FINAL REPORT ON TAYLOR FORGE PIPE DEFECTS

San Onofre Nuclear Generating Station, Units 2 and 3

INTRODUCTION

This final report is submitted pursuant to 10CFR50.55(e)(3). It describes linear indications identified at the surface adjacent to longitudinal seam welds in ASME III, Class 2, main steam piping for San Onofre Units 2 and 3. This final report includes a description of the deficiency, a summary of the corrective action taken and an analysis of the safety implications.

BACKGROUND

By letter dated January 23, 1979, Edison confirmed notification to the NRC concerning a condition in construction of San Onofre Units 2 and 3. An interim report on this condition was forwarded by an Edison letter of February 22, 1979, which was supplemented by letters dated April 6 and June 4, 1979. The condition involved linear indications identified at the surface adjacent to longitudinal seam welds in carbon steel pipe (pipe tubes) manufactured by Taylor Forge of Paola, Kansas, and subsequently used in fabrication of main steam pipe spools by Pullman Power Products (fabricator) for installation by Bechtel Power Corporation (installer).

Approximately 840 feet of this piping was supplied and installed in the main steam systems at San Onofre Units 2 and 3. Eighty-two (82) separate pipe tube lengths make up this piping which consists of four lines (two per unit). Each line extends from a steam generator main steam outlet nozzle through a containment penetration and containment isolation valve to a seismic anchor on the roof of the respective unit's safety equipment building.

This ASME B&PV Code, Section III, Class 2 piping was manufactured in tube sections 42-inch and 40-inch in diameter to material specification SA-155 KCF70, Class 1. The nominal manufactured wall thickness of the 42-inch pipe is 2.250 inches and the 40-inch pipe is 1.813 inches. The project specified

7907100680

minimum pipe wall thickness was 2.000 inches for the 42-inch piping and 1.572 inches for the 40-inch pipe. The project specified minimum pipe wall thicknesses were based on optimizing pipe whip restraint spacing and are considerably thicker than the ASME B&PV Code required minimum wall (1.332 inches for the 42-inch pipe and 1.272 inches for the 40-inch pipe).

A linear indication in the base material heat-affected zone adjacent to the longitudinal weld in a pipe tube was first detected by Bechtel radiographs of a field welded circumferential joint between two piping spool pieces located in a Unit 3 main steam line. This indication was located immediately upstream of the field welded joint where the pipe longitudinal weld intersects the field circumferential weld. Subsequent visual examination of the area, verified by liquid penetrant examination, showed a linear indication on both the inside and outside surfaces of the pipe parallel to the longitudinal seam. A review of the Taylor Forge radiographs of the longitudinal weld (x-ray with film on the pipe ID) showed possible indications that coincided with the visible linear indications found on the OD and ID surfaces along the longitudinal seam. The linear indications aligned with the edge of the weld overlay area and apparently had been interpreted as associated with the weld overlay.

Radiographs of all pipe tubes performed by Taylor Forge were reviewed and a total of twenty (20) pipe tubes were identified as potentially containing surface fissure conditions. In addition, metallurgical samples containing a cross section of the originally detected linear indications were taken from the pipe tube ID and OD to determine the nature of the linear indications.

DISCUSSION

The following is responsive to 10CFR50.55(e)(3).

Description of the Deficiency

The metallurgical samples were analyzed by two independent testing laboratories (Atlas Testing Laboratories and Hi-Rel Laboratories) and by the Bechtel laboratory in San Francisco. The findings from the three laboratories were essentially the same and are summarized as follows:

A. The linear indications were shallow fissures (measured depths from 0.022 to 0.043 inches) in the heat affected zone of the base material, specifically in that portion of the heat affected zone that was untempered martensite prior to the postweld heat treatment. The fissures were open to the surface but heavily oxidized. The oxide was approximately 0.0005 inch thick. The fissure may be located on the ID or OD surface and runs parallel to the longitudinal weld.

B. Chemical analyses of both the weld and base materials were within ASME B&PV Code specified requirements.

C. The hardness of the weld metal, heat affected zone and base material was checked using the 15T Rockwell superficial hardness scale and a Vickers identer with a 10kg load. The results were converted to the Rockwell B scale to facilitate comparison. The base material had an average hardness of 79RB; the weld metal had an average hardness of 90RB and the heat affected zone had an average hardness of 87RB. These values are typical of the base metal, weld metal and heat affected zone for the materials and process used.

A detailed review and evaluation was made by Taylor Forge, Pullman, Bechtel and the two independent laboratories of the data obtained from laboratory tests and of the documentation of the materials and process data for all main steam system piping. This review and evaluation included: weld procedures and procedure qualification tests, welder lists, certified material test reports, impact test data from base metal, weld metal, and heat affected zone, heat treatment procedures and furnace charts, and work process sheets (shop travelers). In addition, chemical composition of weld material was correlated with that of base material, looking for combinations of elements which might result in near-limit fusion zone composition. This review and evaluation of the material and manufacturing data did not point to any single characteristic or element or to any combination of these factors which could be identified as the cause of the condition. Further, the shallow fissures may

not have been detected during the initial review of the radiographs due to their nature and close proximity of the linear indications with the weld overlay.

Corrective Action

The Taylor Forge radiographs of the longitudinal welds for all eighty-two (82) piping tubes were subject to an extensive review with emphasis placed on the weld overlay area. Twenty (20) tubes were identified as potentially containing surface fissure conditions. No sub-surface indications or fissures were observed in either the ID or OD weld metal or base metal for any of the pipe tubes. The suspect areas on each piping tube were identified by radiographic station numbers and are presented in Attachment 1. The longitudinal welds of all twenty (20) pipe tubes were 100% examined on both the ID and OD utilizing MT as the NDE method.

MT (AC yoke) was selected as the NDE method as it is considered the most effective method for the detection of tight surface fissures which may be filled with oxide. It should be noted that surface examination (by MT) of ASME B&PV Code, Section III, Class 2 piping exceeds the NDE examination requirements of the ASME B&PV Code. A 100% OD and ID inspection of the piping tube longitudinal weld was accomplished in order to obtain the maximum data on the condition of the pipe tubes.

As linear indications were identified by MT and removed by surface conditioning, final grind out length, depth and location of all relevant linear indications were appropriately documented. All observations were taken under controlled grinding conditions (i.e., grind-out was accomplished in small increments to ensure that the actual maximum depth of indication was determined) with the exception of the initial nine (9) observations. Further, all depth measurements were made with a calibrated depth measurement tool.

The 100% MT inspection of the twenty (20) suspect piping tubes resulted in the identification of eighty-three (83) relevant surface indications (i.e., those in excess of 1/8-inch

in length). Seventy-four (74) of these indications were investigated under controlled grinding conditions. These indications had an average fissure depth of 0.0298 inches with a deviation of 0.0378 inches. The deepest indication obtained under controlled conditions had a depth of 0.197 inches. Nine (9) indications were investigated prior to the use of a controlled grind-out technique. The deepest grind-out in this set of nine (9) indications was 0.300 inches. When all eighty-three (83) indications are considered the average indication depth is 0.0459 inches with a deviation of 0.0716 inches. The nine (9) indications investigated prior to utilizing a controlled grinding technique are not considered relevant because the recorded depths of fissures are related to the method used for removal rather than to the inherent indication characteristics. The data resulting from the investigation of the twenty (20) suspect piping tubes is summarized in Attachment 2.

All linear indications identified in the twenty (20) piping tubes were removed by surface conditioning and/or weld repair in accordance with the requirements of the ASME B&PV Code. It should be noted that while five (5) of the piping-tubes were weld repaired, these repairs were accomplished to be consistent with Project practice only. Weld repairs for these tubes was not required to meet either ASME B&PV Code minimum wall thickness requirements or Project pipe whip considerations.

In view of the demonstrated difficulty in detecting shallow surface indications in close proximity with the weld overlay by reviewing the radiographs, further evaluations were accomplished. Specifically, a statistical analysis based on the data from the twenty (20) suspect piping-tubes described above, indicated that the probability of any remaining surface indication which would violate the ASME Code minimum wall requirement (i.e., depth of indication greater than approximately 0.5 inches) is exceedingly small (i.e., less than 10^{-11}). Further, a fracture mechanics evaluation substantiated that surface fissures significantly larger than any found are necessary to initiate brittle fracture, even when conservative assumptions of stress and material toughness levels were used. Fissures approximately one-half through-wall depth (one inch deep) and eight inches long are required to initiate brittle

fracture. The pipe will leak before it breaks since very high stresses are required (i.e. greater than yield) for brittle fracture to occur and failure in the pipe will be controlled by a plastic limit load mechanism.

Based on all the information and evaluations, any remaining surface fissure condition in any pipe-tube will be significantly more shallow than those previously identified, investigated and repaired and will not adversely affect the safe operation of the plant.

Analysis of Safety Implications

The extremely shallow fissures in the main steam piping at San Onofre Units 2 and 3 have been comprehensively investigated, evaluated and repaired. If all surface fissure conditions had remained undetected, plant safety would not have been adversely affected and ASME B&PV Code required minimum wall thickness would have been maintained. In addition, any remaining surface fissures do not represent a significant deficiency or adversely affect safe operation of the plant. The condition is reportable in accordance with 10CFR50.55(e) in that an extensive evaluation was required. No further corrective action is required.

Identification of Piping Tubes

Manufacturing Pipe Tube No.*		Suspect RT. Station Interval	Spool No.**	Tube Length
1.	3TR1	12-13	2-ST-001-2	13'
2.	15AR1	0-1	2-ST-001-6	4'1-1/2"
3.	13B1	0-1	2-ST-002-6	2'3-15/16"
4.	3V1	12-13	2-ST-002-11	13'
5.	3U1	1-2, 2-3, 3-4	3-ST-001-4	13'
6.	12B1	0-1, 1-2, 2-3	3-ST-001-10	7'
7.	11A1	0-1, 1-2	3-ST-001-12	9'4"
8.	4J1	11-12, 12-13	3-ST-001-12	13'
9.	17A1	0-1	3-ST-002-1	13'
10.	3M1	12-13	3-ST-002-2	13'
11.	3E1	12-13	3-ST-002-4	13'
12.	3XR1	11-12, 12-13	3-ST-002-4	13'
13.	4A1	12-13	3-ST-002-9	13'
14.	3P1	0-1	3-ST-002-9	13'
15.	4K	12-13	3-ST-002-10	13'
16.	14B1	0-1, 7-8, 8-9	3-ST-002-11	8'9"
17.	17B1	1-2	2-ST-001-1	13'
18.	3J1	0-1, 8-9	2-ST-002-2	13'
19.	4G1	0-1, 1-2	3-ST-002-2	13'
20.	9B1	2-3, 3-4	3-ST-001-4	8'3-1/2"

* Pipe tube numbers are those defined by Taylor Forge on the Certified Material Test Report.

**Spool numbers are those defined by project drawings.

SURFACE INDICATION DATA

ID - Data				OD - Data			
Length	Depth	Length	Depth	Length	Depth	Length	Depth
10 -	.013	- 1/4	.008	14 -	.085	- 1/2	.005
49 -	.120	10 -	.028	- 1/2	.001	4 1/2	.019
- 3/16	.0	15 -	.024	2 -	.0	3 -	.001
11 -	.012	6 -	.079	3 -	.017	4 -	.004
10 -	.045	14 -	.017	6 -	.051	14 1/4	.072
- 3/4	.024	12 -	.024	- 1/8	.100	2 -	.015
11 -	.019	9 -	.031	- 1/4	.100	3 -	.01
18 -	.036	1 -	.061	9 -	.020	2 -	.024
18 -	.036	12 -	.005	7 -	.086	- 3/4	.014
30 -	.169	- 3/4	.001	3 -	.043	- 3/4	.016
16 -	.197	9 -	.002	- 1/4	.001	16 -	.006
15 -	.017	9 -	.002	- 3/4	.010	23 -	.015
5 1/2	.086	32 -	.003	11 -	.010	1 -	.009
14 -	.022	6 -	.003	1 1/2	.073	12 -	.044
1 1/2	.025	- 1/4	.002	2 1/2	.007		
8 -	.022	6 -	.008	5 -	.025		
4 -	.003	96 -	.047	2 3/4	.012		
1 -	.005	96 -	.031	8 -	.020		
2/12	.007	*2 -	.300	*7 -	.230		
- 1/2	.021	*1 1/2	.002	*3 -	.230		
36 -	.021	*4 1/2	.004	*31 -	.300		
12 -	.020			*11 3/4	.247		
36 -	.010						
12 -	.001						
*9 -	.280						
*16 -	.012						

*The nine observations marked with asterisks denote data obtained with uncontrolled grind out depth.