Socket Weld Resolution Guideline

Technical Update

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Technical Update, February 2003

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Repair and Replacement Applications Center

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SUMMARY

Failures of small bore piping connections (2-inch and smaller) continue to occur frequently at nuclear and fossil power plants in the United States, resulting in degraded plant systems and unscheduled plant downtime. Fatigue-related failures are generally detected as small cracks or leaks but, in many cases, the leak locations are not isolable from the primary reactor coolant system, resulting in extended outages. Outages associated with fatigue failures have resulted in extended shut downs and lost revenue costs exceeding $300K per day. Consequently, improvements in socket weld installation methods and repair applications have become a prime target for plant cost reductions. In addition many utilities have modified or improved welder training and qualification procedures to include socket weld tests.

To reduce costs associated with these common failures of small bore piping and fittings, EPRI has conducted several studies to improve the understanding of fatigue failures, in small bore piping connections and reduce the costs associated with the failures. An early EPRI report (TR-104534) indicated that the majority of small bore piping connections (up to 80%) are caused by high cycle vibration fatigue of socket welds. These failures are often accelerated by poor weld quality at the weld root or toe of the fillet weld. Analytical results reported in EPRI TR-107455 have demonstrated that the socket weld profile can have an important effect on its high cycle fatigue resistance. Weld profiles with longer legs along the pipe side of the weld greatly increasing its predicted fatigue resistance. Other potentially important factors influencing fatigue life include residual stress, weld root and toe condition, pipe size, axial and radial gaps, and materials of construction. Solutions to the failures can be a combination of vibration control (i.e. dampening devices), improved weld quality and design criteria for replacement applications. In addition, in-situ weld overlay repairs reported in EPRI TE-1003287, have been shown to provide extended life allowing replacement of the leaking connection to be scheduled during a routine outage with little or no impact on power production.

The objective of this program is to document Case Histories of socket weld failures and repair applications concurrent with EPRI test data stated above. This progress report give a brief description of weld repair alternatives under investigation and is part of an ongoing survey, which will continue to pull together and distribute information regarding the repair of high cycle fatigue failures and the performance of the repairs. The survey currently contains 40 case histories of socket weld failures submitted by 18 utility sites. The preliminary Case Histories will be updated as further information becomes available. The information will validate repair options and assist with future failure analyses and repair decisions.

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1
INTRODUCTION

Failures of small bore piping connections (2-inch and smaller) due to high cycle fatigue (HCF) continue to occur frequently at nuclear and fossil power plants in the United States, resulting in degraded plant systems and unscheduled plant downtime. Fatigue-related failures are generally detected as small cracks or leaks but, in many cases, the leak locations are not isolable from the primary reactor coolant system, resulting in extended outages. Outages associated with fatigue failures have resulted in extended shut downs and lost revenue costs exceeding $300K per day. Consequently, improvements in socket weld installation methods and repair applications have become a prime target for plant cost reductions. In addition many utilities have modified or improved welder training and qualification procedures to include socket weld tests.

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The objective of this program is to document Case Histories of Socket Weld failures to assist with future failure analyses and repair decisions. This is an ongoing program which will continue to pull together and distribute information regarding high cycle fatigue failures of small diameter pipe connections. Section 2 will review socket weld installation and repair options. Section 3 will document Socket Weld Failure and Repair Case Histories.

2 SOCKET WELD REPAIR/MODIFICATION REVIEW

Various high cycle fatigue tests have been completed under the EPRI Repair Replacement Application Center and the PWR Material Reliability Program to determine the effects of weld profile variations on the fatigue strength of socket welds. As a result, utilities have incorporated modifications of the standard “Code Socket Weld” to address high cycle fatigue failures. This section will review the basic socket weld modifications and test results and will include utility best practices for common socket weld applications.

Standard Code Weld Profile

In the past, socket welded connections were typically welded with a standard 1x1 leg length fillet weld with a leg length meeting ASME Code minimum requirements. The ASME Code minimum leg length must equal or exceed 1.09 times the pipe nominal thickness (Figure 2-1). In most cases the weld leg length of the final weld is in excess of the minimal dimensions required. In addition the Code requires a minimum 1/16-in. axial gap. The gap is usually set by bottoming out the pipe or tube into the fitting and scribing a line around the pipe using the face of the fitting as a guide. The pipe is withdrawn from the fitting approximately 1/16-in. and tack welded. Inspection of the fit up (gap) is required prior to welding out the connection.

Most socket weld high cycle fatigue failures reported have been of the 1x1 leg length configuration, meeting the minimum Code requirements. To establish a baseline for comparing the fatigue resistance of recommended repair practices, EPRI has conducted a number of HCF tests on the standard 1x1 weld profile (TR-113890).

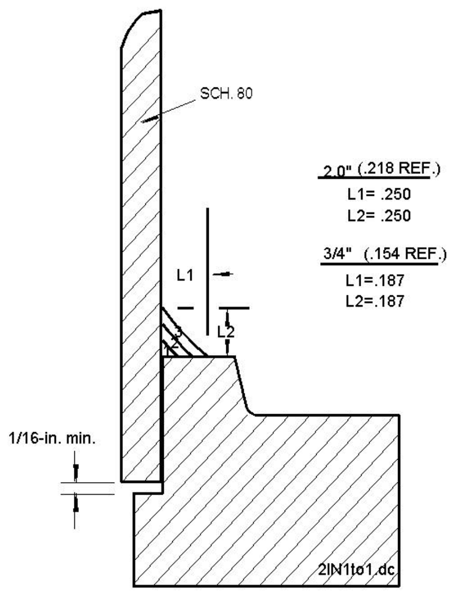

Figure 2-1. Standard Code Fillet Weld Profile for Socket Welded Connections

Best Practices

Best practices identified for 1x1 socket welded connections are generic to most socket weld repair configuration. A few of the best practices include:

Multiple passes welding (two-pass minimum) is typically required by most utilities for all socket weld applications. Although, connections with a thinner pipe wall thickness (i.e. less than .100-in.) or a diameter less than 1.0-in. are often completed with a single pass. Single pass welds are typically restricted to the GTAW process.

GTAW is the preferred welding process for all socket weld connections. The GTAW process is typically required for stainless steel connections and for socket welds with a diameter less than 1-in. The decision on welding process is often based on accessibility, welder preference and past failures.

An inert gas purge or backing is typically not required for socket weld applications, although purging is commonly recommended for stainless steel and Ni-alloys when the thickness is less than 0.113-in. (EPRI Report, SV-113422). Thickness limitations for purging vary significantly between utilities. The thickness limitations are often based on mockup testing, material condition (new or in service pipe) welding process and welder experience. If a purge is utilized, flow rates and oxygen content should conform to the WPS specifications. If utilized, the gas purge should be maintained until the second weld layer is completely deposited.

It has become more common for welders to be subjected to additional weld training and socket weld tests, in addition to the standard weld tests, prior to welding at a plant. Emphasis is placed on assuring socket welds are deposited with an adequate penetration into the base metal at the root of the weld, and the weld profile maintains a flat to convex geometry, while maintaining the minimum required weld leg lengths. The weld should be free of cracks and craters at the weld terminations. Undercut should be limited to 1/32-in. at the toe. If the as-welded condition is not acceptable, weld cleanup (i.e. grinding, polishing) should be closely monitored, especially at the toe of the weld. Excessive or inadvertent grinding marks at or near the toe of the fillet weld have been documented as causing premature failures under high cycle vibration conditions.

Uneven leg weld

The use of even leg lengths on socket weld installation is commonly practiced at susceptible locations (high vibration) where past failures have been documented. EPRI Report TR-113890, showed evidence that the 2x1 weld configuration has an improved fatigue life when compared directly to the standard 1x1 Code weld profile. The improved resistance to vibrational fatigue is based on the increased weld cross sectional area and the reduced moment at the toe of the weld (pipe side). The extended weld leg practice meets all Code minimum requirements while extending the weld leg length on the pipe or tube side, by a factor of two (Figure 2-2).

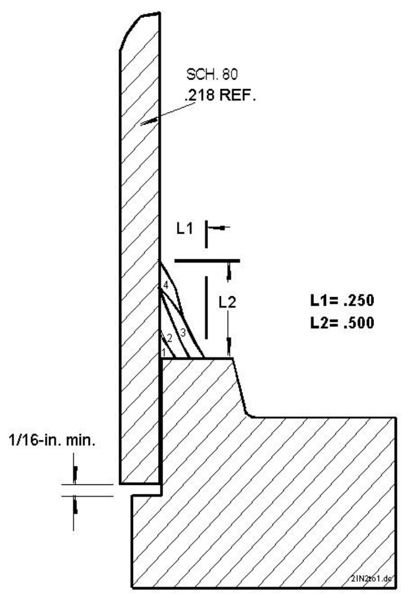

Figure 2-2. 2x1 Weld Profile for Socket Welded Connections

Best Practices

The use of uneven leg welds or welds in excess of the code minimum length have been utilized for many years both intentionally and unintentionally. In the past, these welds typically did not meet the 2x1 weld profile, currently recommended, but were greater than 1x1 leg ratio. The uneven leg length weld profile while in excess of the Code-required minimum, does not exceed or violate Code requirements. Most utilities consider the practice of installing the uneven leg profile (2x1) as an enhancement and do not consider the practice to be a system modification or design change. Currently the 2x1 leg profile has been used by utilities in areas that are deemed susceptible to high cycle fatigue or at locations that have had repeat failures. The practice has not been implemented generically or systemwide.

Most utilities are planning to or have used the 2x1 leg profile for new socket weld installations and as a replacement weld after HCF failures.

Weld Profile Enhancement (1x1 to 2x1)

Preemptive weld build up of 1x1 weld profiles have been installed at locations deemed susceptible to high cycle vibration fatigue. The weld profile enhancement has a cross sectional area similar to the standard 2x1 weld profile. Weld bead sequence varies from the newly installed 2x1 configuration since the existing weld is not removed prior to extending the weld length on the pipe side (Figure 2-3). The weld alteration or enhancement maintains all Code minimum requirements.

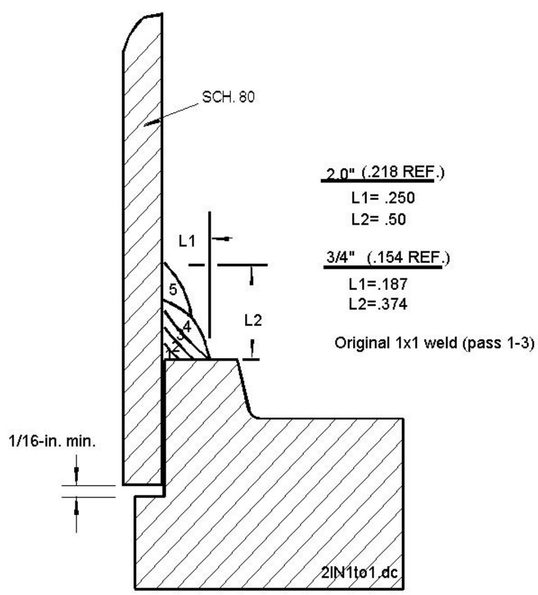

Figure 2-3. Code Minimum Socket Weld Profile enhanced to at 2x1 Weld Profile.

Best Practices

Weld profile enhancement has not been incorporated systemwide, although has been implemented at location susceptible to repeat failures, unisolatable lines and at problematic areas that have been identified with poor weld quality.

Polished toe

The practice of blend-grinding, filing or polishing the socket weld was initially thought to improve the resistance to fatigue failures. The practice implemented by some utilities in the past has consisted of blend grinding the toe on the pipe side to techniques which completely polishing the entire surface of the weld deposit. Blend-grinding produces a smooth transition from the weld to the pipe, reducing any notch effect, similar to undercut.

EPRI fatigue testing results (TR-113890) have shown that polishing the toe of the weld has the potential of reducing the fatigue life. Three out of four standard code welds (1x1 weld profile) failed prematurely compared to welds remaining in the as-welded condition. The practice of preparing (grinding or polishing) the surface of the socket weld, no matter what the weld profile, has been discontinued unless required due to poor weld quality (i.e. porosity).

Best Practices

Test results have revealed that small gouges, scratches and undercut at the toe of the socket weld, on the pipe side, can significantly reduce or alter the fatigue life of socket welded connections. The practice of polishing the toe of the weld has been utilized for preferentially inducing toe cracks in current EPRI fatigue tests.

If the as-welded condition is not acceptable weld cleanup (i.e. grinding, polishing) should be closely monitored, especially at the toe of the weld. Grinding defects should be repaired prior to returning to service.

Overlay Repair

Overlay repairs were introduced as a means of repairing leaking socket welds in-situ. The initial EPRI test results indicated that a leaking socket weld repaired with a weld overlay would replace or improve the original life of the standard Code socket weld (EPRI TR-113890). As a result a Code Case has been established to allow the use of overlay weld repairs for Class 2 and 3 Connections (EPRI Report, TE 1003165).

The design of the overlay considers that the fatigue crack in the original socket weld could have originated from the root or toe or from both locations simultaneously. The overlay provides reinforcement at all locations equivalent to the original fillet weld throat. Fillet weld size is specified by leg length, therefore the throat of the reinforcement is 0.71 times the specified minimum fillet leg size. For welds made in accordance with ASME Section III, socket weld leg size for a fitting must be a minimum of 1.09 times the nominal wall thickness of the connecting pipe. Assuming an equal leg fillet weld, the throat dimension is 0.71 times the leg size or 0.77 times the nominal wall of the connecting pipe.. Therefore, the minimum reinforcement at all locations from the face of the socket weld, including both weld toes, is 0.77 t_n. The minimum dimensions are shown in Figure 2-4.

Only socket welded fittings were tested in this program, but it should be noted that various codes specify different weld sizes. For example, for socket welding flanges made in accordance with ASME Section III, socket weld leg size must be a minimum of 1.4 times the nominal wall thickness of the connecting pipe. Therefore, for a socket welded flange, the minimum reinforcement at all locations from the face of the socket weld, including both weld toes, is 0.98 $t_{n.}$ It is recommended that the final surface of the overlay be left in the as-welded condition.

A leaking socket weld must be seal welded before applying the reinforcement. The dimensions of the reinforcement must be measured from the surface of the seal weld rather than from the face of the original socket weld. This ensures that the minimum throat dimension is measured from a crack-free surface.

An ASME Section XI Code Case (Code Case N-666) has been developed based on the testing program and is being reviewed by the various Section XI groups and subcommittees. The Case permits overlay repair of leaking carbon and stainless steel socket welds to be performed in a pressurized line while the plant is operating.

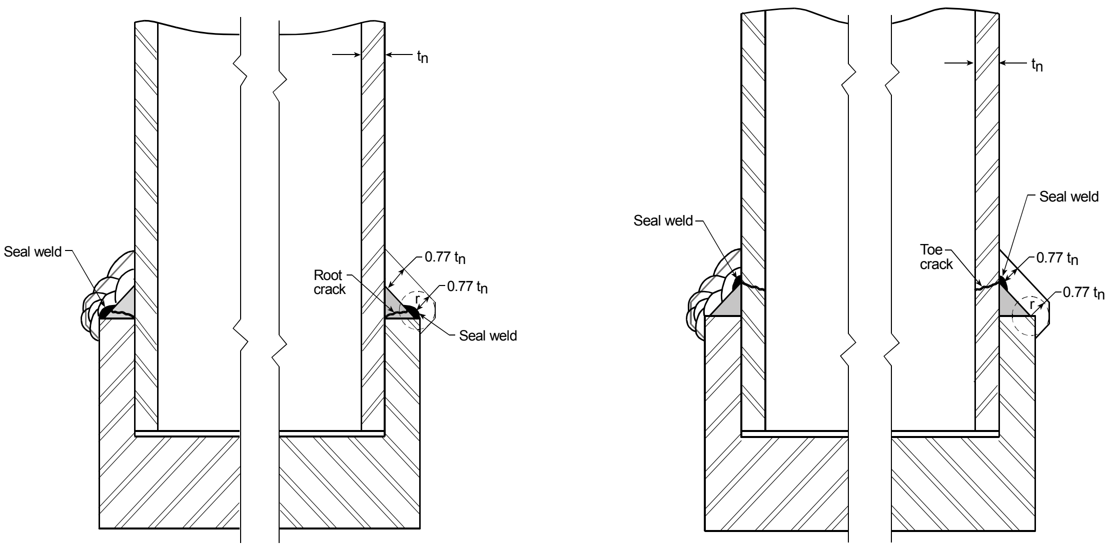

Figure 2-4. Socket Weld Reinforcement Dimensions for root cracks and toe cracks. **Note: The right side of each figure shows the design dimensions while the left side shows the as-welded appearance.**

Last Pass Improved (LPI)

The LPI weld configuration utilizes a standard 1x1 code weld configuration with an additional pass placed at the toe of the weld on the pipe side. This additional weld typically increases the leg length on the pipe side but does not meet the requirements for a 2x1 recommended weld profile. The actual weld leg ratio is typically less than 1.5 x 1 (Figure 2-6). Unlike the test results of the 2x1 welds, the LPI did not consistently promote greater fatigue life. The LPI weld profile has not been utilized for socket weld repairs and is currently not recommended as an enhancement to the 1x1 weld profile.

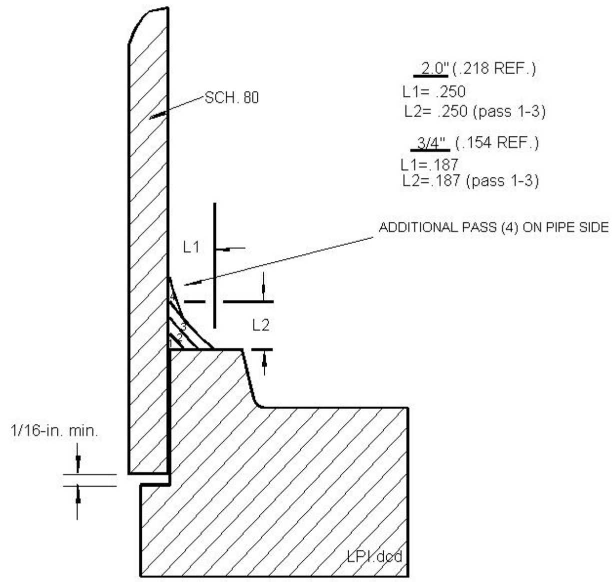

Figure 2-6. Last Pass Improved Weld Profile for Socket Welded Connections

PWHT

Post weld heat treatment (PWHT) in most cases is not practical or recommended for carbon and stainless steel socket weld repair applications. EPRI evaluation of PWHT to improve HCF of socket welded connections has indicated that the benefits of PWHT may result in detrimental side effects. The location of HCF failures may be altered from the more typical root location to the toe of the weld on the pipe side. PWHT neutralizes the stresses in the weld location, which are initially in compression at the toe and in tension at the root. As a result, the beneficial compressive stresses at the toe location are eliminate, allowing crack formation at the toe to be more prevalent.

3 SOCKET WELD REPAIR CASE HISTORIES

An EPRI-RRAC questionnaire identified that a number of utilities have utilized various socket weld repair modifications or enhancements that have been evaluated in past HCF testing. Although the most prominent weld profile enhancement utilized is the 2x1 uneven weld leg profile, other weld enhancements including polished weld surfaces, full penetration welds and overlay repairs (temporary of non-safety related connections) have been implemented. A few of these repairs have been documented in Table 3-1. These case histories will be used to monitor the outcome of the socket weld repairs and to establish an improved understanding of high cycle vibrational fatigue failures and their repair. The Case histories will be updated periodically when additional information becomes available.

The case histories include the following criteria when available:

- Type of repair or modification (date, location, material)
- Temporary or permanent repair/modifications considered temporary or permanent.
- Failure analyses of the initial failure.
- Follow up actions specific to the repair/modification (if any).
  - Inspection schedule/results
  - Repeat failures/repairs

Table 3-1 Case Histories of Small bore Piping Failures

Owner	Date	Location	Down time	Material	Cause of Failure	Repair Method	Results of Repair
A	July 1999	Drain line in an unisolatable portion of Feedwater System	Plant shut down for 7 days	2-in. Schedule 80	HCF and root defect.	Replaced with 2x1 weld geometry (5/16 x 5/8-in. weld profile	
A	1992	½-in bypass line on the Recir/RWCU isolation valve body	Several Days of Production	½-in		Non-Code temporary repair with NRC approval	
A	Dec., 2000	Reactor Feed pump turbine steam chest	Not Reported	Not Reported	Not Reported	Overlay repair	Not Reported
A	June, 2000	Extraction Steam System	Loss of 3 days production	10-in. butt welded line	Not Reported	HCF	Not Reported
B	September, 1997	Valve body reducer to pipe connection in the B recirculation pump discharge valve bonnet vent line	Plant shutdown	Not Reported	HCF	Not Reported	Not Reported
B	Not Reported	Not Reported	Not Reported	Not Reported	HCF	2x1	Treated as a modification
B	Since 1992	Eight through wall cracks on reactor recirculation system	Not Reported	1 and ¾-in NPS, 7 failures on stainless steel and 1 on carbon steel	One case low cycle fatigue, remainder HCF.	Prior to 1997, replaced with 1x1. Recent LCF and HCF failures both repaired with 2x1 weld profiles. Support modifications, natural frequency modification	No failures reported of 2x1 weld repairs or modifications.
C	Not Reported	Socket weld failure	Not Reported	Not Reported	HCF	2x1	Not Proceduralized
D	March, 2000	The first socket welded elbow in a ¾-in. leak test line off the 10-in. accumulator injection line. (ASME Section III, Class	Located during scheduled outage	¾-in. schedule 160, 300 series SS	Root Failure, HCF	Replaced with a 2x1 weld profile and tie-back designed to mitagate vibration. Other welds	Not Reported

		2 line).	outage	series SS		in line were also modified to a 2x1 weld profile.	
D	March, 2000	½-in. instrumentation line between valves	Located during scheduled outage	½-in.	Not determined	Replaced section of tubing.	Not Reported
D	September, 1998	½-in. leak off line to isolation valve connection. Spent Fuel Pool HX Return Isolation Valve.	System remained operable during repair.	½-in.	Not determined	Weld defect ground out and rewelded.	Not Reported
E.		Used in susceptible areas and HCF susceptible areas		Socket welds		2x1 fillet including blend grind or polished toe.	Not Reported
E.	July, 1994	Reactor coolant system loop 3 and 4 intermediate drain valves	Plant shut down for repairs	Socket weld	Weld defects (porosity)	Freeze seal and weld repaired. Additional inspections of similar valves and socket welds were completed. No additional problems located.	Not Reported
F.	May, 1997	¾-in. vent line off the Recirculation System Flow Control Valve. 4-in line between the Globe Vent Valve and the FC valve.	Cost estimate $1.18M	¾-in. SA-312, Type 316L pipe. SA-182, F316 SS globe valve. ER 316L stainless steel filler material.	HCF accelerated by weld defects. The weld was field installed in the overhead position, with a lot of grinding plus LOF at root.	4-in. spool replacement with a 2x1 socket weld on both ends.	No Cracking observed in the replacement to date.
G.	July, 2000	Nonisolable socket connection on a flange in the control bleed-off line from the Primary Coolant Pump (PCP) seal	Not Reported	Not Reported	HCF, incorrect piping support at the failure location	Not Reported	Not Reported

H.	Dec., 2000	Through wall crack at elbow location in the charging pump discharge line. Failure located in containment, nearest to the charging inlet nozzle of the Regenerative heat exchanger.	2 ½ days at reduced power level	2-in. Schedule 160 pipe and 6000# fitting, Type 316 SS	HCF	2x1 weld profile, modified restraints to adequately reduce vibration level.	Additional inspections recommended, nothing reported
H.	Not Reported	Not Reported	Not Reported	Not Reported	HCF	2x1 socket weld, contour weld profile, remove all sharp edges and polish entire weld joint	Not Reported
H.	Not Reported	Not Reported	Not Reported	Not Reported	HCF	Cracked removed and rewelded.	Not Reported
I.	Dec., 1998	Main Feed Pump Suction Line Vent, Suction Vent Valve (B31.1)	Not reported	¾-in. NPS 600# Globe Valve, carbon steel	HCF	Unisolatable, Overlay weld repair to get to next outage. Crack remained. Overlay and failed weld were removed after 12 months and replaced with a 2x1 weld profile. No system modifications to reduce vibration.	No repeat failure, Overlay remained for 12 months. 2x1 replacement has not been inspected since installation
I.	Nov. 15, 2000	Thermal Relief line for letdown heat exchanger. Crack at elbow connection attached to thermal relief valve. ASME Class 3)	Not Reported	Not Reported	SCC, Socket weld was installed with excessive cold spring.	Candidate for overlay but not used (ASME Class 3 line). Replaced with a 1x1 weld profile	Not Reported

J.	April 30, 2001	Residual Heat Removal (RHR) Loop Suction Valve Leak off line.	Not Reported	½-in. schedule 160	HCF	Repaired by removing from RCS pressure (reconfigured valve packing) Recommendations, Additional pipe/tube supports, 2x1 weld size and inspection.	Not Reported
J.	November, 2001	1-in. drain line, upstream of ‘B’ MSIV	Plant shut down for repairs	1-in.	Not Reported	Unknown repair scenario.	Not Reported
K.	November 1999	RHR system piping 21.3-mm pipe (OD)	Total outage 8 weeks, 4 weeks due to safety authority position.	Not Reported	Not Reported	Unknown repair scenario. Total outage 8 weeks, 4 weeks due to safety authority position.	Not Reported
L.	Not Reported	Boiler level control line failure. Pipe to weldolet off a 16-in. inlet header.	$250K lost revenue per day. $20K per inspection, plus repair costs.	2-in. Carbon Steel, Schedule 40	Failed at weld toe. Failure due to high vibration and thermal fatigue (adjoined by a SS pipe)	Piping system modified in two of four units. Candidate for 2x1	Inspection required for every shut down until system modified ($20K per inspection).
L.	Not Reported	Piping at reciprocating pumps in the fueling machine facility	$250K per day for unit shutdown	Stainless Steel, 1-in. and ¾-in. schedule 160 and 80.	Weld toe crack at socket weld due to high line vibration down stream of pump	Not Reported	Not Reported
L.	Not Reported	Instrumentation Line off main steam pipe at valve socket to pipe weldolet (2 locations).	App. $50K	¾-in. schedule 40 carbon steel	Weld toe and weld root crack in two separate valves	Failure due to unsupported valves	Cost app. 50K for engineering and repair.

		pipe weldolet (2 locations).		carbon steel	High line vibration	Occurred during pre-startup activities of shut down plant.	repair.
M.	Sept. 1999	EHC	Unit down 24 hours	3/8-in. Tubing	HCF	Not Reported	Not Reported
M.	Oct. 1999	EHC	Isolatable, No loss of power	1-in pipe	HCF	Not Reported	Not Reported
M.	Jan. 2000	EHC	Isolatable, No loss of power	1-in pipe	HCF	Not Reported	Not Reported
N.	Oct. 2000	Socket weld in MS supply to Aux. Steam desuperheater. SW connection between a reducer and control valve.	Not Reported	2 ¼ Cr – 1Mo, 2-in. NPS x ½-in wall pipe to 2-in. control valve	360-degree failure at fusion line (root to toe) on valve side of connection.	Failure due to poor weld procedures (i.e. no preheat, LOF, no penetration) and 0-gap	Not reported
O.	Dec. 2002	Pipe to nozzle socket weld in a pressure sensing line in the reactor 'A' recirculation loop. Nozzle was attached to a 28-in. recirc. Pipe with a full pen. weld.	Not Reported	1-in. NPS schedule 80 to nozzle, SA-403 Grade 316L and SA-182, Grade 316L.	Root initiated HCF failure, with cold spring during installation.	Repaired with a 2x1 weld. Nozzle not replaced. Tie back supports added.	Repeat failure after 12 days
O.	Dec. 2002	Repeat failure from same month	Not Reported	1-in. NPS schedule 80 to nozzle, SA-403 Grade 316L and SA-182, Grade 316L.	HCF failure, toe crack	Repaired with a 2x1 weld. Modifications to tie-back supports and monitoring equipment suggested. Reduce cold spring.	Not reported
O.	Dec. 2002	Two T type socket connection in the 'B' recirculation loop sensing line.	Not Reported	Not Reported	HCF failure	Tie-back supports were added to both 'A' and 'B' lines.	Not reported

O.	November, 1997	High pressure instrument line for the "B' loop recirculation pump venturi flow element.	Plant shut down for repair	Not Reported	HCF accelerated by weld defects	Socket weld replaced with standard 1x1 weld profile.	Repeat failure in 1999
O.	March, 1999	Repeat failure from November 1997.	Plant shut down for repair (2 days)	Not Reported	HCF accelerated by weld defects	Pipe section, elbows, tee replaced with new material. Repaired with a 2x1 weld profile.	Not reported
P.	Feb. 2003	Not Reported	Not Reported	Not Reported	HCF failure	Repaired with 2x1 weld profile.	Not Reported
P.	April, 1997	Safe end to pipe weld on high pressure injection and makeup line.	Plant shut down for repair	2.5-in.	HC Thermal Fatigue	Not Reported	Not Reported
Q.	December, 1995	Flow instrument sensing line on the 'C' reactor coolant loop and 'C' reactor coolant pump seal injection drain line.	Plant shut down for repair	Not Reported	HCF	Socket welds were cut out and replaced with full penetration butt welds. All 16 RCS flow transmitter sensing lines and all 4 RCP seal injection line drains were removed and capped.	Not Reported
Q.	September, 1994	Flow instrument sensing line on the 'C' reactor coolant loop.	Plant shut down for repair	¾-in. socket weld	Weld defect	Not Reported	Not Reported
Q.	May, 1992	Flow instrument sensing line on the 'D' reactor coolant loop	Plant shut down for repair	¾-in. socket weld	HCF accelerated by weld defect.	Sensing line was modified and replaced.	Not Reported
R.	May, 1999	Three socket weld failures in the motor driven auxiliary feewater pump recirculation lines on the A and B loops	Not reported	Not Reported	HCF	Not Reported	Not Reported
S.	April, 1998	Crack in a 1-in branch line to the recirculation line high point vent and a 2-in. recirculation line.	Not Reported	Tee joint with a 2-in. butt weld by 2-in. butt weld by 1-in.	HCF accelerated by weld defect at the root (LOF).	Not Reported	Not Reported

				butt weld. Material 300 series SS and ER308 filler metal.			
T.		Instrument line of the Recirculation System	Failure located during refueling outage	Socket weld connection	HCF	Not Reported	Not Reported

4 DISCUSSION AND RECOMMENDATIONS

The database of case histories will promote an improved understanding of socket weld failure modes and will assist with future failure analyses and repair decisions. Additional Case Histories and a follow up on past repairs will be continued in 2003.

Observations of the initial Case histories includes:

- The primary weld profile enhancement utilized by the utilities has been the 2x1 weld profile.
- Only one repeat failure has been documented of a 2x1 weld repair, which was a result of inaccurate monitoring of vibration at the weld location, resulting in improper vibration dampening in the failure location.
- Weld quality (i.e. root penetration, grinding) is a significant contribution to high cycle fatigue failures and needs to be addressed by welder training and testing.

About EPRI

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