PRELIMINARY REPORT ON IE BULLETIN 79-17

INSPECTIONS OF STAINLESS STEEL SAFETY RELATED PIPING

CONTAINING STAGNANT, OXYGENATED, BORATED WATER

SAN ONOFRE NUCLEAR GENERATING STATION

UNIT 1

September 10, 1979

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I. INTRODUCTION

In response to IE Bulletin 79-17 Item #2, liquid penetrant examinations on a representative sample of stagnant, oxygenated, borated water piping systems were commenced on September 6, 1979.

During the conduct of liquid penetrant examinations on the refueling water pump suction piping, a total of six linear indications in the weld heat affected zone of two separate welds were discovered. These indications have been evaluated as circumferentially oriented cracks emanating from the outside diameter (OD). Four of the OD cracks are located in the heat affected zone of one weld. The remaining two are apparent through wall cracks in the heat affected zone of the other weld. The through wall cracks have barely perceptable weepage. In all cases, the observed cracking appears to be externally generated chloride stress corrosion cracking and is similar to that previously identified on piping at San Onofre Unit 1.

The purpose of this report is to present the findings of inspections conducted thus far, to describe short term and long term corrective actions being taken as a result of these findings, to describe and summarize the status of the continuing program of non-destructive examinations (NDE) in view of these findings and of IE Bulletin 79-17, and to evaluate the adequacy of corrective actions and NDE with respect to continued safe operation of San Onofre Unit 1.

II. FINDINGS OF INSPECTIONS TO DATE

In accordance with IE Bulletin 79-17, Item 2(b), liquid penetrant examination was commenced on September 6, 1979 of a representative number of circumferential welds in normally accessible portions of safety related, stainless steel piping systems containing stagnant, oxygenated, borated water. Ultrasonic examinations had been planned as required by 79-17, but have not been initiated as yet.

During liquid penetrant examination of twenty three (23) circumferential welds on September 6, 1979, several linear indications were found on two separate welds in the suction piping to the refueling water pumps. These indications were evaluated as cracks and written prompt notification of these findings was given to the NRC Office of Inspection and Enforcement, Region V by SCE letter (J. M. Curran) to NRC (R. H. Engelken) dated September 7, 1979.

In accordance with IE Bulletin 79-17, Item 2(c), the examinations are being expanded to encompass all safety related, stainless steel piping systems containing stagnant, oxygenated borated water. However, since the cracks discovered thus far emanate from the OD surface of piping and are readily detectable by surface liquid penetrant examination, an accelerated program of PT examinations has been initiated prior to implementing volumetric examinations in order to quickly assess the extent of OD cracking.

II. Findings of Inspections to Date (Cont'd)

As of the morning of September 10, 1979, approximately 200 circumferential welds in the above described piping systems located outside containment have been PT examined with the following results:

A. Two through wall cracks have been found in the heat affected zone of weld #729-16 (refer to Sketch A-1 for location in refueling water pump suction piping). Weld #729-16 joins the refueling water suction piping to the suction side isolation valve of refueling water pump G27(N). Each crack is approximately 1/4 inch in length, is circumferentially oriented and adjacent to one another and is on the underside of the pipe side of weld #729-16. Upon close visual examination, moisture can be detected on the surface area immediately encompassing the two cracks. Based upon a visual inspection of the cracks and upon previous experience with cracking of stainless steel piping at San Onofre Unit 1, the cracks are considered to have originated from the OD with the probable cause being chloride stress corrosion.

B. Four OD cracks have been found in the heat affected zone of weld #729-6 (refer to Sketch A-1), approximately six feet upstream of the through wall cracks discussed in II.A above. Weld #729-6 joins a short (approximately 1 foot) verticle run of pipe to an elbow in the common suction line to both refueling water pumps. The cracks are on the pipe side of the pipe to elbow weld #729-6, are circumferentially oriented, and are approximately 1/4 inch, 3/8 inch, 3/4 inch and 1 inch in length. The cracks are distributed within a 120° arc (approximately 9 inches). Based upon visual inspection and upon previous similar observations at San Onofre Unit 1, the cracks are considered to originate from the OD with the probable cause being chloride stress corrosion.

III. CORRECTIVE ACTION

Short term corrective action consisting of repairs and monitoring of affected piping weld areas and long term corrective action consisting of replacement of affected piping are discussed below.

A. Repair

1. System Design Features.

The cracks are located in refueling water pump suction piping having the following design features:

III. Corrective Action (Cont'd)

Line No. 729-8"-HP
Design Code - ASA B31.1-1955
Material - ASTM A 312TP 304
Schedule - 10S (.148 nominal wall thickness)
Service Pressure and Temperature (Suction Side)

15 psig/ambient (normal)
15 psig/ambient (post LOCA - Injection mode)
105 psig/200° F max. (post LOCA - Recirculation mode)
Safety Service - Containment Spray
System Configuration - Refer to Sketch A-1

2. Description of Repair

The repairs to the two affected areas (i.e. welds #729-6 and 729-16) entailed fabricating four half-circular reinforcing collars (two halves for each affected weld) from 1/2" by 1" carbon steel bar stock formed to the contours of the pipes. Welded to each end of the half-circular collar segments is a flange formed from 1/2" thick carbon steel bar stock drilled for two 1/2" diameter bolts. A 1/4" thick carbon steel plate is formed to fit over each half-circular reinforcing collar segment and welded in place. Each complete collar is designed to be centered over the affected weld and held in place by four 1/2" diameter bolts.

Material specification meets or exceeds the requirements of ASTM A-36 for the bar and plate stock and ASTM A-307 for the bolts.

See attached Sketch A-2 for fabrication details and dimensioning of the reinforcing collars.

Following fabrication of the collars, the collars and collar welds were magnetic particle examined for cracking and none was observed. The collars were then installed as described above with a stainless steel shim inserted between the stainless steel pipe and the carbon steel collar for pipe corrosion protection.

These repairs are intended to return the piping to its original stress margins or better and do not provide a leak tight boundary. The above repairs were effected for welds #729-6 and #729-16 on September 8, 1979.

3. Analysis of Repair

The repair has been evaluated in accordance with the requirements of paragraph 104.8.2 (Stress Due to Occasional Loads) Chapter 2 of ANSI B31.1-1977 which meets or exceeds the original design requirements. To

III. Corrective Action (Cont'd)

meet the requirements of this paragraph, occasional loads, including seismic loads, and sustained loads, including pressure and weight, must meet the requirements of equation 12a:

Equation (12a) $$\frac{PDo}{4L_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \leq kS_n$$

where

L_n = Nominal wall thickness of component, in.

M_A = Resultant moment loading on cross section due to weight and other sustained loads, in lbs.

Z = Section modulus, in.^{3}

i = Stress Intensification Factor. The product 0.75i, shall never be taken as less than 1.

S_n = Basic material allowable stress at maximum temperature from allowable stress tables, psi.

k = 1.2 for occasional loads acting less than 1% of operating period.

M_B = Resultant moment loading on cross section due to occasional loads such as thrusts from pressure and flow transients and earthquake.

P = Internal design pressure, psig.

Do = Outside diameter of pipe, inches.

The following conservative simplifications will be applied to equation 12a to bound the maximum anticipated material stress in the repair configuration in relation to the original piping material stress.

a. The reinforcing clamp constitutes the sole structural boundary for the segment of pipe spanned by the clamp, i.e. no credit is taken for the piping.

b. No credit is taken for the wall thickness of the piping. In reality the effective wall thickness is the aggregate of the clamp and pipe wall thicknesses.

III. Corrective Action (Cont'd)

c) The section modulus is based upon the pipe diameter rather than the actual radial diameter occupied by the clamp, i.e., Do - a constant = 8.625 inches.

In evaluating the impact of the reinforcing clamp on moments M_A and M_B, the following is noted:

1) The total metal addition to the system amounts to less than ten pounds for either clamp.

2) The weight of the metal and water per foot of pipe in the eight inch line is 37 pounds.

3) There are three valves in the suction lines.

Based upon the above, the increase in weight due to the reinforcing clamps is negligible (less than 2% increase) and does not significantly alter the values of total weight and other sustained load (i.e. M_A is essentially unchanged). In relation to M_B there is no change in this value because it deals with the resultant movements caused by externally applied occasional loads (e.g. seismic events) applied to the piping mass. As noted above this mass increase is negligible.

Evaluation of Equation 12a is as follows:

$\frac{PDo}{4t_n}$ = Constant (conservative simplication as the relative variation in Do is smaller than that of t_n)

Therefore:

$$\frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} < K\,S_n - \frac{PDo}{4t_n} = S$$

Where S - Sustained and Occasional allowable stresses.

The comparison of S without the reinforcing collar and S with the reinforcing collar will bound the collar's effect as compared to the condition of the subject line as originally designed.

Original Condition $\frac{0.75iM_A}{8.21} + \frac{0.75iM_B}{8.21} < S$ (for stainless steel)

Collared Condition $\frac{0.75iM_A}{10.71^*} + \frac{0.75iM_B}{10.71^*} < S$ (for stainless steel)

III. Corrective Action (Cont'd)

*The actual section modulus of the repair configuration is 13.39. This value has been reduced to the value 10.71 to account for the differences in S_n between the stainless steel and carbon steel materials by a ratio of the allowable stresses for the two materials corrected by $\frac{PDO}{4t_n}$.

As can be seen above, the stresses in the repaired condition are less than those in the original designed condition.

With respect to the effects of seismic disturbance on the original design configuration as well as the repair configuration, a review of the piping configuration (see Sketch A-1) reveals a relatively rigid system as a result of multiple anchors and close spacing of supports. The relatively high rigidity of the system, i.e., high frequency, compiled with the relatively low elevation of the system has a resultant effect of minimizing the seismic loads. The high rigidity of this system prevents any significant relative displacement of the suction piping and precludes the necessity to analyze for this condition.

Thermal effects in regard to the reinforcing collar are insignificant as a result of the low variations in fluid temperature and the relatively short piping runs.

Due to the high rigidity of the piping system and the relatively low contribution of mass from the collars to the system, the vibrational characteristics of the repaired piping configuration are not significantly altered. It is further noted that the system does not experience pump induced vibration in the resonant range and therefore shall not experience it with the collars installed.

Until such time as permanent repairs are made as described in III.B below, the following monitoring program will be adhered to:

a) On a weekly basis visually inspect the through wall crack area for increased weepage.

b) On a monthly basis liquid penetrant examine the six cracks. Inspection reports will be compared from each examination to ascertain the status of the cracks.

c) Any changes observed during the above monitoring program will be evaluated and appropriate corrective action taken, including reporting to the NRC Office of Inspection and Enforcement Region V.

III. Corrective Action (Cont'd)

B. Future Repair and Replacement

Based upon the findings from the continuing examinations being conducted in response to IE Bulletin 79-17, the following program of repair and replacement will be accomplished:

1. The sections of refueling water pump suction piping which have been repaired as discussed in III.A above will be replaced during the next refueling outage presently scheduled for March, 1980. Replacement material will be stainless steel type 304L in order to minimize the effect of chlorides on the metal.

2. The results of the continuing examinations being conducted in responses to IE Bulletin 79-17 and any proposed corrective actions will be reported to the NRC Region V Office in accordance with the reporting requirements of 79-17.

IV. STATUS OF CONTINUING NON-DESTRUCTIVE EXAMINATIONS

As stated in Section II above, an accelerated program of liquid penetrant examination of safety related stainless steel piping is being conducted to quickly assess the extent of OD cracking. This program is confined to those stagnant, oxygenated, borated water lines outside containment using Schedule 10 piping and a limited number of associated branch line welds. Approximately 300 welds are involved of which 200 welds have been completed to date. Among these 200 welds, two welds have indications of cracking as previously noted in this report.

Volumetric examinations of stainless steel piping welds in accordance with IE Bulletin 79-17, Item 2(c) will consist of ultrasonic examinations (UT) of piping 2-1/2 inches and greater in diameter. Where UT results are inconclusive due to weld geometry, radiographic examinations (RT) will be performed. A total of approximately 600 welds are planned to be UT examined. Of these 600 welds, about 220 are located inside containment. Of the 220 located inside the containment, about 100 are located inside the secondary shield wall and would necessitate a hot shutdown to conduct the UT examinations.

It is SCE's objective to complete the examinations as outlined above by October 24, 1979 and to file a written report to the NRC Region V Office by November 23, 1979 as required by IE Bulletin 79-17, Item 6. It is noted, however, that as the examination program proceeds, certain welds may be found to be inaccessible to examination within the required time frame due to high radiation, structural interference or other factors. The NRC Region V Office will be notified prior to October 24, 1979 of any such welds which cannot be examined and of SCE's schedule for completing the examinations.

V. CONCLUSIONS

A. The analysis indicates that the reinforcing collars will return the piping system to its original design margins or better based upon the following:

1. The reinforcing collars serve to effectively increase wall thickness and section modulus thus reducing sustained and occasionally applied stresses in the area of the crack to values less than those of the original design.

2. The reinforced line segments will be able to withstand increased seismic loading compared to the original design.

B. A monitoring program of cracks in the repaired piping sections has been implemented consisting of the following:

1. Weekly visual examination of cracks to determine any adverse change in the extent of weepage.

2. Monthly liquid penetrant examinations of cracks to determine any change in the length of the cracks as an indication of crack propagation.

C. Based upon the nature and limited extent of cracks and leakage observed and upon the repairs and monitoring program in effect, it is concluded that San Onofre Unit 1 can continue power operation without undue risk to the public health and safety.