Enclosure

RESPONSE TO NRC BULLETIN NO. 87-01,
THINNING OF PIPE WALLS IN NUCLEAR POWER PLANTS

The following information concerning high-energy carbon steel piping systems is provided in response to the action requested in the NRC Bulletin No. 87-01.

1. Information Requested:

Identify the codes or standards to which the piping was designed and fabricated.

Licensee Response:

Codes and standards for carbon steel piping in condensate, feedwater, steam and connected high-energy systems that has been identified as susceptible to erosion-corrosion and incorporated in the monitoring programs established for the San Onofre Nuclear Generating Station, Units 1, 2 and 3 are as follows:

Unit 1: ANSI B31.1 and ASME Section I

Units 2 and 3: ASME Section III for safety related piping
ANSI B31.1 for non-safety related piping

2. Information Requested:

Describe the scope and extent of your programs for ensuring that pipe wall thicknesses are not reduced below the minimum allowable thickness. Include in the description the criteria that you have established for:

a. selecting points at which to make thickness measurements
b. determining how frequently to make thickness measurements
c. selecting the methods used to make thickness measurements
d. making replacement/repair decisions

Licensee Response:

The scope of the monitoring programs for piping covers the extraction steam (wet steam) systems and feedwater/condensate systems. The scope of the programs was established by reviews of the systems considering piping material (i.e., carbon steel), operating temperature, bulk fluid velocities, and moisture content (for wet steam systems). The final selection of all the specific points for examination has not yet been completed. Examinations for those locations already selected are in progress.

a. The points for examination have been selected based on geometric configurations (e.g., elbows, reducers, etc.) which are known to cause turbulent flow conditions. Emphasis in sample selection has been given to the more highly rated configurations and combinations (For the criteria used, see enclosed San Onofre Nuclear Generating

Station procedure numbers SO1-XVII-4, SO23-XVII-4 and SO123-XVII-4). In addition to this manual selection, the EPRI CHEC computer program has been used to select areas in single phase systems for examination. Points are also selected where past San Onofre and/or industry experience has shown high susceptibility to erosion-corrosion. (Also see item 3 below.)

b. The determination of the frequency for the performance of thickness measurements is made by comparing the thickness measurements with the standard tolerances for the size and schedule of the piping. If the thickness of the item (e.g., elbow, reducer, etc.) is not within the manufacturer's tolerance for the specified nominal pipe size and schedule, it is subject to monitoring during each refueling cycle, at least until a determination of the actual erosion-corrosion rate can be made. For single-phase systems, the items selected by the EPRI CHEC computer program will be subject to monitoring during each refueling cycle. Those items where past experience has shown high susceptibility will also be monitored on a frequent basis, which will be determined on a case-by-case basis.

c. The ultrasonic method was selected over radiography as the primary method for making the thickness measurements, because of its greater accuracy and reproducibility. Radiography may be used as a supplement or as an alternative after the baseline measurements are completed.

d. Where the thickness is determined to be less than the minimum design wall thickness plus 5% for an item, the item will be subject to further evaluation for potential replacement.

3. Information Requested:

For liquid phase systems, state specifically whether the following factors have been considered in establishing your criteria for selecting points at which to monitor piping thickness.

a. piping material (e.g., chromium content)
b. piping configuration (e.g., fittings less than 10 pipe diameters apart)
c. pH of the water in the system (e.g., pH less than 10)
d. system temperature (e.g., between 190 and 500°F)
e. fluid bulk velocity (e.g., greater than 10 ft/s)
f. oxygen content in the system (e.g., oxygen content less than 50 ppb)

Licensee Response:

a. The piping material alloy content was assumed to be zero (worst case) for all the piping in the systems since quantitative data concerning elements which inhibit erosion-corrosion (primarily chromium) was not available. These elements are present as impurities in the commercial grades of piping used in the original

fabrication of the feedwater/condensate and extraction system systems and the manufacturers do not provide quantitative information on the alloy content for impurities.

b. Piping configuration was considered for the selection of areas to be examined. Emphasis is placed on highly susceptible configurations and combinations, such as expanders downstream of control valves. A description of the approach to selection of areas based on configuration is included in San Onofre Nuclear Generating Station procedure number SO123-XVII-4.

c. The pH of the water in the system was assumed to be constant throughout the system for purposes of selection. In Units 2 and 3, the pH of the water in the feedwater piping is normally maintained within the procedural limits of 8.8 to 9.2. In Unit 1, the average pH in the feedwater/condensate piping is around 9.1. In Units 2 and 3 the average pH in the feedwater/condensate piping averages near 8.9. Local quantitative measurements of pH in order to designate areas for examination were not performed; however, such local variations in pH are not expected.

d. The system temperature was considered in the selection of specific areas to be monitored. A rating system for piping based on system temperature was used which was based on the temperature versus erosion rate relationships discussed in EPRI Report NP-3944 for single phase systems and on additional information provided by Virginia Power Corporation. This rating system is included in procedure number SO123-XVII-4.

e. Fluid bulk velocity was considered in the selection of specific areas to be monitored. A rating system for piping based on the fluid bulk velocities was established and is included in procedure SO123-XVII-4. Piping with higher fluid velocities (greater susceptibility) is given a higher number.

f. The oxygen content of water in the system was assumed to be constant for the purposes of selection. In Unit 1, the oxygen content of the water in the feedwater piping averages around 2 ppb and in the condensate system averages around 5 ppb. In Units 2 and 3, the oxygen content of the water in the feedwater piping is normally maintained at less than 5 ppb in the feedwater system and near 10 ppb in the condensate system, averaging around 1 ppb and 10 ppb, respectively. Local quantitative measurements of oxygen content in order to designate areas for examination were not performed.

4. Information Requested:

Chronologically list and summarize the results of all inspections that have been performed, which were specifically conducted for the purpose of identifying pipe wall thinning, whether or not pipe wall thinning was discovered and any other inspections where pipe wall thinning was discovered even though that was not the purpose of that inspection.

a. Briefly describe the inspection program and indicate whether it was specifically intended to measure wall thickness or whether wall thickness measurements were an incidental determination.

b. Describe what piping was examined and how (e.g., describe the inspection instrument(s), test method, reference thickness, locations examined, means for locating measurement point(s) in subsequent inspections).

c. Report thickness measurement results and note those that were identified as unacceptable and why.

d. Describe actions already taken or planned for piping that has been found to have a nonconforming wall thickness. If you have performed a failure analysis, include the results of that analysis. Indicate whether the actions involve repair or replacement, including any change of materials.

Licensee Response:

Listed below is a chronological summary of all the inspections performed which are relevant to pipe wall thinning. Unless otherwise indicated, all inspections were performed specifically to identify pipe wall thinning. In all cases the test method used was ultrasonic (pulse-echo technique). Except where noted, the inspections were performed using a standard A-scan (CRT display) ultrasonic instrument. Other inspections were performed using an ultrasonic-imaging type instrument (Balteau TMI 150 Metal Imager Scanning System) and are indicated as such in the following discussion. Where the imaging system was used, scanning was performed on the outside radius of elbows, and the backside of tees (where there was impingement due to the flow direction). Piping downstream of fittings (tees, elbows and reducers) was scanned 100% for a distance of one foot for elbows, two pipe diameters for tees and three pipe diameters for reducers, when the imaging system was used. If the wall thickness was evaluated to be insufficient to remain above the minimum design wall thickness for an additional fuel cycle, the thickness was considered unacceptable, and the fitting was replaced. Where piping is described as being "well above minimum wall thickness", the measured wall thickness is approximately two or more times the minimum design wall thickness.

1978 - High Pressure Steam Extraction Piping, Unit 1

During an ultrasonic inspection of high energy steam extraction piping welds, an area of wall thinning was discovered on a fitting (elbow) adjacent to a weld (with a backing ring). Although the area was not below minimum wall thickness, the affected fitting was replaced. The same area on a parallel train was examined and found acceptable.

1980 - High Pressure Steam Extraction Piping, Unit 1

70 fittings (elbows) on the steam extraction lines were examined. All areas were found to be well above minimum wall thickness and none were replaced. Measurements were taken at locations on either side of the weld and at three locations along the length of the fitting. At each location, measurements were taken at approximately every 45 degrees around the circumference of the fitting.

1985 - Steam Extraction Piping, Units 2 and 3

76 areas (elbows, tees and piping downstream of reducers) in each Unit were examined by scanning with an ultrasonic imaging system. This was a baseline examination and all areas were found to be well above minimum wall thickness.

1986 - Steam Extraction Piping, Unit 1

During an ultrasonic inspection of high energy steam extraction piping welds, an area of wall thinning was discovered on a fitting (elbow) adjacent to a weld (with a backing ring). Although the area was not below minimum wall thickness, the affected fitting was replaced. The same area on a parallel train was examined and found to be well above minimum wall thickness. Eight other fittings were examined including those having the lowest wall thickness measurements recorded during the 1980 examinations. Measurements were recorded every 90 degrees around the circumference of the fitting adjacent to the weld and that area was scanned over the circumference for any significant wall loss. Several readings were taken along the outside radius of the eight additional elbows to confirm that these were still well above minimum wall thickness.

1986 - Main Steam and Feedwater Piping, Unit 1

Twelve main steam fittings (tees and elbows) and five feedwater fittings (elbows) were examined. Readings were taken along the outside radius of the elbows and along the backside of tees. All areas were still within the manufacturer's tolerance for the associated pipe size and schedule.

1986 - Steam Extraction Piping, Unit 2

93 areas, including the 76 areas examined in the 1985 baseline examination, were examined using the ultrasonic imaging system. A qualitative evaluation of the imaging results to identify possible wear patterns showed no significant wall thinning.

1986-1987 - Feedwater/Condensate Piping, Unit 3

After a leak was identified in a reducer downstream of a heater drain pump level control valve in Unit 2 (see discussion in the following paragraph), the same reducers were examined in Unit 3 and found to be at or below the minimum design wall thickness. Both reducers were replaced

with a corrosion resistant material (304 stainless steel). An extensive examination program followed during the refueling outage, which included examination of approximately 35 lines. Four additional reducers (all downstream of the control valves) were found to have wall thicknesses at or below the minimum design wall thickness. All four reducers were replaced with reducers fabricated from a more corrosion resistant material (2 1/4% chromium - 1% molybdenum, low-alloy steel).

1986-1987 - Feedwater/Condensate Piping, Unit 2

Following the leak which occurred in a reducer downstream of one heater drain pump level control valve, the same reducer on a parallel train was examined and found to have a thickness at or below the minimum design wall thickness. Both reducers were replaced with in-kind material due to lack of availability of fittings of a more corrosion resistant material. The reducers are scheduled to be replaced with a more corrosion resistant material during the next (Cycle IV) refueling outage. The equivalent fittings found to be at or below minimum wall thickness in Unit 3 were also examined immediately in Unit 2, but were found to be acceptable. In July 1987 (following the EPRI workshop on erosion-corrosion), an examination program was initiated on Unit 2. This program includes over 80 areas (elbows, tees, reducers and valves). The inspections are being performed in accordance with NUMARC guidelines for establishing grid locations for measurements supplemented by scanning. Datum markers and templates are being constructed to facilitate the location of measurement points in subsequent inspections.

1987 - Steam Extraction Piping, Unit 3

The 76 areas examined during the 1986 baseline examination were reexamined. Although some wall thinning was recorded, all fittings were 140% or more of the minimum design wall thickness, which was determined to be an acceptable condition based on estimates of the erosion-corrosion rate.

1987 - Steam Extraction Piping, Unit 1

A formal program was established this year to examine both high and low pressure steam extraction lines for erosion-corrosion. To date, under this program, 16 fittings have been examined and all have been found to have thicknesses well above the minimum design wall thickness. The inspections are being performed in accordance with NUMARC guidelines for establishing grid locations for measurements supplemented by scanning. Datum markers and templates are being constructed to facilitate the location of measurement points in subsequent inspections.

1987 - Feedwater/Condensate Piping, Unit 1

In July 1987, a formal program was established for the examination of feedwater/condensate piping in Unit 1. The lines have been identified, and seven fittings, out of a sample of approximately fifty, have been examined through August 1987. Prior to the beginning of the examinations, a leak in a reducer downstream of a control valve occurred. The cause of the leak is assumed to be erosion-corrosion; however, the leak was sealed by a reinforcing wrapper plate so a failure analysis has not yet been performed but is planned to be performed at the time the reducer is replaced. Final selection of all specific areas for examination is still in progress. The inspections are being performed in accordance with NUMARC guidelines for establishing grid locations for measurements supplemented by scanning. Datum markers and templates are being constructed to facilitate the location of measurement points in subsequent inspections.

5. Information Requested:

Describe any plans either for revising the present or for developing new or additional programs for monitoring pipe wall thickness.

Licensee Response:

A program for monitoring the pipe wall thickness of steam extraction lines was formally established on July 9, 1987 for Unit 1. Monitoring of the pipe wall thickness of steam extraction lines in Unit 1 has been ongoing since 1980, but a formal program did not exist prior to July 9, 1987.

A revision of the program for monitoring the pipe wall thickness of steam extraction lines in Units 2 and 3 was issued on July 9, 1987. The previous program addressed elbows only, and the revision was made to include other susceptible piping geometries as well, e.g., reducers and flow orifices.

A new program for monitoring the pipe wall thickness of feedwater and condensate lines in Units 1, 2 and 3 was formally established on July 9, 1987.

The procedures for the San Onofre programs for monitoring of both steam extraction and feedwater/condensate lines for pipe wall thickness contain provisions for periodic revision; however, the programs will be revised as needed when new information and/or improved selection methodology, such as improvements in the EPRI CHEC code, become available.