ATTACHMENT 2

Consumers Power Company
Palisades Plant
Docket 50-255

CHECK VALVE LEAK ROOT CAUSE, ENGINEERING ANALYSIS AND REPAIR REPLACEMENT OPTIONS

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Nuclear Safety-Related

Check Valve Leak
Root Cause, Engineering Analysis
and Repair/Replacement Options

Prepared for
Palisades Nuclear Station

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Sargent & Lundy

Prepared by: J. T. Louden Date 3-5-94
J. T. Louden

Reviewed by: J. W. [illegible] For R.J. Kerhin Date 3-5-94
R. J. Kerhin

Approved by: Gary W. DeBoo Date 3/5/94
G. W. DeBoo

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PALISADES STATION

CHECK VALVE LEAK

ROOT CAUSE, ENGINEERING ANALYSIS, AND REPAIR/REPLACEMENT OPTIONS

I. INTRODUCTION

A leak identified in a check valve located in the auxiliary building west safeguards room has resulted in a Notification of Unusual Event (NUE) being declared Thursday, February 17, 1994, and the plant subsequently shutdown.

The objectives of this report are:

- To establish the root cause of the leak
- To provide an engineering evaluation of various repair/replacement options including associated supporting analysis.

II. BACKGROUND

A 24-inch check valve located between the containment sump and the HPSI, LPSI, and Containment Spray pumps was identified during walkdown by plant personnel as having an accumulation of boron crystals at the 12 o'clock position.

The area of boron crystal accumulation was cleaned, a visual and a Liquid Penetrant examination (PT) was performed to ascertain the presence and extent of a potential leak path. Two indications in the valve base metal were discovered (one rounded, one linear) indicating a potential leak path.

To further investigate, the line was drained and a Radiographic examination (RT) of the area was performed.

The radiograph revealed a linear indication approximately 3/4 inch long, oriented transverse from the circumferential weld and lining up (in plan view) with the two indications identified earlier by PT. In addition, two more linear indications were identified approximately 2 1/2 inches from the previous indication, oriented parallel to one another and also transverse from the circumferential weld. Radiographic examination of the remainder of the weld circumference was performed with no new indications being detected.

Surface replication to facilitate examination of the metallurgical structure of the area was performed and upon examination, weld repair sites in the valve casting were identified and later confirmed by acid etch.

An Ultrasonic examination (UT) of the valve casting in the same area revealed an indication oriented circumferentially and corresponding to RT location marker 61 1/4, through 0 (circumference approximately 78 inches), to 2 (approximately 19 inches). A second Ultrasonic examination of the remainder of the circumference was performed. This examination on February 23, 1994 identified five additional indications. Due to ultrasonic examination limitations of cast stainless steel and the indication locations in the valve transition, the depth and through wall positions were not determined. The attached Figure 1 shows a sketch locating all indications found. Two of the indications were axial to the toe of the weld. One was at location 18" and one at 32.75" from top dead center. Neither has a length or depth given but appear to be less than 1/2" in axial length. Three of the indications were oriented circumferentially. The first is located at 37" and is approximately 1 3/8" long, the second is located at 44 1/2" and is approximately 2 1/8" long. The third is located at 47 3/8" and is approximately 2 1/4" long. None of these has a depth or through wall component given nor is the axial distance from the weld given, but they appear to be within 1" from the toe of the weld axially.

III. CHECK VALVE INFORMATION AND HISTORY

The 24" check valve unique identification is CK-ES3166, and is identified on P&ID M204, Sh. 1A and Stress Iso. 03319 Sh. 4 (M107, Sh. 2281-1).

The line number is HC-3-24", conforming to Bechtel Piping, Class HC. The valve rating is 150#, and the valve body is an austenitic stainless steel casting specified to meet the requirements of A-351 Grade CF-8M (Type 316).

The valve was made in 1962 by Chapman (later bought by Crane Valve Co.) and sold to CPCo by Crane Valve Co. for Palisades. The valve was installed during plant construction however, the valve was cut out in 1969 due to leaking during testing and sent back to the vendor (Crane) for repairs. Once completed, the valve was returned to the plant and welded back into the piping system. Through replication and etching, multiple weld repairs to the casting were identified. One weld repair site was discovered adjacent to the 3/4" axial indication. The extent of repairs performed is indeterminate at this time. As such, CPCo has contacted the vendor (Crane) for any records that may be available to aid in the determination of the root cause. No records were available.

IV. METALLURGICAL ASSESSMENT

Similar instances of stainless steel piping leaks in stagnant borated water lines were summarized in NRC Bulletin 79-17. Licensees concluded that the problem was intergranular stress corrosion cracking (IGSCC) due to a sensitized heat-affected-zone (HAZ), residual welding stress and chloride (plus oxygen) contamination of the borated water.

The situation at Palisades Plant is different. First, the chemical analyses of this water shows that the chlorides and fluorides combined total only 54 ppb. Secondly, metallurgical examination of replicas taken at the surface in the leak area showed an intergranular attack that did not follow a continuous path as any crack would, but rather a random grain boundary dissolution. This microstructure was typical of intergranular corrosion (IGC). IGC is a selective form of corrosion that attacks the grain boundaries with the majority of the grain unaffected. It can affect certain alloys (e.g., several of the austenitic stainless steels) that are highly resistant to general and localized attack. These alloys are made susceptible to IGC by sensitization.[1]

A third factor was that a photograph of the leak area was taken prior to polishing for replication because of an unusual depression (a few mils in depth) that followed the shape and location of the radiographic indication. This indicated that the top surface has sunk slightly. We postulated that the material below the surface had been subject to corrosion of the base metal in the defect area. Finally, it should be noted that the casting had a measured ferrite of about 9%. This level of ferrite has been reported to be highly resistant to IGSCC.

The history of this stainless steel valve shows that it was re-welded in the system after being cut out and weld repaired by the vendor. The leak area is immediately adjacent to the circumferential weld and a weld repair (discovered by acid etching the area). Consequently, the leakage area has been sensitized from three known welds. Replica examination revealed carbide precipitation primarily in the grain boundary typical of sensitization. Chemical analysis showed the carbon content was .09%, which exceeds the .08% max. specified. The higher carbon content makes this casting more susceptible to sensitization.

[1]Metal Handbook, 9th Edition, Volume 13,"Corrosion", P. 324.

V. CONCLUSIONS

Metallurgical examination of replicas concluded that the microstructure at the surface of the valve in the leak area showed considerable carbide precipitation at the grain boundaries, i.e. sensitization. Historical records combined with acid etching to find weld repairs, indicate that the leak area was in the heat-affected zone of at least two and probably three welds. A high carbon content contributed to sensitization. An ID defect such as shrinkage or a slight hot tear would concentrate the boric acid in the crevice. Based on the above findings, it is concluded that the root cause of the leakage was an intergranular corrosion due to a severe sensitization, and the probability of a boric acid concentration at the initiation site (ie crevice).

VI. OPTIONS FOR CORRECTIVE ACTIONS:

1. Use as is with injected leak sealant:

Prepare a relief request with technical justification for continued operation as allowed by 10CFR50.55 a(g)(6)(i). The technical justification must ensure the capability to shutdown the reactor and maintain it in a safe shutdown condition and to ensure the capability to prevent or mitigate the consequences of accidents that could result in potential offsite consequences comparable to the 10CFR Part 100 guidelines.

To provide this assurance, a flaw evaluation, CMED-058597, was performed to demonstrate the structural integrity of the check valve. This evaluation assessed the potential for flaw growth and plastic collapse during seismic events. To assess the potential for flaw growth, the operating environment of the check valve must be examined. The operating environment of the check valve does not subject it to any significant cyclic loading. It is subject to the SIRW tank head pressure, a very low weight bending stress of 1129 psi and no thermal loading during normal plant operation. A review of LERs for borated water systems did not indicate that this system is affected by degradation mechanisms such as thermal stratification or erosion/corrosion. The check valve is a cast A-351 grade CF8M material usually at room temperature and therefore is not subject to embrittlement from thermal aging. Based on these operating conditions, the potential for flaw growth is minimal for this check valve.

To assess the ability of the system and this check valve to perform its specific safety function, a flaw stability evaluation during normal and emergency/faulted operating conditions was performed, CMED-058597. This evaluation considered the effects of SSE and post LOCA thermal loading on the flaw using a limit load approach as described in ASME Section XI appendix C, and the NRC's proposed Standard Review Plan 3.6.3, Leak Before Break Procedures, September 1989. This evaluation reviewed the impact of a circumferential versus axial through wall flaw and evaluated the circumferential orientation. The circumferential orientation was chosen because the SSE bending moments would contribute to mode I tearing. The weight, thermal and seismic loads would not influence crack growth in the axial orientation. A through wall circumferential flaw of 20" was evaluated.

The evaluation included required code Safety Factors of 2.77 for normal operating load and 1.39 for emergency/faulted conditions. Because the flaw is located in the HAZ of the valve body butt weld, the Z factor for a submerged arc weld was used. The Z factor is a correction used to predict elastic-plastic behavior of the material. Using the Z factor for Submerged Arc Welding (SAW) with its associated lower toughness properties is a conservative approximation of the installed material behavior. The radial thermal gradient associated with the recirculation mode produces a local through wall bending stress. By assuming the 20" circumferential flaw is through wall, this bending stress is released and does not contribute to flaw propagation. The thermal shock associated with post LOCA recirculation from the containment sump was not included in this evaluation. Similarly, the residual stress is a through wall bending stress distribution which is released when the flaw propagates through wall. The residual stress is not a concern because the evaluated flaw is through wall.

The results of the evaluation demonstrated that the 20" circumferential through wall flaw met the plastic collapse acceptance criteria with a margin factor of 1.97 for the normal/upset conditions and a margin factor of 2.4 for the emergency/faulted conditions.

As a positive measure to comply with the off-site exposure requirement, the application of a leak sealant encapsulated by a mechanical clamp (e.g., Furmanite) would be used to eliminate leakage during a seismic event.

2. <u>Weld Overlay/Code Case N-504-1</u>

Code Case N-504-1 allows for three types of weld overlays. The overlay necessary for this valve is a type 1 overlay. Type 1 is based on the assumption the flaw is through wall and extends around the entire circumference of the pipe. The overlay alone must restore the entire structural design basis margin. No credit is taken on the structural component of the uncracked portion of the pipe circumference. This may be considered a long term repair and provide technically justifiable alternatives to valve replacement.

3. Code Repair

Per Palisades Nuclear Plant administrative procedures (Procedure No. 9.06, Rev. 3), repairs are governed by IWA/IWC 4000, 1983 ASME B&PV Code with Summer 83 Addenda. Paragraph IWA-4120 states repairs will be made to the original construction code.

The original construction code of B31.1 1955 requires use of the material specification for material repairs.

The ASTM A-351 material specification allows the repair of base metal defects with the following rules:

1. Completely remove defect to sound metal
2. Visually check for defect removal
   a) If the defect was removed with a method involving high temperatures, it should be liquid penetrant examined
3. Repair to be performed with welders and procedures qualified to ASTM A-488 for welding of steel castings.
4. Weld repairs shall be inspected to the same quality standards as the original.
   a) If supplemental standard S4 of ASTM A-351 was involved, the weld repair shall be liquid penetrant tested by the same standard as used to inspect the castings.

This method has the advantages of not requiring the entire circumference to be welded but problems with 100% through wall repair purging requirements, debris control, joint rewelding, casting defects, the extent of the excavation, ALARA concerns and location of the repairs relative to the existing circumferential weld will create a whole new set of problems to overcome.

4. Valve Replacement

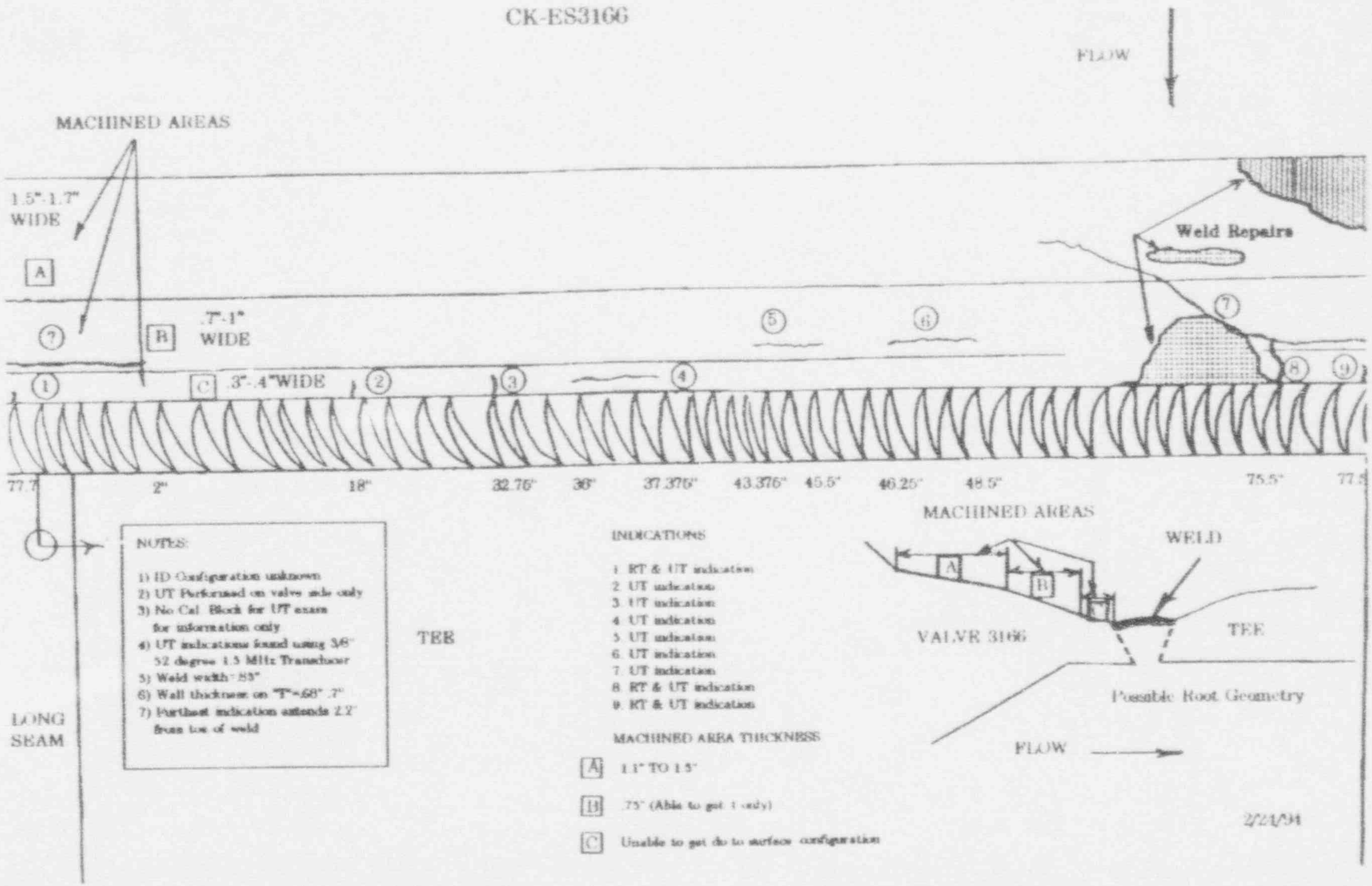
If an acceptable replacement valve is available, this option would be the easiest and most effective to accomplish.

VII. CORRECTIVE ACTION RECOMMENDATIONS

The referenced calculation demonstrates that the flaw is stable. On this basis, the existing condition could be left as is provided an injected leak sealant is used (Option 1). This would be the least conservative option since some design margins would be decreased.

The more conservative option of providing a Code Case N-504-1 weld overlay would provide a long-term repair (Option 2), and is the option recommended by Sargent & Lundy. This option would restore structural design basis margin and be considered a permanent repair and remain in place for the balance of plant life.

Option 3 (Code repair) presents more potential for complications, particularly with the number and location of repairs on the casting, and is not recommended. Option 4 (Valve replacement) would be viable only if an acceptable replacement valve is available.


CK-ES3166
FLOW
MACHINED AREAS
1.5"-1.7" WIDE
A
7
B
.7"-1" WIDE
C
.3"-.4"WIDE
1
2
3
4
5
6
7
8
9
Weld Repairs
77.7
2"
18"
32.76"
36"
37.376"
43.376"
45.5"
46.25"
48.5"
75.5"
LONG SEAM
NOTES:
1) ID Configuration unknown
2) UT Performed on valve side only
3) No Cal. Block for UT exam for information only
4) UT indications found using 3/8" 52 degree 1.5 MHz Transducer
5) Weld width=.85"
6) Wall thickness on "T"=.68"-.7"
7) Farthest indication extends 2.2" from toe of weld
TEE
INDICATIONS
1. RT & UT indication
2. UT indication
3. UT indication
4. UT indication
5. UT indication
6. UT indication
7. UT indication
8. RT & UT indication
9. RT & UT indication
MACHINED AREA THICKNESS
A 1.1" TO 1.5"
B .75" (Able to get 1 only)
C Unable to get do to surface configuration
MACHINED AREAS
WELD
VALVE 3166
TEE
Possible Root Geometry
FLOW
2/21/94