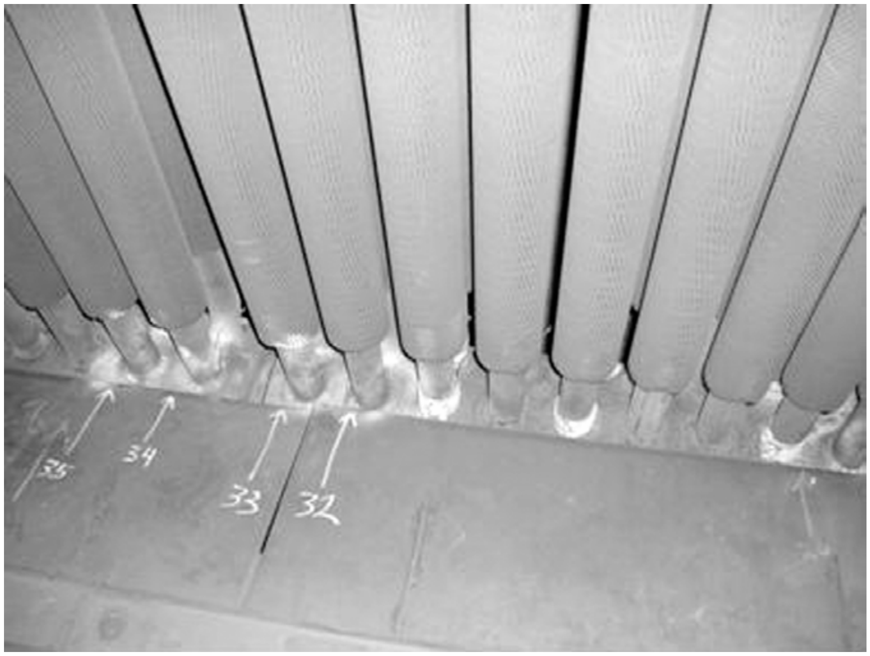

Figure 3-2
Tight Configuration of Tubes at the Tube Attachment Location

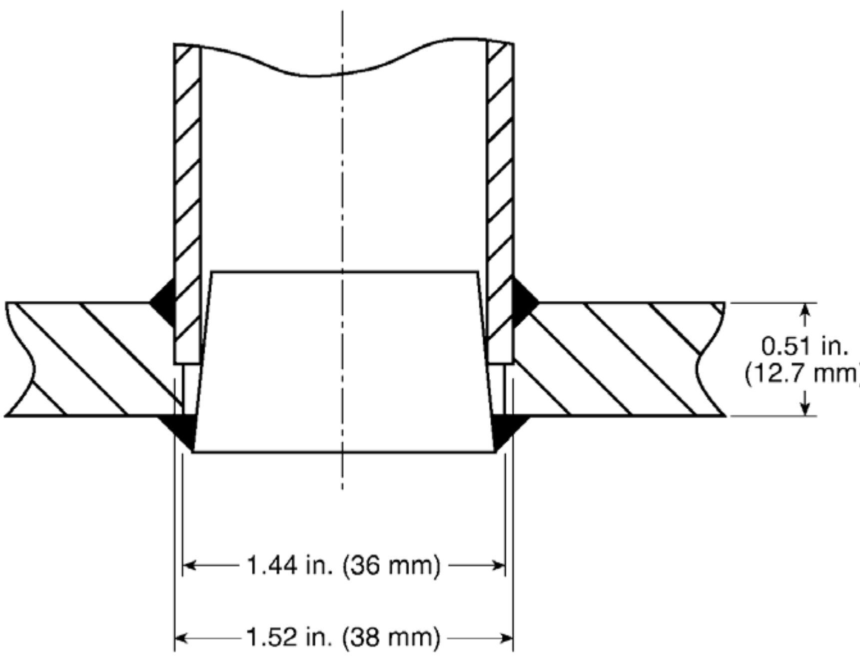

Figure 3-3
Plug Weld Configuration

The selection of a repair methodology is complicated by the number of different attachment configurations used by industry. Tube-to-tube attachment weld designs used by original equipment manufacturers (OEMs) include:

Partial-penetration welds

Full-penetration welds

Forged nipples with full-penetration welds

Separate nipples and full-penetration welds between nipple and header and header to tube

Examples of each of these weld designs are provided in Figure 3-4. Advantages and disadvantages for each form of repair are described in the EPRI report, *Delivering High Reliability Heat Recovery Steam Generators* (1004240) [3]. Following several internal discussions, EPRI identified an approach applicable to all four designs.

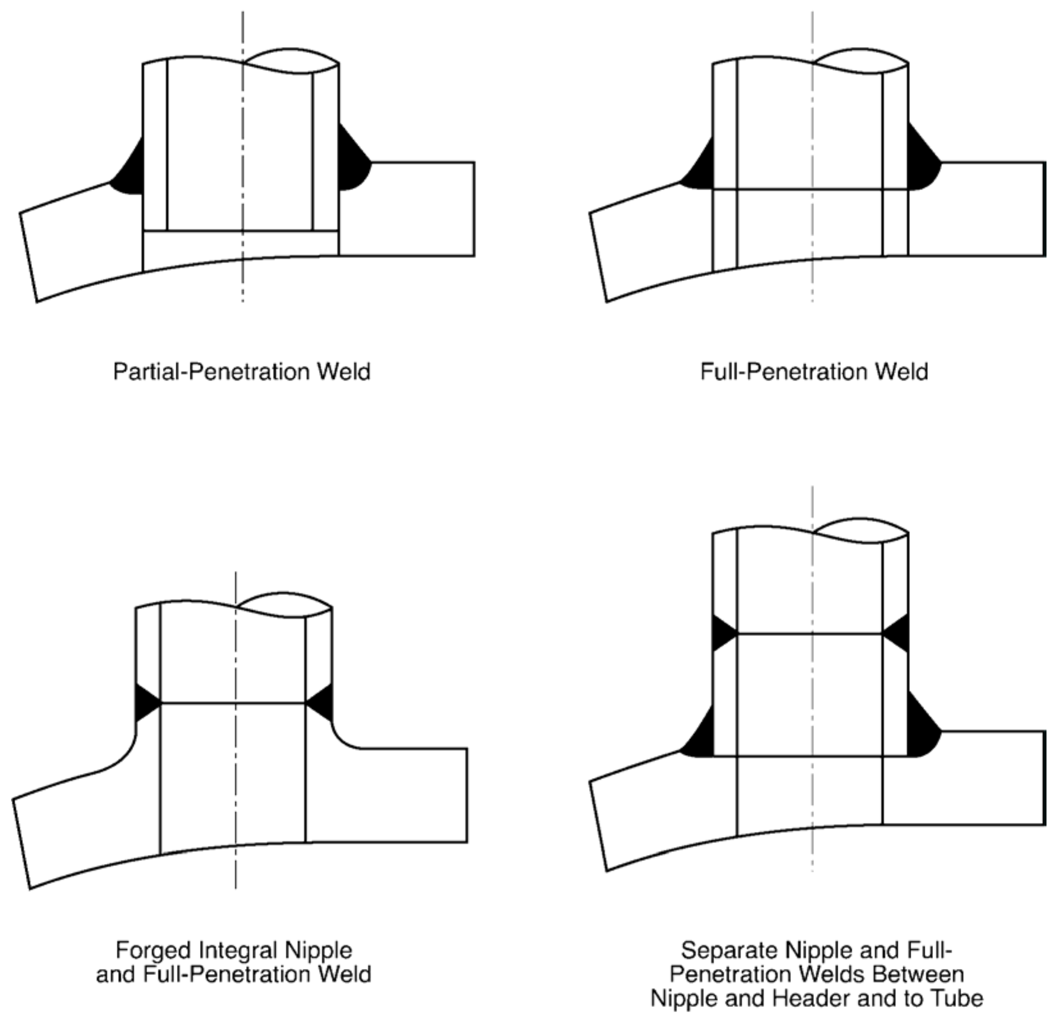

Figure 3-4
Example Heat Recovery Steam Generator Header Attachment Configurations

The EPRI methodology considers a more pragmatic approach to addressing HRSG header-to-tube damage than is currently used by industry. Repair vendors and OEMs currently address tube attachment damage from the outside of the header. This requires cutting past a number of tubes in a tube bundle, performing the weld repair from the outside of the tube (often requiring partial tube replacement), and re-welding all of the tubes that had to be cut to gain access to the header-to-tube damage. This approach is not only time consuming and costly but also often results in poor weld quality due to the welder's limited access. It also requires cutting multiple tubes that otherwise have no damage and re-welding these tubes once the damaged tube is repaired.

The EPRI approach sought to address the header-to-tube damage from the inside of the header. During 2004-05, a patented repair approach (U.S. Patent 6,596,957 B2) [4] was identified and equipment developed to address straight tube type repairs. The following approach builds upon this technology and is targeted for use with elbows (or bent tube) repairs associated with the header attachment region. This approach requires a number of steps as outlined in the following discussion

Repair Steps

1. Install *EDM Header Penetration Cutting Head* and remove "access plug."
2. Install *Saddle* onto header.
3. EDM through header and existing elbow weld attachment.
4. Install *Fin Tube Severance Cutting Machine* (new device) onto finned tube at desired position and perform severance.
5. Install *Fin Tube Retaining Device* (new device).
6. Using *EDM Header Penetration Cutting Head*, sever FAC damaged elbow from the header while holding the tube in place with the *Fin Tube Retaining Device*.
7. Remove FAC damaged elbow (bent tube).
8. Install *Prep Machine* to machine existing tube prep.
9. Insert "new" elbow (from inside header).
10. Tack the new elbow into place using C-Frame device.
11. Perform OD weld that secures new elbow to exiting finned tube.
12. Insert new stub tube through header to secure new elbow.
13. Perform New Elbow Weld-to-Stub Tube Weld.

14. Insert Header-To-Stub Tube Welding Device.

15. Perform Header-to-Stub Tube Welding (including root and fill passes).

16. Perform Inspection.

17. Complete closure weld.

18. Post weld heat treat all three welds (if required).

Each of these steps is explained in greater detail below. Before beginning the discussion however, it is worth noting that a total of four welds are required to accomplish the elbow (bent tube) replacement including:

1. Existing finned tube to elbow (this follows severing of old elbow and replacement with a new one). This weld is performed completely from the outside of the tube.

2. Attachment of a stub tube to the new elbow (from the tube ID).

3. Welding of the stub tube to the header (from the inside of the header).

4. Completion of the closure weld.

The 18 steps required for this bent tube (elbow) replacement will now be described.

Step 1: Install EDM Header Penetration Cutting Head and remove "access plug"

The first step in the repair process involves the use of the electro-discharge-machine (EDM) process to open an access hole in the header. Conventional machining could have been employed for this step, but investigators believed that EDM would minimize the machine shavings and introduce only minimal particulate (which, hopefully, could be trapped) into the overall machining process. The EDM process employed is sufficiently rapid to remove an access hole in under 20 minutes once the EDM tooling has been installed, thus the entire process can be accomplished in under 30 minutes.

Step 2: Install Saddle onto Header

A saddle attached is attached to the header at a location 180 degrees away from the damaged weld location to accommodate various tooling used in many of the following steps. The saddle shown in Figure 3-5 has been reconfigured somewhat from that identified in the earlier EPRI Report (1010441) that describes the repair approach utilized for straight tube to header connections. The purpose of this reconfiguration is to accommodate new EDM and modified header ID welding equipment (described later). Saddle attachment can be accomplished using either a chain-type approach or a belt-type arrangement.

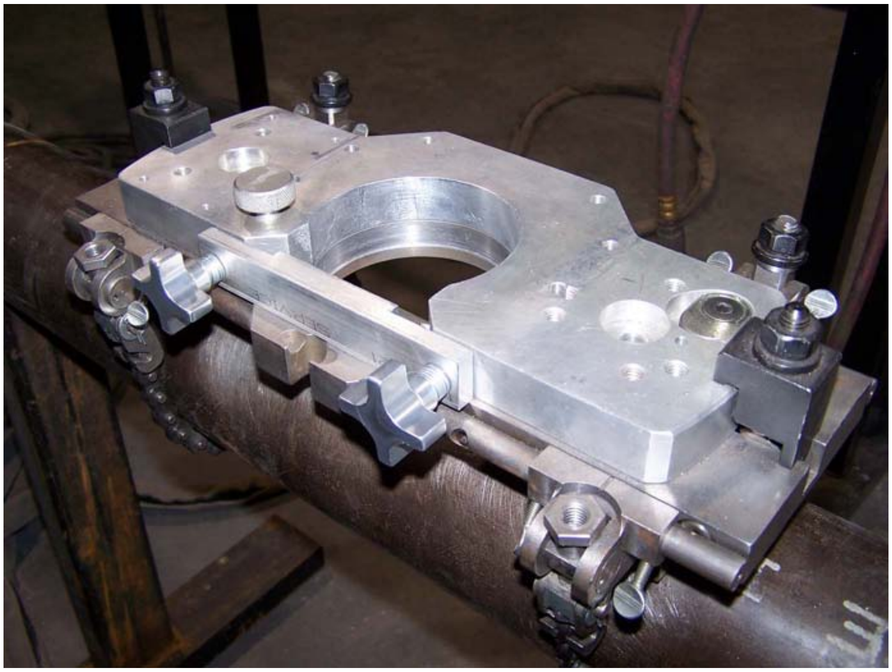

Figure 3-5
A Saddle is Attached to the HRSG Header to Accommodate Various Tooling Used in the HRSG Elbow Repair Process

Step 3: EDM through header and existing elbow weld attachment

In the previous approach used for removal of the damaged header to weld attachment region, a machining device was employed (Report 1010441). The machining approach generated a considerable amount of machining chips and concerns about leaving chips inside the header or in the tube were expressed. To eliminate this concern, the EDM head developed for Step 1 is utilized to also remove the header-to-existing weld attachment and is positioned 180 degrees from the access hole. This is accomplished using a smaller profile device than was used for the "access hole" in Step 1. The device is shown in Figure 3-6.

The device creates a penetration in the header that is slightly oversized (0.125 inches) over the original tube size. This facilitates insertion of a slightly oversized stub tube later in Step 12 and removal of the elbow through the header ID in Step 7.

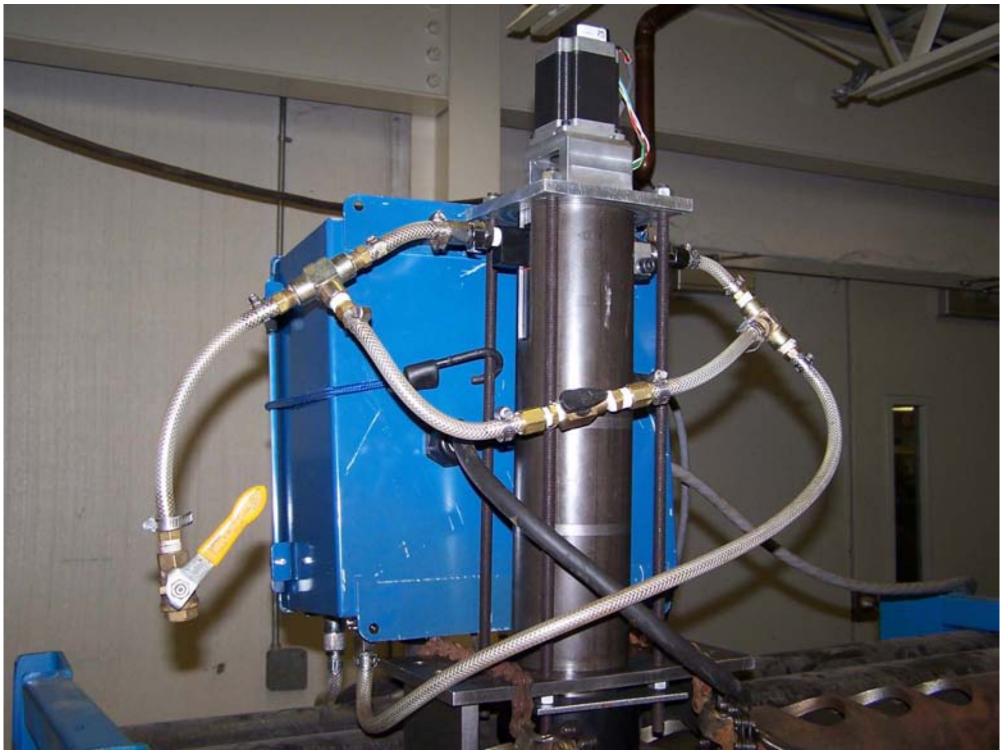

Figure 3-6
A Contoured EDM Profile Device is Used to Remove the Damaged Header-to-Existing Weld

Step 4: Install Fin Tube Severance Cutting Machine (new device) onto finned tube at desired position and perform severance.

One of the key steps in the curved tube (elbow) repair approach is to capture and sever (Step 6) the existing finned tube from the damaged elbow. This will be accomplished with a Finned Tube Severance Cutting Machine. The machine employs and an “extended arm reach” approach which utilizes a long arm to reach the damaged location and a cutting device which is mounted on to this arm. Figure 3-7 though 3-8 show this approach graphically. Figure 3-9 pictorially describes the low profile of the severance cutting machining from different vantage points.

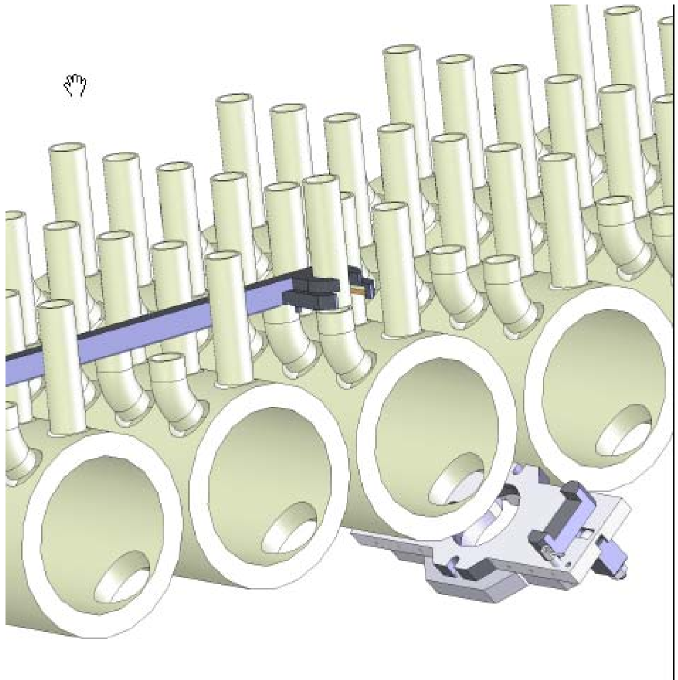

Figure 3-7
Finned Tube Severance Cutting Machine is Installed 180 degrees from Access Hole and Saddle

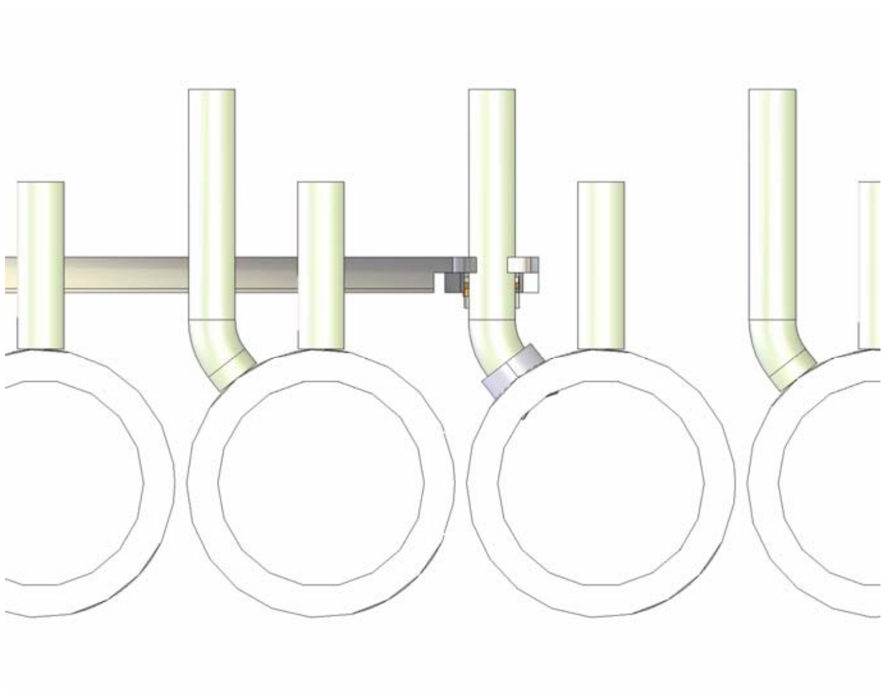

Figure 3-8
A Cross-Sectional View of the Fin Tube Severance Cutting Machine from the End of a Header Section.

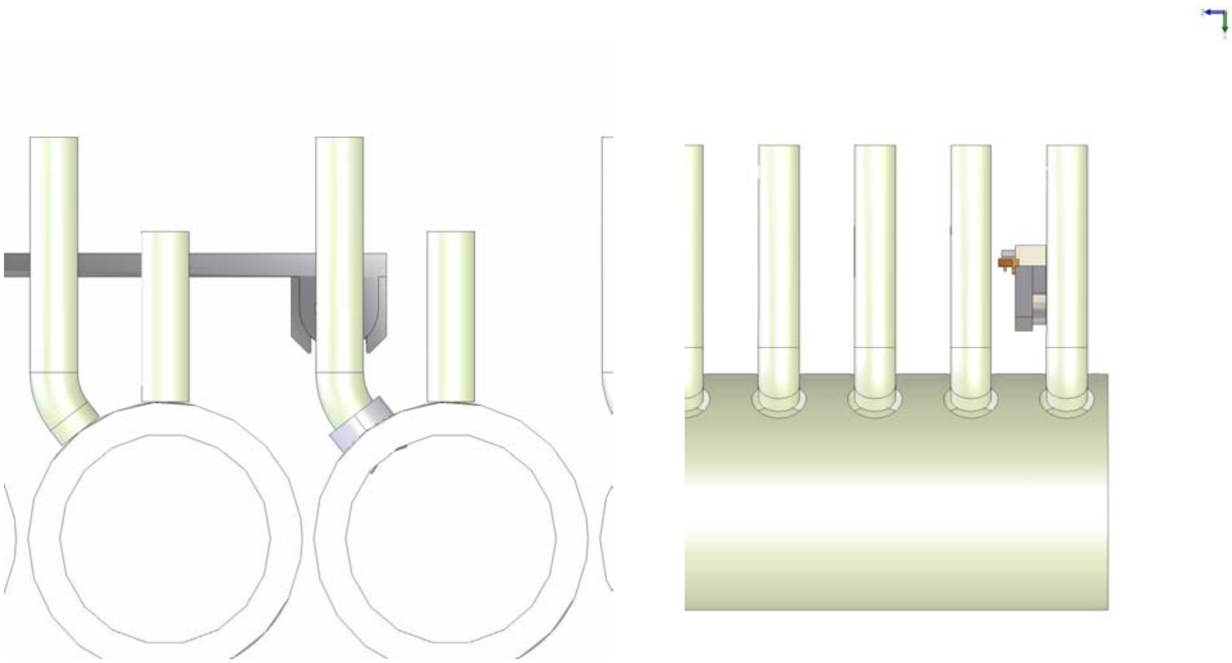

Figure 3-9
Views of the Fin Tube Severance Cutting Machine from the End of a Header and from the Side. Sketches show the machine can be rotated to reduce its operating envelope.

Step 5: Install Fin Tube Retaining Device (new device)

Once the tube-to-elbow sever has been made, some method of capturing the tube to assure that it doesn't spring aside is required. No work has been accomplished on this activity at this point in development. This is a 2007 task.

Step 6: Sever FAC Damaged Elbow Form Header

At this point, the fin tube retaining device has been installed to capture the tube once it is severed. A sever cut is made just above the elbow and below the tube fins to separate the elbow from the existing tubes. This is accomplished using a device similar to the one shown in Figure 3-10.

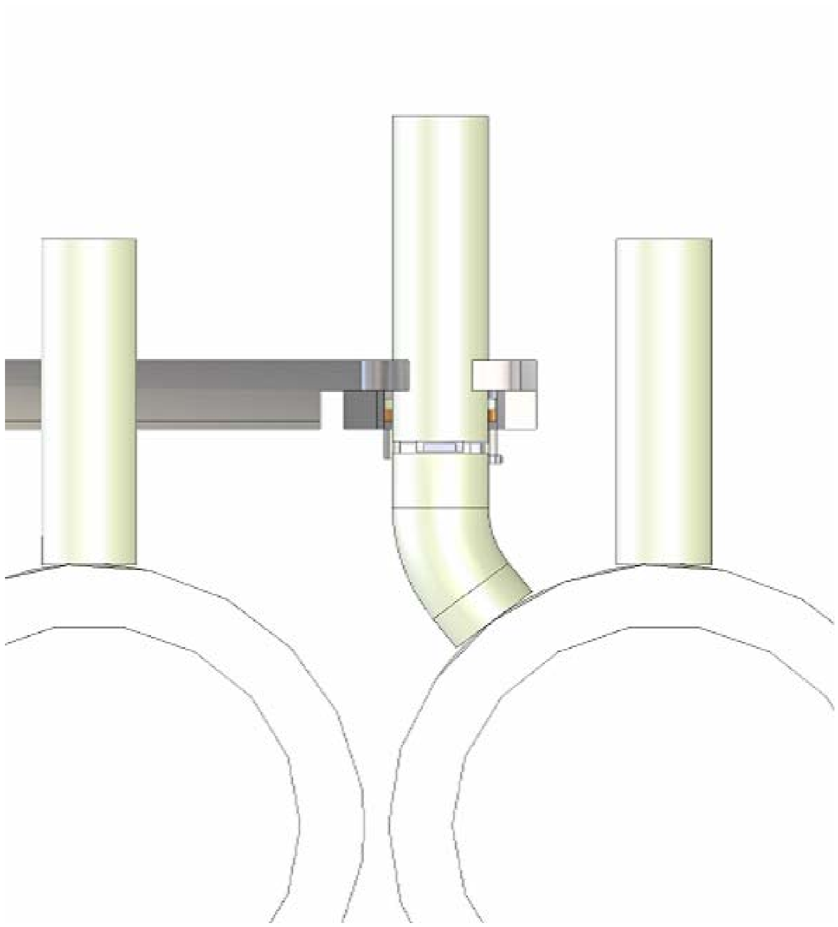

Figure 3-10
Tube Severance is Accomplished Using a Tube Severance Cutting Machine. This frees the elbow for removal.

Step 7: Remove FAC damaged elbow (bent tube)

In this step, the FAC damaged elbow is removed through the header ID. The process is shown graphically in Figure 3-11. Removal of the damaged elbow is facilitated by the slightly over-sized hole created during earlier steps to remove the original attachment weld and to provide room for the oversized stub tube.

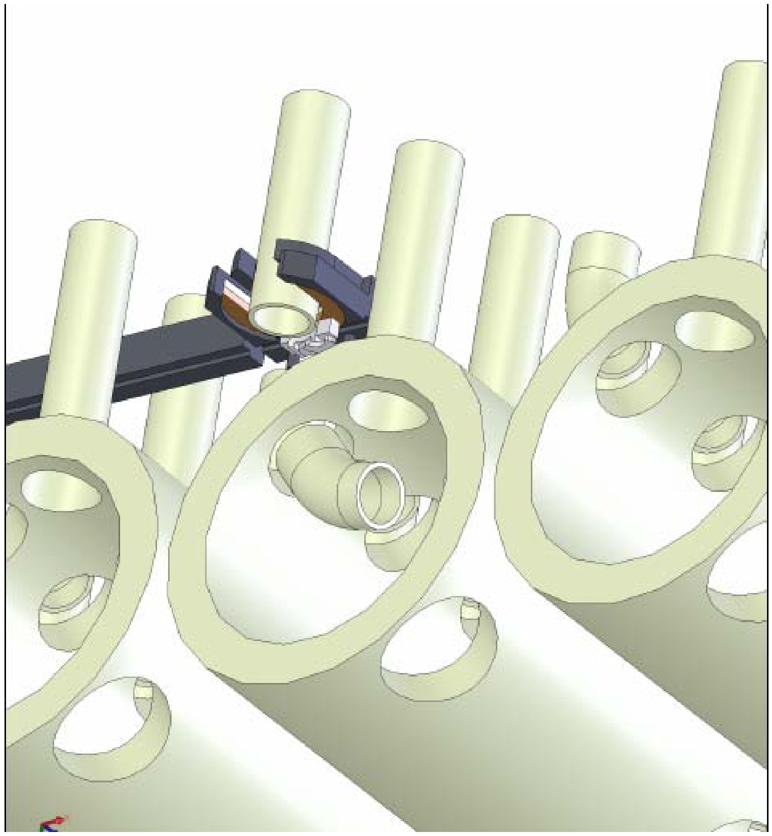

Figure 3-11
Removal of the FAC damaged elbow is now permitted.

Step 8: Install *Prep Machine* to machine existing tube prep

The next step in the repair process is to machine prepare the existing HRSG finned tube for welding. Machining is accomplished once again using the extended arm and C-frame apparatus along with a “form tool” attached to this device. Figure 3-12 shows a conceptual drawing of this approach.

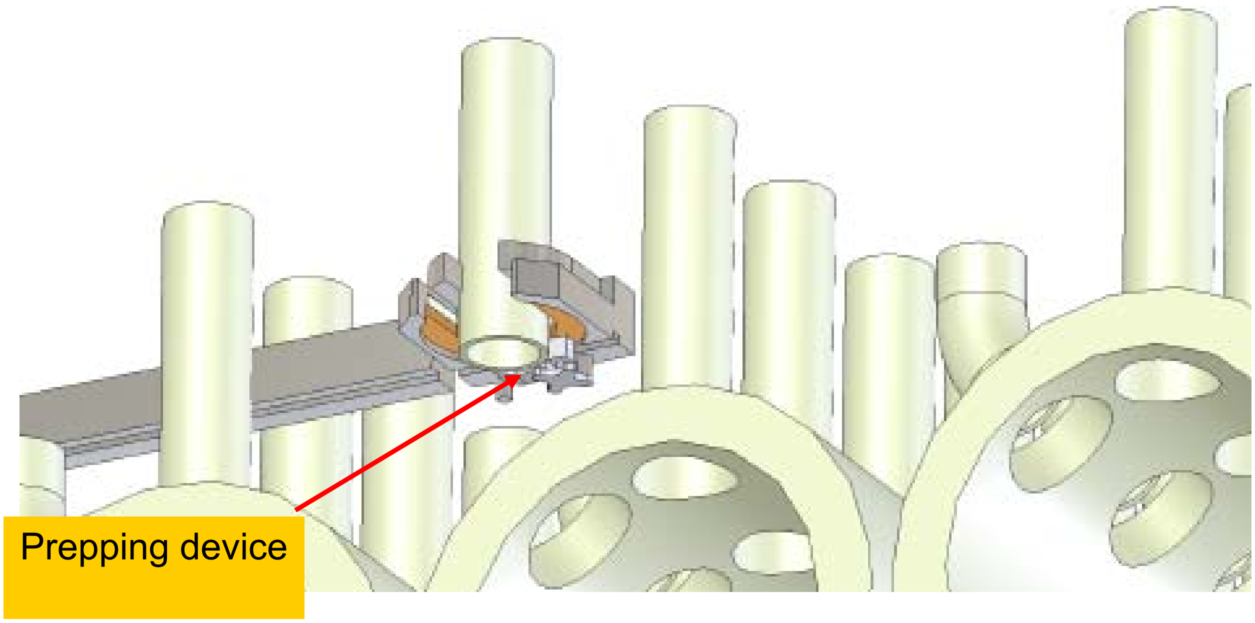

Figure 3-12
The end of the existing finned tube is machine prepared for welding.

Step 9: Insert "New" Elbow

Step 9 of the process involves insertion of a new replacement elbow. This is accomplished once again from the inside of the header. The tube can be inserted through the access hole and then through the "over-bored" hole wherein the stub tube will be inserted later in Step 12. Insertion of the new replacement elbow is shown in Figures 3-13 through 3-15.

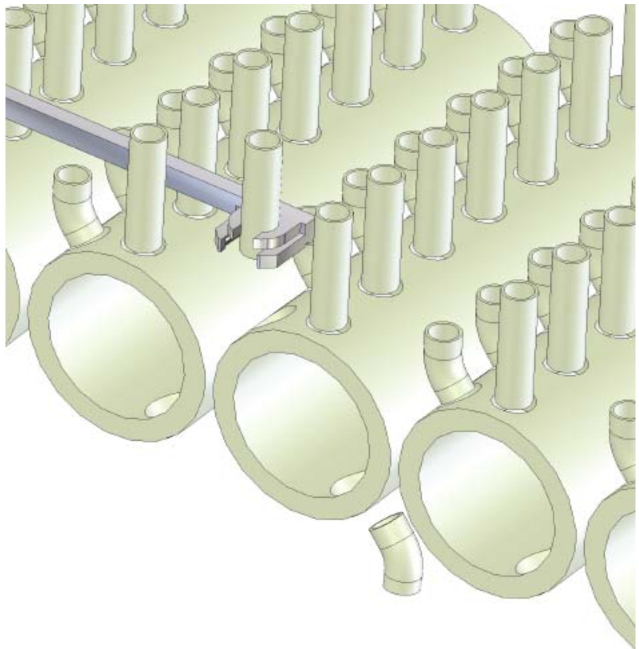

Figure 3-13
The replacement elbow is inserted through the header access window

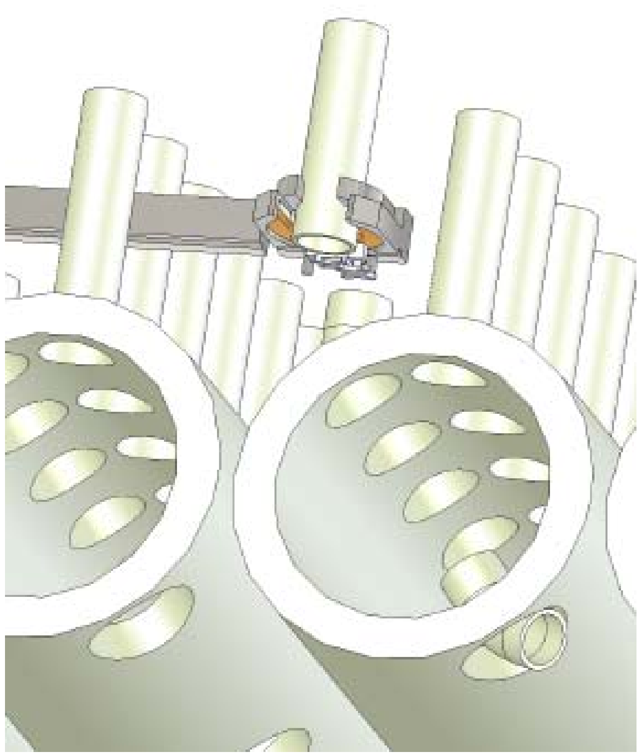

Figure 3-14
Another view of the replacement elbow being inserted in through the header access window

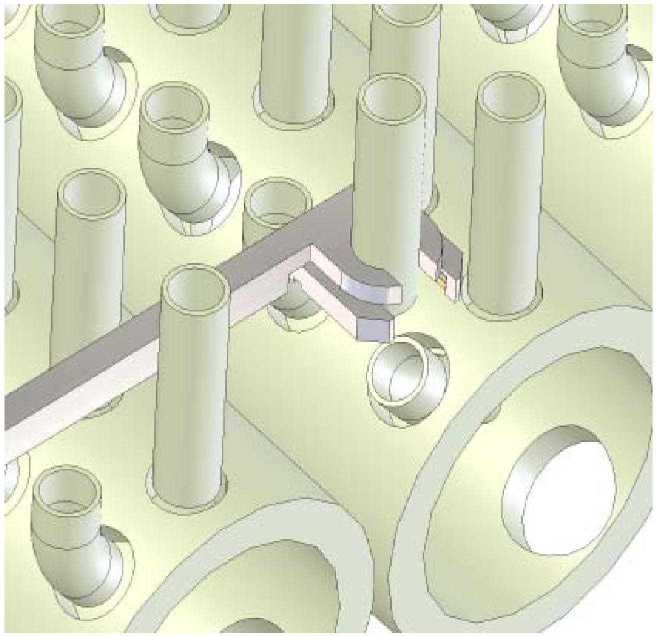

Figure 3-15
Continuing on from Figures 3-13 and 3-14, the replacement elbow is inserted through the "over-bored" hole where the stub tub will be inserted in Step 12.

Step 10: Tack The New Elbow Into Place Using C-Frame Device.

Once the elbow has been inserted into place, the elbow will be tacked into place using a new device that captures the existing tube and the new elbow as shown schematically in Figure 3-16. Several weld tacks will be made at specified locations around the tube thereby allowing it to be welded in Step 11. Note as before, that tacking process operates off of the extended arms reach approach.

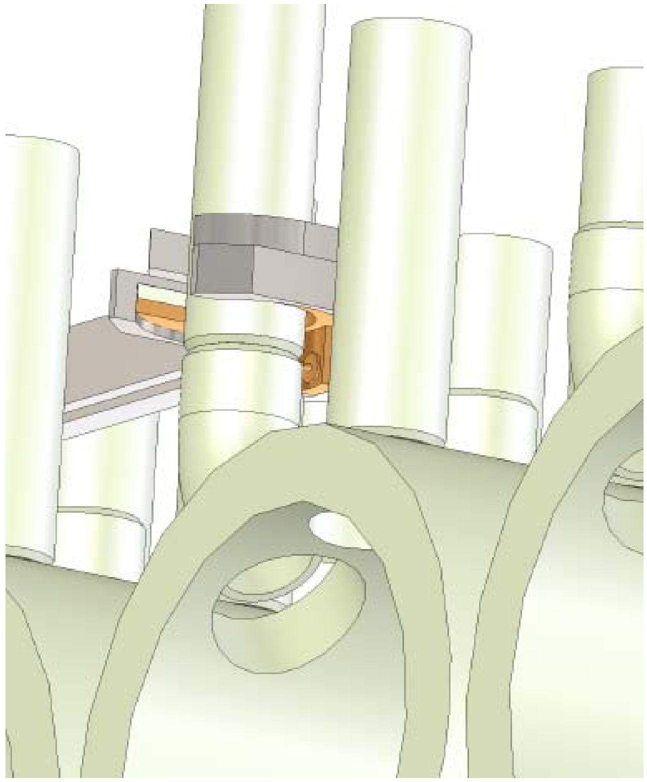

Figure 3-16
The new elbow is tacked into place.

Step 11: Perform OD Weld That Secures New Elbow To Exiting Finned Tube.

Step 11 involves completing the fin tube-to-elbow weld using a C-frame welding apparatus similar to that shown schematically in Figure 3-17. The C-frame welding concept was developed and patented by Encompass Machines for use on CANDU reactor tubing. EPRI staff believes the C-frame (extended arms reach) approach has huge potential for use in HRSG tubing repairs and for superheater/reheater tube repairs, sampling, and replacement.

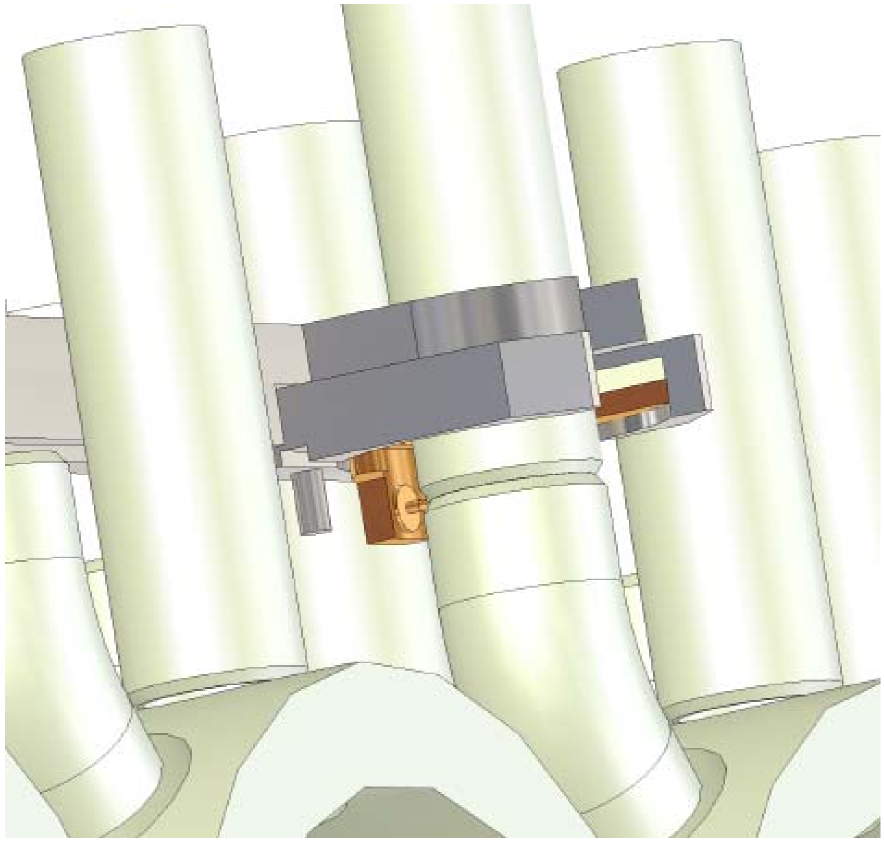

Figure 3-17
Schematic of the C-Frame Welding Device to Be Used For Completing Existing Tube to Elbow Welds.

The current equipment as shown in Figure 3-18 through 3-20 is being modified to address somewhat more confined spaces and smaller diameter tubing than was encountered for the CANDU tubing applications.

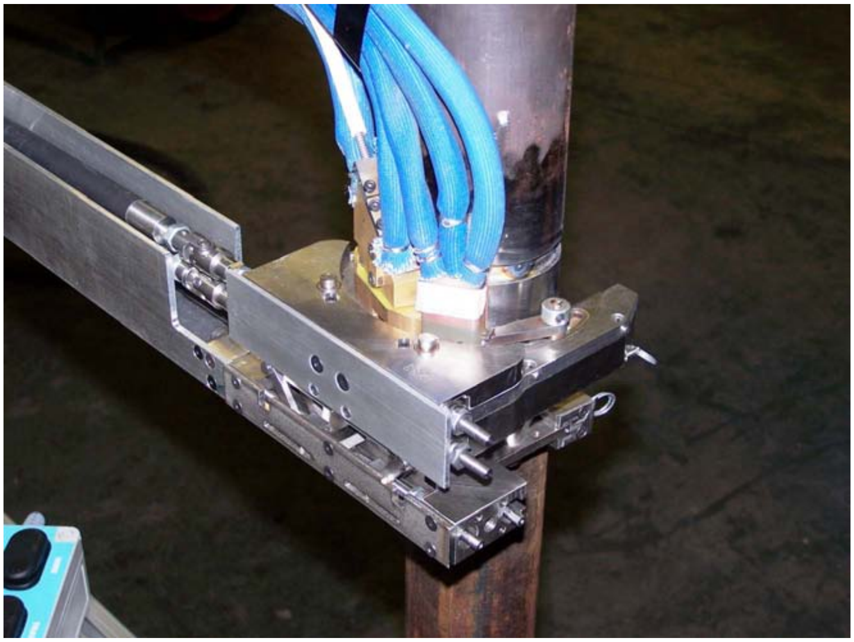

Figure 3-18
C-Frame welding approach used for CANDU reactor tubing.

Figure 3-19
Another view of the C-Frame welding approach used for CANDU reactor tubing.

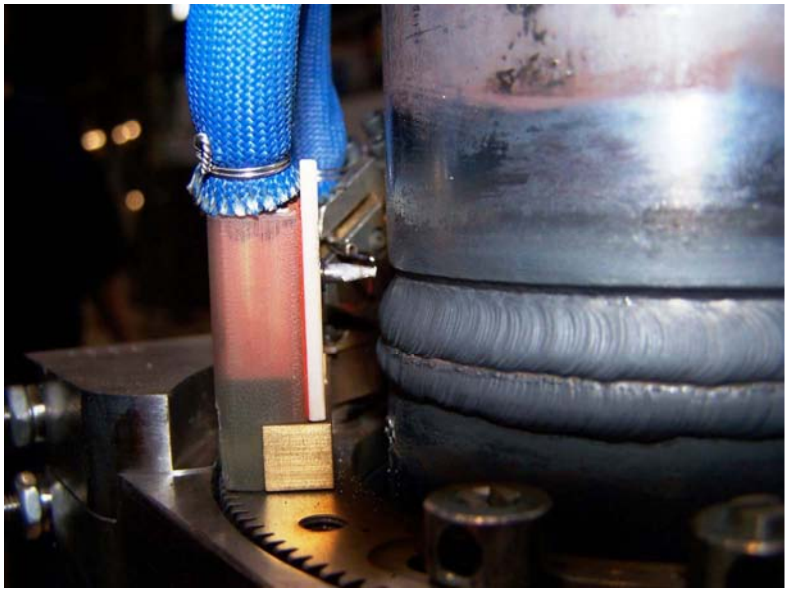

Figure 3-20
A third view of the C-Frame welding approach used for CANDU reactor tubing.

Step 12: Insert New Stub Tube Through Header to Secure New Elbow.

Step 12 involves insertion of the new, slightly larger, stub tube through the header (at the attachment location) until it is contacts and is slid over the new elbow section. The stub tube is designed with a recess (or female) receptor on the tube end which acts similar to a backing strip during welding that occurs in Step 13 (Figure 3-21 and 3-22). The stub tube is identical to that described in Report 1010441 for straight tube. Figure 3-23 shows the insertion of the stub tube, while Figure 3-24 shows the tube being inserted over the elbow.

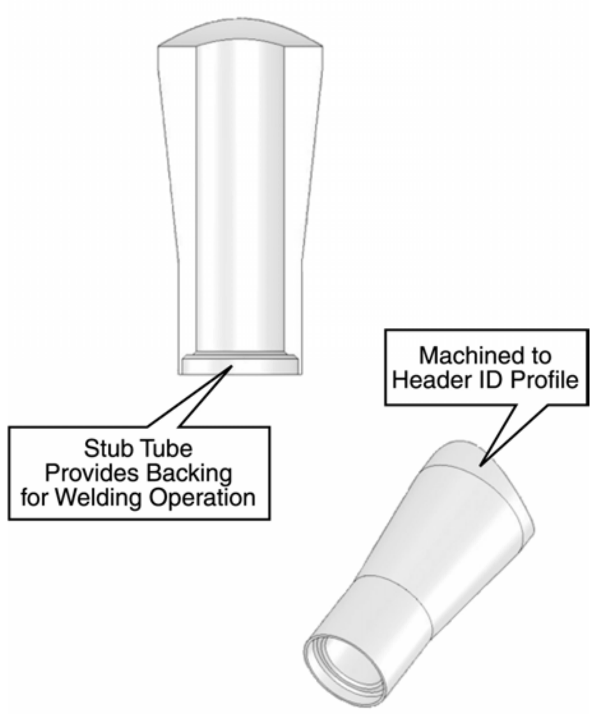

Figure 3-21
Schematic of the oversized tube.

Figure 3-22
Upper Profile of Tube Fabricated to Match Contour of Header ID

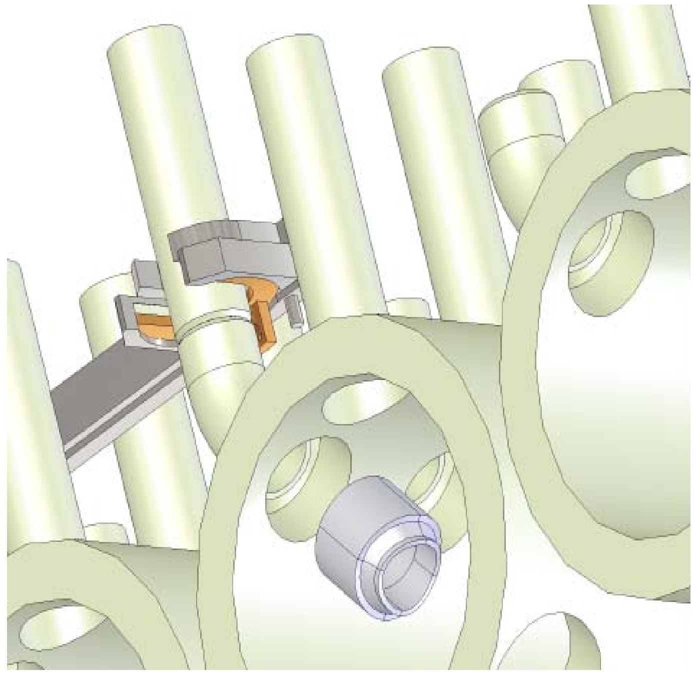

Figure 3-23
Insertion of the new oversized stub tube.

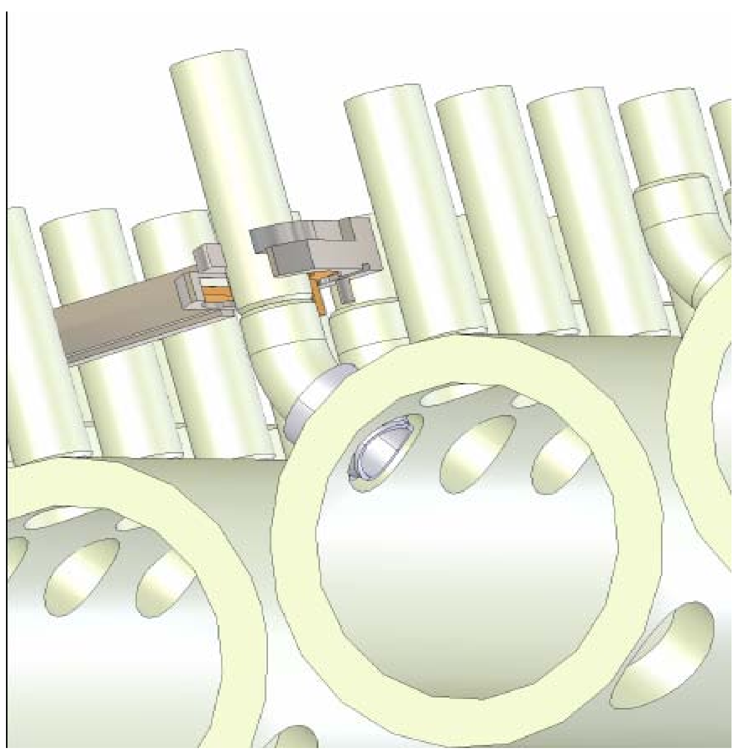

Figure 3-24
Completion of the stub tube insertion.

Step 13: Perform New Elbow Weld-to-Stub Tube Weld

The elbow-to-stub tube weld is accomplished using a new, more compact ID welding system compared with the one described in EPRI Report 1010441. The device can be used for either straight tube-to-tube welds or for elbow-to-stub tube welds. The device is shown schematically in Figures 3-25 and 3-26.

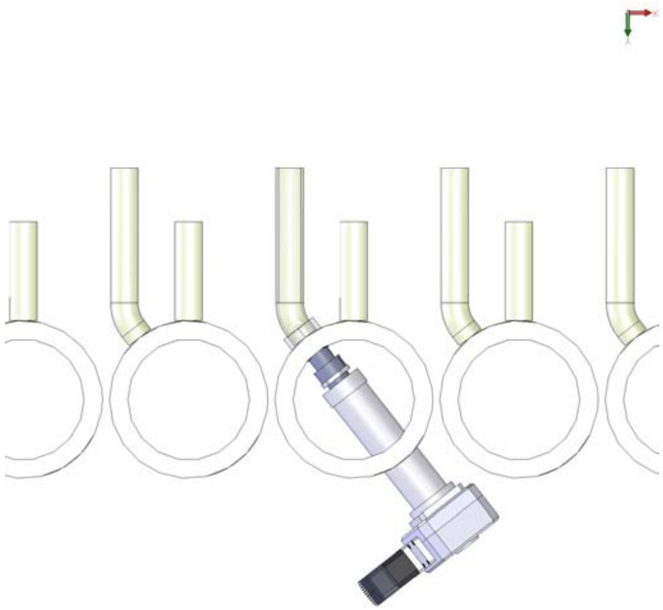

Figure 3-25
Schematic View of the Compact Elbow-To-Stub Tube Welding Device

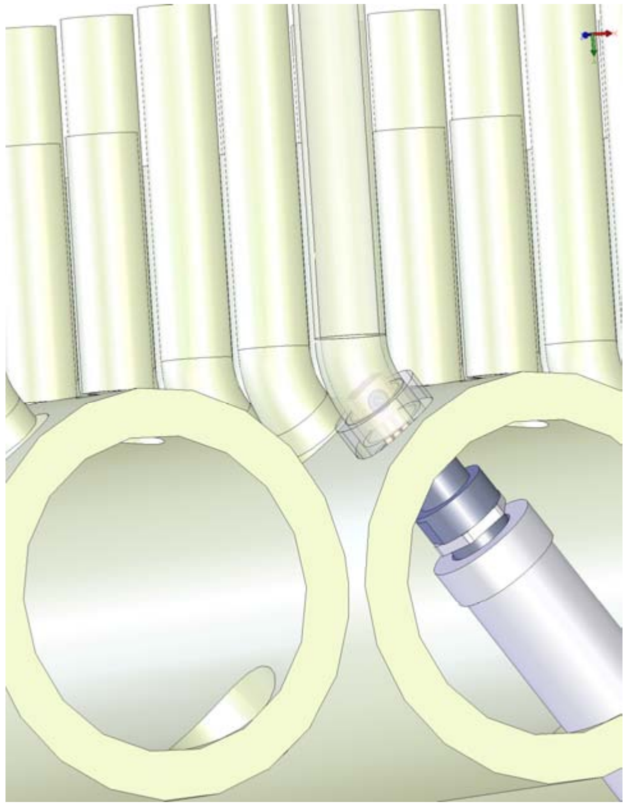

Figure 3-26
A closer view of the schematic shown in Figure 3-25

Two photographs of the actual ID welding device are shown in Figures 3-27 and 3-28. Figure 3-29 provides a cut-away view of a tube welded with the ID welding device. To date, >25 welds have been made with the ID welding device demonstrating its consistency.

Figure 3-27
ID Tube Welding Head

Figure 3-28
A closer view of ID Tube Welding Head shown in Figure 3-27

Figure 3-29
The ID Tube Weld Head Is Shown Inserted Into a Cut-away of a Tube (top) to Stub Tube (bottom) Mockup. Tube Diameter is 1-1/4 inches.

Step 14: Insert Header-To-Stub Tube Welding Device

At this point in the repair process, the new elbow has been inserted and joined to the existing tube. Additionally, the stub tube-to-elbow weld has been completed. The third and final welding step is to complete the stub tube-to-header weld which is shown schematically in Figure 3-30. This weld is performed in much the same way as that identified for straight tube welding. This particular step involves insertion of revised welding device that now includes a cam follower (discussed in Step 15) to improve welding consistency. A schematic of the welding device is provided in Figure 3-31.

Figure 3-30
Schematic Showing ID of Header with Stub Tube Inserted

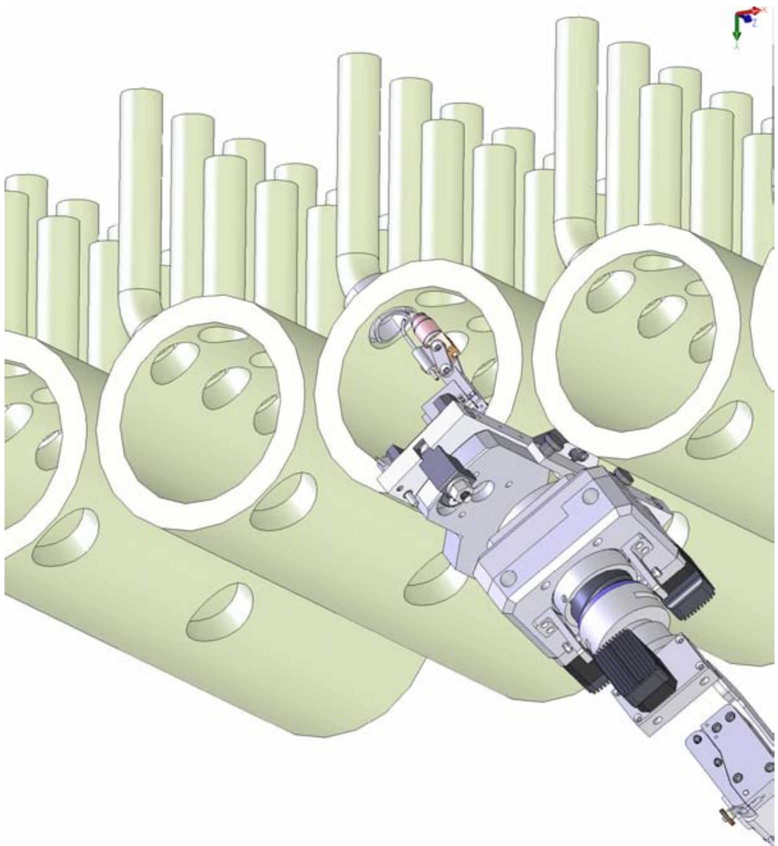

Figure 3-31
A schematic of the header-to-stub tube welding device inserted into a header. The actual welding device is shown in Figure 3-32.

Step 15: Perform Header-to-Stub Tube Welding (including root and fill passes)

The third welding step in the process utilizes the device shown schematically in Figure 3-31. The actual welding device is shown mounted onto a 4-inch diameter tube in the shop (Figure 3-32). The welding device is approximately 21 inches tall and mounts directly into the saddle fixture described earlier. The device employs a cam follower (Figure 3-33) to improve welding consistency and quality. It also minimizes welder error.

Figure 3-32
Header-to-stub tube welding device inserted into a header.

Figure 3-33
A cam follower is an integral part of the ID header welding device.

Step 16: Perform Inspection

Upon completion of the header weld root pass, the weld should be inspected visually. Additionally, upon completion of the entire weld, an ultrasonic inspection of the weld should be performed from the ID of the header to assure weld integrity and quality.

Step 17: Complete Closure Weld

Completion of the closure weld is the final weld of 4 welds required to replace a damaged elbow. This weld makes use of the plug that was removed via the EDM process in Step 1. The closure weld was discussed extensively in Report 1010441 for the straight tube entry design and thus is not described in detail here.

Step 18: Post Weld Heat Treat All Three Welds (If Required)

The last step in the process is to complete a post weld heat treatment of the 3 welds (existing tube-to-elbow, elbow-to-stub tube, and stub tube-to-header). Post weld heat treatment is required for low alloy steel headers/tubes, whereas it may or may not be required for carbon steel header/tubes. Owners are encouraged to involve a welding engineer in the repair process to assure quality and to make sure Code rules are followed.

4
SUMMARY AND CONCLUSIONS

- In 2005, both a repair approach and equipment were developed to address HRSG tube-to-header repairs. This approach eliminates the need to "cut your way in and weld your way out" by addressing the repair from the inside of the header (EPRI Report 1010441). The approach addressed repairs involving straight tube-to-header welds.

- Many tube-to-header failures involve flow accelerated corrosion in curved tubes (elbows) that are attached to the header at a short distance from the outside of the header. This report provides an update of the repair methodology being developed to perform the curved tube repair once again from the inside of the header. The process involves complete removal of the HRSG tube elbow from the inside of the header, insertion of a new elbow, welding of the elbow to existing tube from the outside of the tube using an extended arms reach welding device, elbow to stub tube welding from the ID of the header, welding attachment of the stub tube to the header, and finally a closure weld. This 18-step process and progress accomplished toward this goal during 2006 are described herein.

5
REFERENCES

1. *HRSG Material Selection and Repair Guidelines.* EPRI, Palo Alto, CA: 2004. 1004875.
2. *Repair Welding Technologies for Heat Recovery Steam Generators.* EPRI, Palo Alto, CA: 2005. 1010441.
3. *Delivering High Reliability Heat Recovery Steam Generators.* EPRI, Palo Alto, CA: 2003. 1004240.
4. U.S. Patent Office, Patent 6,596,957 B2, *Method and Apparatus and Prefabricated Replacement Tube for Localized Waterwall Repair*, July 22, 2003.

Export Control Restrictions

Access to and use of EPRI Intellectual Property is granted with the specific understanding and requirement that responsibility for ensuring full compliance with all applicable U.S. and foreign export laws and regulations is being undertaken by you and your company. This includes an obligation to ensure that any individual receiving access hereunder who is not a U.S. citizen or permanent U.S. resident is permitted access under applicable U.S. and foreign export laws and regulations. In the event you are uncertain whether you or your company may lawfully obtain access to this EPRI Intellectual Property, you acknowledge that it is your obligation to consult with your company's legal counsel to determine whether this access is lawful. Although EPRI may make available on a case-by-case basis an informal assessment of the applicable U.S. export classification for specific EPRI Intellectual Property, you and your company acknowledge that this assessment is solely for informational purposes and not for reliance purposes. You and your company acknowledge that it is still the obligation of you and your company to make your own assessment of the applicable U.S. export classification and ensure compliance accordingly. You and your company understand and acknowledge your obligations to make a prompt report to EPRI and the appropriate authorities regarding any access to or use of EPRI Intellectual Property hereunder that may be in violation of applicable U.S. or foreign export laws or regulations.

The Electric Power Research Institute (EPRI)

The Electric Power Research Institute (EPRI), with major locations in Palo Alto, California; Charlotte, North Carolina; and Knoxville, Tennessee, was established in 1973 as an independent, nonprofit center for public interest energy and environmental research. EPRI brings together members, participants, the Institute's scientists and engineers, and other leading experts to work collaboratively on solutions to the challenges of electric power. These solutions span nearly every area of electricity generation, delivery, and use, including health, safety, and environment. EPRI's members represent over 90% of the electricity generated in the United States. International participation represents nearly 15% of EPRI's total research, development, and demonstration program.

Together…Shaping the Future of Electricity

Printed on recycled paper in the United States of America

1012762

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com