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Assessment of United States Industry Structural Codes and Standards for Application to Advanced Nuclear Power Reactors

Appendices

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Prepared for
U.S. Nuclear Regulatory Commission

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Abstract

Through out its history, the USNRC has remained committed to the use of industry consensus standards for the design, construction, and licensing of commercial nuclear power facilities. The existing industry standards are based on the current class of light water reactors and as such may not adequately address design and construction features of the next generation of Advanced Light Water Reactors and other types of Advanced Reactors. As part of their on-going commitment to industry standards, the USNRC commissioned this study to evaluate U.S. industry structural standards for application to Advanced Light Water Reactors and Advanced Reactors. The initial review effort included: (1) the review and study of the relevant reactor design basis documentation for eight Advanced Light Water Reactors and Advanced Reactor Designs, (2) the review of the USNRC's design requirements for advanced reactors, (3) the review of the latest revisions of the relevant industry consensus structural standards, and (4) the identification of the need for changes to these standards. The results of these studies were used to develop recommended changes to industry consensus structural standards which will be used in the construction of Advanced Light Water Reactors and Advanced Reactors. Over seventy sets of proposed standard changes were recommended and the need for the development of four new structural standards was identified. In addition to the recommended standard changes, several other sets of information and data were extracted for use by USNRC in other on-going programs. This information included: (1) detailed observations on the response of structures and distribution system supports to the recent Northridge, California (1994) and Kobe, Japan (1995) earthquakes, (2) comparison of versions of certain standards cited in the standard review plan to the most current versions, and (3) comparison of the seismic and wind design basis for all the subject reactor designs. Finally provided is a suggested plan of action to achieve implementation of the recommended industry consensus standard changes.

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Appendix A: Summary of the Actual Response of Systems, Structures and Components to Strong Motion Earthquake

Overview

As part of this program Stevenson and Associates conducted a review of structural performance data obtained from investigations of power plants and industrial facilities subjected to actual strong motion earthquakes. This review effort was conducted in 3 distinct tasks. First a review of previous investigations and studies of the performance of distribution systems and distribution system supports was conducted and is provided in Appendix A1. A second, on site investigation of the performance of distribution systems during the 1994 Northridge, California Earthquake was conducted and the results of this investigation is summarized in Appendix A2. Finally an onsite investigation of the performance of power plant structures and distribution system supports during the 1995 Kobe, Japan earthquake was conducted and is summarized in Appendix A3. Appendix A4 provides a summary of observations from these experience reviews and investigations and also provides suggested industry code and standard changes which arise from these reviews. The suggested changes are also summarized in Section 3.6 of the main report.

Appendix A1: Overview of Distribution System Earthquake Experience Data

A1.1 Introduction

The appendix provides an overview of the existing earthquake experience data and information on the seismic performance of distribution systems and the associated distribution system supports which have been subjected to strong motion earthquakes. This overview is provided for piping systems, cable tray systems, HVAC and fire protection systems.

A1.2 Piping Systems

A1.2.1 Background

Since the 1960's a great deal of detailed field data has been collected on the performance of piping in strong motion damaging earthquakes. These efforts have been sponsored by NSSS Vendors, the USNRC, EPRI and the US Department of Energy. Some of the more significant of these studies are references [A1] through [A15] of this Appendix. (Appendix A5)

A1.2.2 The Earthquake Experience Data Base for Piping Systems

The experience data base for piping systems consists of the following:

(1) Casual data from various, mostly older, reports on earthquakes pre-dating about 1979. These reports typically discuss only damage to piping, without elaborate discussions on the causes of damages and on the inventory of undamaged piping.

(2) Specific data from various, mostly newer, reports on earthquakes since about 1971. These data are typically of two types -- damage reports by the operators of facilities and investigation reports by outside earthquake engineers who visited and studied the affected facilities.

(3) Detailed reports include detailed data on the piping itself for a given facility, its performance, and all damage, including the causes of the damage. Such reports are typically based on a very detailed data collection effort at a specific facility.

The data base currently includes about 60 earthquakes, dating back to the 1933 Long Beach, California earthquake. Table A1.1 lists selected, more important earthquakes for which detailed data have been collected.

Damage and some inventory data have been collected for about 30 earthquakes. That includes about 200 industrial sites, and several hundred commercial structures that house piping. These facilities contain many millions of linear feet of pipe, over one million pipe supports and restraints (for lateral loads), many tens of thousands of piping components such as nozzles and elbows and thousands of valves. The strength of the data base is in the quantity and variety of piping configurations, piping runs, and support and ground motions.

Peak free field horizontal ground accelerations at affected data base facilities vary up to 1.0g, with durations of strong motion in excess of 60 seconds, as compared to a typical nuclear power plant SSE design basis of less than 0.25g and a duration of motion of 15 seconds. The magnitudes of the data base events vary from about 5.0 to more than 8.0. The data base piping is supported within a tremendous variety of structures, whose natural frequencies vary from very flexible (less than 1.0 Hz) to practically rigid (greater than 10hz).

The thousands of housed piping systems include a wide variety of support conditions, geometrical configurations, size distributions and all other piping system variables. The natural frequencies of these systems vary from extremely flexible (less than 0.25 Hz) to rigid. Further, the quality of construction of many data base systems is much lower than the quality of typical nuclear plant systems -- that is particularly true of the data base from foreign facilities and older petrochemical facilities.

The large majority of data base piping systems were not specifically designed for seismic loads. A few systems were dynamically analyzed and some were seismically designed using static approaches, a few systems were designed with sway braces and snubbers (although it is not clear that the snubbers were specified for seismic reasons). In newer plants, some earthquake resistance is typically provided through motion limiters (such as gapped supports).

A1.2.3 Analyses of Piping Experience Data

Numerous analyses of the piping experience data have been conducted. Such analyses have typically addressed the failures in the data base piping and how these failures could be used, in conjunction with the inventory of undamaged pipes, to define design and review criteria.

Reference A11 summarizes all known damage andfailures to piping from earthquakes included in that data base through the 1985 Chile earthquake. These data are summarized in Table A1.2. Failures were defined as leaks, breaks, collapses, or loss of flow control. For above ground welded steel piping, failures were due primarily to seismic anchor motion (caused by movement of terminal end equipment, header movements at small branch connections, or differential movements between buildings). Deterioration of the wall thickness, progressive hanger failure, threaded fittings, and seismic interaction were also significant contributors to piping systems failure during earthquakes. Failures resulting directly from seismic inertia forces were not observed.

Given the fact that less than one tenth of one percent of the piping at risk demonstrated any failures as a result of earthquake loading, piping failure due to earthquake inertial loading does not appear to be an condition which should be given major consideration in the design of piping systems. To the extent that inertial failures may have occurred they appear to be related to non-ductile support designs or degraded conditions in the piping system.

Table A1.1 - Selected Larger Power and Industrial Facilities and Earthquakes Included in the Data Base

Earthquake	Facilities	Range of PGA(G)
1. Kern County, 1952, M=7.7	1 Power Plant	0.20 - 0.30
2. Alaska, 1964, M=8.2	3 Power Plants, 1 Commercial Facility	0.25 - 0.60
3. San Fernando, 1971, M=6.5	4 Power Plants, 4 Substations, 1 Hospital	0.20 - 0.50
4. Point Mugu, 1973, M=5.7	1 Power Plant, 1 Substation	0.10 - 0.20
5. Ferndale, 1975, M=5.5	1 Power Plant	0.35
6. Santa Barbara, 1978, M=5.7	1 Power Plant, 1 Substation	0.28 - 0.35
7. Imperial Valley, 1979, M=6.6	3 Power Plants	0.25 - 0.50
8. Humboldt County, 1980, M=7.0	1 Power Plant	0.25
9. Coalinga, 1983, M=6.7	5 Petrochemical Plants, 4 Natural Gas Plants, 1 Pumping Plant, 3 Commercial Facilities	0.25 - 0.60
10. Hawaii, 1983, M=6.7	1 Hospital, 1 Industrial Facility	0.15 - 0.25

Table A1.1 - Selected Larger Power and Industrial Facilities and Earthquakes Included in the Data Base (continued)		
Earthquake	**Facilities**	**Range of PGA(G)**
11. Morgan Hill, 1984, M=62	1 Chemical Plant, 2 Electronics Facilities, 2 Wineries, 1 Pumping Plant, 3 Commercial Facilities	0.10 - 0.50
12. Chile, 1985, M=7.8, 7.2	5 Power Plants, 3 Substations, 2 Refineries, 1 Chemical Plant, 3 Water Treatment Plants, 5 Commercial Facilities	0.25 - 0.60
13. Mexico, 1985, M=8.1, 7.5	2 Power Plants, 2 Large Heavy Industrial Plants, 1 Commercial Facility	0.15 - 0.30
14. Adak, Alaska, 1986, M=7.5	Power Plants, Substations	0.25
15. Desert Hot Springs, 1986, M=6.0	1 Substation, 1 Hydroelectric Plant	0.50 - 0.85
16. Chalfant Valley (Bishop), 1986, M=6.0, 5.5	4 Hydroelectric Plants, 3 Substations	0.20 - 0.50
17. San Salvador, 1986, M=5.4	2 Substations, 2 Pumping Plants, 1 Commercial Facility	0.25 - 0.70
18. Cerro Prietto, 1987, M=5.4	1 Power Plant	
19. New Zealand, 1987, M=6.3	2 Power Plants, 3 Steam Plants, 2 Substations, 2 Industrial Plants, 1 Water Treatment Plant, 3 Large Pulp and Paper Mills	0.30 - 0.50
20. Whittier, 1987, M=5.9	4 Power Plants, 4 Substations, 4 Data Processing Centers, 100+ Structures	0.20 - 0.70
21. Superstition Hills, 1987, M=6.3	2 Power Plants, 1 Industrial Plant	0.20 - 0.30
22. Loma Prieta, CA, 1989, M=7.1	5 Power Plants, 3 Substations, 7 Industrial Plants, 4 Water Treatment Plants, 2 Telephone Switching Centers, 2 Data Processing Facilities	0.10 - 0.50
23. Luzon, Philippines, 1990, M=7.7	4 Substations, 2 Industrial Plants	0.25 - 0.50
24. Costa Rica, 1991, M=7.4	2 Diesel Power Plants	
25. Cape Mendicino, CA, 1992, M=7.0	2 Power Plants, 1 Industrial Plant, 1 Data Processing Center	0.25 - 0.55

Table A1.2 - Piping Damage in Power Plants and Other Facilities

Category	Total Pipe Damage Cases	Power Plants	Other Facilities
Seismic Anchor Movement	142	15	127
Corrosion	8	7	1
System/Spatial Interaction	72	62	10
Non-welded Joints	153	46	107
Supports	74	40	34
Internal Equipment	34	34	0
Buried	450	5	445
Miscellaneous	87	10	77
Total	1,020	219	801

A1.3 Cable Tray Systems

Reference [A16] provides an extensive review of the seismic experience data base for cable tray and conduit systems in past earthquakes, along with the results of available shake table testing programs. The observations and conclusions from that report are as follows:

- Cable tray and conduit systems have excellent performance history in strong-motion earthquakes. They have a large capacity for withstanding seismic inertial loads, even though the supports and systems are almost always designed for gravity loads only.
- Available shake table test results support this observation. The damage from earthquakes to trays, conduit, and supports, have not compromised the structural integrity of the raceway systems. There is a high degree of redundancy in standard raceway systems that tolerates local damage without approaching structural collapse.
- At the acceleration levels expected for most U.S. nuclear plant SSEs, earthquake inertial loading should not be considered as a primary source for potential seismic damage as long as the support system (including the anchorage) is design to carry at least three times the deadweight load of the raceway system.
- The only structural system collapse due to inertial loads, at the UTC facility near Morgan Hill, occurred on an anomalous support configuration which is not likely to be found in nuclear plants. In spite of the severe structural damage, functionality tests performed after the earthquake showed that there was no damage to the cables.
- The only reported instance of damage to an electrical cable in a raceway, at the Pacific Bell Grand Central Station in downtown Los Angeles, occurred where a taut cable was routed over a rough cut sheet metal edge. The cable was found to be cut after the earthquake.
- The large capacity for withstanding seismic loads appears to stem from the many sources of nonlinear behavior in the response of cable tray and conduit systems. Primary mechanisms for the nonlinear behavior include slippage and rotation of friction and bolted connections, the minor yielding of ductile steel members and connections in the supports, and sliding and bouncing of cables.
- This large capacity for withstanding seismic loads applies to all cable tray and conduit configurations commonly found in power plants and industrial facilities. The high capacity does not appear to be sensitive to details in parameters such as construction, system layout, location within building structures, age or system complexity.

A1.4 Fire Protection and Sprinkler Systems

Based on Stevenson and Associates' investigations, the seismic experience with fire protection piping systems subjected to strong motion earthquakes is not as good as that for process pipe. Fire protection distribution piping and sprinkler systems should be installed using NFPA-13 and/or local building codes and requirements. These codes permit the use of materials, fittings, and support details that have not performed well in strong motion earthquakes. The items suspectable to failure in strong motion earthquakes include:

(a) cast iron and malleable iron pipe and fittings

(b) friction fittings

(c) thread joints and fittings

(d) multiple support types and details which are subjected to brittle failure such as: cast iron and lead sleeve anchors, beam clamps, small fillet welds, very short fixed end rods, and cast iron and malleable iron members.

NFPA-13 does provide seismic design criteria for lateral system bracing to address seismic inertial loadings and criteria to address seismic anchor motions. However, in reviewing the performance of fire protection systems, it is not clear that this seismic design guidance has been judiciously or appropriately applied. Fire protection systems also appear to be particularly susceptible to failures resulting from seismic anchor motions. These anchor motion effects include differential building joint motion, equipment motion, and especially large run pipe motions causing failures in branch lines. Also as these distribution systems exhibit very low frequencies and are subject to large inertial motions, spatial interacted issues are of significant concern. These large inertial motions can also induce spacial interaction failures in friction couplings and fittings, sprinkler heads, and brittle support members.

A1.5 HVAC Systems

HVAC systems designed to typical industry standards (SMACNA) have performed quite well when subjected to strong motion earthquakes. In general, the observed failures have been due to poor anchorage of the duct supports and large motions of inadequately supported or attached HVAC equipment.

Appendix A2: Survey of Damage to Fossil Plant Piping and Piping Supports Due to the 1994 Northridge Earthquake

A2.1 Overview of Northridge Earthquake

At about 4:31 A.M. on Monday, January 17, 1994 a Richter magnitude 6.6 earthquake struck a densely populated area in the San Fernando Valley, in northern Los Angeles. The main shock (epicenter) was located at about 34.217 degrees north latitude and 118.550 degrees west longitude, at a depth of about 15 km. This location is about 3 km southwest of the city of Northridge, California. Even though the magnitude was moderate, large vertical and lateral ground motions with a duration of about 20 seconds were recorded. The largest peak ground accelerations were recorded at the Tarzana Cedar Hill Nursery, where a horizontal acceleration of 1.82g and a vertical acceleration of 1.18g were measured about 7 km from the epicenter. At the Sylmar County Hospital the recorded peak ground acceleration was 0.91g. A ground acceleration spectra generated from the Sylmar County Hospital (about 15 km from the epicenter) site ground acceleration record revealed that the peak spectral acceleration exceed the UBC design spectra by a factor of 3.

The Northridge earthquake is considered the most destructive earthquake in California since the 1906 San Francisco disaster. It is also the third very destructive earthquake to occur in California in the last 25 years. (The first was the 1971 San Fernando Earthquake, the second was the 1989 Loma Prieta Earthquake south of San Francisco.)

Severe and wide spread damage occurred, including significant damage to structures very distant from the epicenter (32 to 49 km away). Damage has been estimated at up to $20 billion, more than 40,000 buildings were destroyed or damaged, with 57 deaths and 10,000 injuries. Included in the damage list are parking structures, roads and freeways, bridges, water distribution pipes, and building structures. The damaged building structures included unreinforced masonry, concrete, concrete tilt-up, wood, and steel frame construction. In addition, large vertical ground motions damaged unsecured components and equipment inside buildings such as computers, and electrical and mechanical equipment.

A2.2 Summary of Power Plants Surveyed for Damage

There are four fossil fired power stations within a 15 mile (24 km) radius of the epicenter of the Northridge earthquake which saw an effective[1] zero period ground acceleration (ZPGA) in excess of 0.15g. These stations are the Valley Steam Plant, the Glendale Plant, the Burbank Plants (Magnolia and Olive) and the Pasadena Station's Broadway units. Three of the four stations saw seismic inputs in excess of 0.2g ZPGA and sustained some damage. The Valley Steam Plant saw an estimated peak ground acceleration of approximately 0.45g which exceeded the estimated peak acceleration of about 0.3g ZPGA at this site during the 1991 San Fernando earthquake. The Pasadena Station, Broadway Units B1 and B3, with an estimated effective ZPGA of 0.17g suffered no damage. It should be noted, however that the Broadway units have seen larger accelerations in the past associated with the San Fernando-1991 and Whittier-1987 earthquakes. These earlier earthquakes tended to act as seismic proof tests for the facility. The other three stations saw accelerations which equaled or exceeded the accelerations caused by previous earthquakes.

Figure A2.1 shows the approximate peak horizontal ground accelerations observed at the Tarzana Nursery, the Sylmar Hospital, and the four power plants as a function of their distances from the epicenter. Two of the plants, Valley Steam and Burbank, saw ground accelerations in the 0.4g to 0.5g range.
The responses of these four power stations (except Pasadena) were reviewed in detail because they were subjected to a range of seismic excitations which are similar to the design or review earthquake levels which nuclear power plants located east of the Rocky Mountains would be expected to experience. In addition, the process piping in these plants was constructed to the ASME B31.1 Power Piping Code which has requirements similar to the ASME B&PVC

[1] Effective seismic accelerations are recorded on the foundations of relatively large monolithic structures located on relatively soft soils. These accelerations often are smaller than accelerations recorded at the free field ground surface on smaller instrument pads and provide the seismic in[illegible] to distribution systems supported by these stru[illegible].

Section III, NC and ND-3600 requirements used in the construction of most safety related piping in nuclear power plants.

Other non-power plant distribution systems such as building HVAC, electrical cable trays, municipal water distribution piping, and municipal gas distribution lines were also surveyed. These systems are designed and constructed to standards such as:

- •AISC-SCM
- •SMACNA
- •AISI-CFSDM

A2.3 Summary of Piping System and Piping Support Damage

A2.3.1 Valley Steam Plant

The basic damage in the four Valley Steam Plant units was limited to piping supports and none of the process piping experienced pressure boundary failure. The most severely damaged supports were horizontal sway braces used to laterally restrain large diameter piping. It was determined that approximately 20 such sway braces either ruptured or were badly bent.

A total of 10 lateral restraints or attachments of the restraints to the building or piping were broken. The failures observed in the structural attachments can be attributed primarily to poor or undersized welds. Ten lateral restraints were bent or buckled. One snubber and one sway brace were found to be over-extended. Of these numbers the following breakdown was observed:

(a) 2 broken rigid restraints for boiler steam drum (3-inch pipe struts)

(b) 4 broken structural attachments for Grinnell Sway Braces

(c) 1 broken Grinnell Sway Brace

(d) 8 bent Grinnell Sway Braces

(e) 3 broken exposed spring type sway braces

(f) 1 bent lateral restraint turnbuckle rod

(g) 1 buckled lateral restraint turnbuckle rod

(h) 1 over-extended Grinnell Sway Brace

(i) 1 over-extended snubber

Typical pipe support and boiler support damage is depicted in the photographs of the Valley Steam Plant, Pictures 1-23.

A2.3.2 Glendale Plant

In addition to damage to the unit 5 turbine, there were two cases of significant damage to piping at the Glendale Plant. Two of the five 24-inch vertical risers from the condenser to the cooling towers experienced a pressure boundary breech at the surface of the ground where the piping emerged.

A2.3.3 Burbank Plants

During the Northridge earthquake there was damage to the lateral seismic restraints for boiler components and to the Feed Water heater support pedestals but no damage to piping or piping supports was observed.

An after shock of Magnitude 5.3 occurring on March 20, 1994 caused a failure of a buried 60-inch diameter reinforced concrete main cooling pipe to the condenser from the cooling tower basin at the point of entry to the turbine building.

A2.3.4 Pasadena Plant

No damage was observed due to the Northridge earthquake.

A2.4 Detailed Description of Piping System and Support Damage

A2.4.1 Valley Steam Plant

The Valley Plant units 1 & 2 are normally left in cold stand-by status. At the time of the Northridge earthquake all four units were shut down. However, all of the 4 units were brought back into service in approximately 4 hours following the earthquake.

It should be noted that while there were many lateral seismic restraint failures on the piping there was no failure (loss of structural or leak tight integrity) of the process piping pressure boundary. Only minor damage was observed on vertical weight support hangers. In Unit 1 at elevation 960 a spring hanger was bent (Photographs of Valley Steam Plant, Item 32) but was still supporting the weight load as designed. In Unit 4 at elevation 935 a spring hanger cradle (Photographs of Valley Steam Plant, Item 79) for the cold reheat steam line was off the pad support. The other hangers on this line appeared to be taking the redistributed load and there was no noticeable sag in the line.

The spring type sway braces used for lateral restraint in the plant are the Grinnell type shown in Item 24 of the photographs of the Valley Steam Plant or the exposed spring type shown in Item 26. It is not clear when the sway braces were installed, but they appear to have been installed without any engineered design specification or procedures.

The restraint failures observed were of three types. The first and second types of failures were either bent rods or fractured rods. The fractured rods failed in tensile overload. In the third type of failure the support bracket welds failed allowing the brackets to bend and separate thus disengaging the pin support.

The welds used to attach the brace brackets to the structure show substandard workmanship as compared to the American Welding Society requirements and often were undersized. In addition, the sway braces and attachments were in many instances highly corroded.

The broken and damaged sway braces and sway brace structural attachments shown in Table A2.2 represent a significant percentage (approximately 25%) of the sway braces that were located on lines 10 NPS and larger. It appears that installation construction of the sway braces was not engineered and exhibited poor workmanship with significant corrosion in the "as found" condition. It is further interesting to note that most of the failed sway braces were apparently installed following the San Fernando-1971 earthquake in an effort to increase the seismic capacity of the piping. The stiffening of the piping via the sway braces may have been unnecessary and potentially detrimental. It appears that the stiffness added by the restraints shifted the piping response frequencies back towards the spectral peak thus increasing the load on the piping and supports. As the sway braces in the stiffened system failed under the increased seismic loading, the unrestrained piping became very flexible. The flexible piping then moved off the spectral peak and rode out the seismic event without pressure boundary damage. (See Figure A2.2)

Power plant boiler components in Units 1 and 2 (furnace probes) suffered minor damage as shown in photographs of the Valley Steam Plant Items 27 and 30. There was significant damage to seismic lateral restraints for the boilers in all four units (photographs of the Valley Steam Plant Items 18, 19, 33, 34, 35, 36, 37, 48, 49, 84, 85) which are hung from the power plant building roof structure. This type of suspended component construction is not typically found in modern nuclear power plants.

Damage to other plant components was limited to a broken deaerator gage glass in Units 1 and 2. (Photographs of the Valley Steam Plant Items 28 and 29.)

There was minor damage to the insulation and lagging on some main steam bottle drain lines in Units 1 and 2 and on the main steam line as it exits from the boiler penthouse in Unit 3. (Photographs of the Valley Steam Plant Items 21, 22, and 50.)

A drain line carrying condensate from the air conditioning unit in the chemical feed room for Units 1 and 2 failed. It appears that large lateral movement of the mechanical equipment imposed large anchor motions on the piping. (Photographs of the Valley Steam Plant Item 62.)

A flexible electrical conduit in Unit 1 was slightly deformed by impact from an adjacent pipe. The electrical circuit did not malfunction. (Photographs of the Valley Steam Plant Item 20.)

In Unit 1 the ground cable for the fuel oil heaters parted. (Photographs of the Valley Steam Plant Item 41.)

A2.4.2 Glendale Plant

At the time of the Northridge earthquake, Glendale units 2 and 5 were on-line. Unit 5 tripped on a low level alarm in the steam drum. At the same time the unit tripped there was a loss of offsite power. This condition left the unit 5 AC motor driven turbine bearing lubrication pumps unpowered and deprived the turbine bearings of lubricating oil during coast down. The babbit metal bearing liners were nearly worn through as the turbine coasted down. While the turbine casing filled with oil, hydrogen was also released. Had the babbit liners completely worn through, bearing seizure might have resulted. This would have provided an ignition source for the hydrogen and the accumulated oil in the turbine casing. The potential for a significant detonation and deflagration hazard was created.

Unit 2 also tripped on electrical overload due to excessive demand from the electrical grid. However, unit 2 had steam driven turbine bearing lubrication pumps and did not suffer any bearing damage during post-trip coast down.

Two of the five 24-inch diameter cooling tower risers from the condenser also suffered damage as shown in the photographs of the Glendale Plant, Pictures 31, 32, 35 - 37. In two of the five risers leakage occurred at the surface of the ground where the risers emerge. As can be seen in Picture 35 there was significant corrosion of all five risers under the concrete jacket at the failure site. The failures appeared to be due to large lateral motions of cooling tower components at the point where the piping attached. All five lines were subsequently repaired by welding a split steel jacket around the failure site as shown in Pictures 36 and 37.

Surprisingly, the control room suspended ceiling panels were undisturbed by the event. (Photographs of the Glendale Plant, Pictures 33 and 34.)

A2.4.3 Burbank Plants

At the Burbank Plant the Magnolia 3 and Olive 2 units were operating at the time of the Northridge earthquake. Both units were shut down because of a mismatch with the electrical grid demand. In addition, Magnolia unit 3 experienced a high vibration alarm on the turbine which is also a unit trip condition. There was cracking in the unit 1 feedwater heater concrete support pedestals. This damage is shown in the photographs of the Burbank Plants, Pictures 1-8.

The only other damage was to the boiler seismic restraints. Most of this damage was associated with the seismic stops (lateral restraints) for the boiler components that are suspended from the top of the building structure. A detailed description of the boiler damage is provided in a report by Riley Stoker dated February 23, 1994. [A21]

Piping and piping supports and restraints were undamaged as evidenced by photographs of snubbers and restraints on a steam line. (Photographs of the Burbank Plants, Pictures 9-20)

On March 20, 1994 an after shock of magnitude 5.3 caused a failure in the buried 60-inch diameter reinforced concrete main cooling pipe to the condenser from the cooling tower basin at the point of entry to the turbine building. There was a similar failure to this piping in 1977 which was not associated with an earthquake.

A2.4.4 Pasadena Station

The Pasadena unit B-2 was on line at the time of the Northridge earthquake. It tripped as a result of a load mismatch with the electrical grid, but was restored to on-line status in a few minutes as soon as a load match was achieved. The B-1 unit was in hot standby and unit B-3 was down for maintenance at the time of the earthquake.

The maximum ground acceleration at the Pasadena plant site was about 0.17g which is about 15% less intensive than the site experienced during the San Fernando-1971 earthquake or the Whittier-1987 earthquake. No damage was observed in the plant except that there was some distortion of the unit B-2 steel stack hold down flange due to possible rocking of the stack during the earthquake.

At the time of the earthquake, new additional hydraulic snubbers were being installed on the unit B-3 Hot and Cold Reheat lines. In the original construction, snubbers had been installed on the Main Steam line, but not on the Hot and Cold Reheat. The Main Steam snubbers were installed because of the results of a static seismic analysis of the piping (using an input acceleration of 0.2g) that was performed during the original design. In unit B-2, a new snubber had been installed on the Main Steam line adjacent to the boiler steam drum near the top of the boiler. This snubber was undamaged. None of the snubbers, their support steel or attachment brackets showed any signs of damage due to the seismic event.

A2.5 Other Distribution System Damage Summary

Observations in non-power plant facilities revealed extensive damage to fire protection spray piping, gas and water distribution pipelines, heating, ventilating, and air conditioning systems, and building mechanical equipment.

A2.5.1 Fire Protection Spray Piping

Many cases of sprinkler system damage were observed in buildings. Damage occurred when sprinkler heads punctured through the ceiling tiles introducing conditions for large relative movements between the sprinkler heads and the distribution headers. Several cases of broken seismic braces for the sprinkler distribution mains were also observed.

A2.5.2 Gas and Water Distribution Pipelines

Water and natural gas supply and distributions systems were affected by numerous pipeline breaks in the epicenter area. Breaks occurred in 54-inch, 84-inch, and 120-inch water lines, and repair required from 2 to 10 days. Large diameter welded steel water and gas lines failed in tension on one end and compression on the opposite end of a 1,000 foot-long block of soil that moved longitudinally down Balboa Boulevard. Welded joints failed as bells cracked. Bell and spigot joints separated. Pre-existing corrosion may have contributed to failures in some cases.

Three local water treatment plants suffered only minor damage. Many earthquake measures employed in their design worked successfully.

- The Jensen Water Treatment Plant had been heavily damaged in the 1971 San Fernando earthquake. Mitigation measures implemented at the plant since that time resulted in better performance in the Northridge event. One of two 84-inch welded steel water feeder lines cracked at a bell due to longitudinal movement.

- The Los Angeles Water Treatment Plant, in the San Fernando Valley, had minimal damage.
- The Castaic Lake Water Agency Water Treatment Plant experienced minimal damage, but the primary 54-inch treated-water transmission line feeding the Santa Clarita Valley had a failure rate of one break per mile. The pipeline is constructed of reinforced concrete.

Major gas line breaks were associated with ground rupture, not fault rupture. Initial reports indicated about 1,000 leaks and breaks in gas lines. Only 5% of these failures occurred in the transmission lines, with 95% occurring in distribution lines. Of the breaks in the low-pressure (<60 psi) distribution system, all of the damage occurred in steel components.

A2.5.3 Building Mechanical Equipment

At numerous locations, spring-isolated mechanical equipment mounted on building roofs moved from their foundations. Such damage was reported as far away as Hunington Beach (50 miles from the epicenter), where several rooftop units walked off of their vibration insulators. In some cases, the penthouses sheltering the equipment moved, causing electrical wiring or chilled water piping to break. Even seismically braced, spring-supported air-handling units supported on the roofs of buildings were thrown free from their supports. Factors contributing to these failures may have included amplified building motions, the use of non-seismic vibration isolation devices, and poor bracing of piping. Cooling towers welded directly to the roof support frames without spring isolation were undamaged. Rigidly supported emergency diesel generators, chilled water pumps and chiller systems performed well at the ground level.

A2.5.4 HVAC Ducts

No damage was reported for HVAC ducts in building structures.

A2.5.5 Electrical Cable Trays

No damage was reported for electrical cable trays in building structures.

A2.6 Conclusions

A2.6.1 General

In general, piping and piping supports in the surveyed fossil generating stations performed quite well and only two cases of pressure boundary failure were observed. Buried gas and water distributions systems did not fair as well and suffered numerous pressure boundary failures. Fire protection spray piping also suffered numerous pressure boundary failures.

In one plant, Valley Steam, numerous lateral restraints failed on one piping system.

No damage was observed in HVAC air ducting, or electrical conduit and cable tray systems.

A2.6.2 Piping

Piping pressure boundary failures observed in the Northridge earthquake along with their probable causes can be summarized in Table A2.2.

The conclusion is that ductile steel, weld-joined piping supported for weight in accordance with the spans recommended in ANSI B31.1 appears to have excellent resistance to seismic failure if adequate flexibility is provided to absorb any large anchor motions that may occur. Piping buried in the soil may fail due to large relative motions of the soil itself.

A2.6.3 Piping Supports

Of the four fossil generating stations surveyed, only the Valley Steam Plant suffered damage to piping lateral seismic restraints. These restraints had been installed in an effort to improve the seismic resistance of the piping, but were not engineered and exhibited poor installation workmanship. The failures may have been initiated by the stiffness added by the restraints which may have shifted the piping response frequencies back towards the spectral peak thus increasing the load on the piping and supports. As the sway braces in the stiffened system failed under the increased seismic loading, the unrestrained piping became very flexible. The flexible piping then moved off the spectral peak and rode out the seismic event without pressure boundary damage.

A2.6.4 Other Distribution Systems

No damage was observed in HVAC air ducting, or electrical conduit and cable tray systems.

A2.6.5 Considerations for Design Codes and Standards (For Supports Only)

A2.6.5.1 Observed Failure Modes

While data presented in this section dicusses overall distribution system performance during the Northridge earthquake relative to this program the focus is on distribution (primarily piping) supports. The failure modes observed for piping system supports were as follows:

- Under sized attachment welds
- Corrosion
- Bent rods due to compression buckling
- Ductile fracture of rods due to tensile overload

A2.6.5.2 Design Guidance

There are several design lessons to be learned from the observed support failures. They are as follows:

- Seismic restraints should not be placed on piping under the singular assumption that a more rigid piping system is better able to resist seismic loading. From the observations it appears that flexible piping is inherently more seismic resistant.
- The need for lateral supports on piping should be carefully determined from a realistic engineering analysis that considers the effects of both inertial and anchor motion loading.
- Support attachment welds must be adequately sized for the expected loading.
- Visual inspection of support attachment welds should be performed to assure that the quality level of AWS is achieved.
- Supports should be protected from the influence of corrosion.
- The selection of materials and the design practice for supports should be directed at providing conditions favorable to ductile failure. Thus if the supports do fail, the energy absorbed tends to protect the supported piping from damage.
- Supports and restraints for mechanical and electrical equipment must be designed to limit motion during a seismic event. This will mitigate the magnitude of anchor motions that must be absorbed by the attached piping.
- The design practice for HVAC ducting and electrical cable tray supports appears to be adequate.

Table A2.1 List of Damaged Lateral Supports at the Valley Steam Plant

Item	Unit	Type	Location	
			Elev.	Column
18	1	Broken boiler drum lateral restraint	1006	G6
19	2	Broken boiler drum lateral restraint	1006	G12
23	1	Broken structural attachment for Grinnell Sway Brace	1006	---
24	2	Broken structural attachment for Grinnell Sway Brace	1006	---
25	1	Broken Spring Sway Brace	992	---
26	2	Broken Spring Sway Brace	992	H12
31	2	Broken Spring Sway Brace	960	F12
38	3	Broken structural attachment for Grinnell Sway Brace	964	---
39	3	Bent Grinnell Sway Brace	954	---
40	3	Bent Grinnell Sway Brace	946	---
42	3	Broken Grinnell Sway Brace	930	---
43	3	Buckled turnbuckle rod for lateral restraint	930	---
44	4	Bent turnbuckle rod for lateral restraint	930	---
45	4	Bent Grinnell Sway Brace	945	---
46	4	Broken structural attachment for Grinnell Sway Brace	945	---
46	4	Bent Grinnell Sway Brace	945	---
47	4	Bent Grinnell Sway Brace	945	---
77	4	Bent Grinnell Sway Brace	1016	---
78	3	Bent Grinnell Sway Brace	1016	---
80	3	Bent Grinnell Sway Brace	930	---
81	4	Over-extended Grinnell Sway Brace	983	---
83	4	Over-extended snubber	915	---

Table A2.2 Probable Causes of Piping Pressure Boundary Failures

Failure Description	Probable Cause
Glendale Fossil Electrical Generating Plant, 20-inch Cooling Tower Risers	Large Anchor Motions, Corrosion
Valley Steam Plant Fossil Electrical Generating Station, HVAC Unit Condensate Drain	Large Anchor Motions
Fire Protection Systems in Buildings	Large Anchor Motions
Water Distribution Systems	Soil Movement, Ground Rupture, Mechanical Joints, Corrosion, Non-Ductile Materials
Gas Distribution Systems	Soil Movement, Ground Rupture

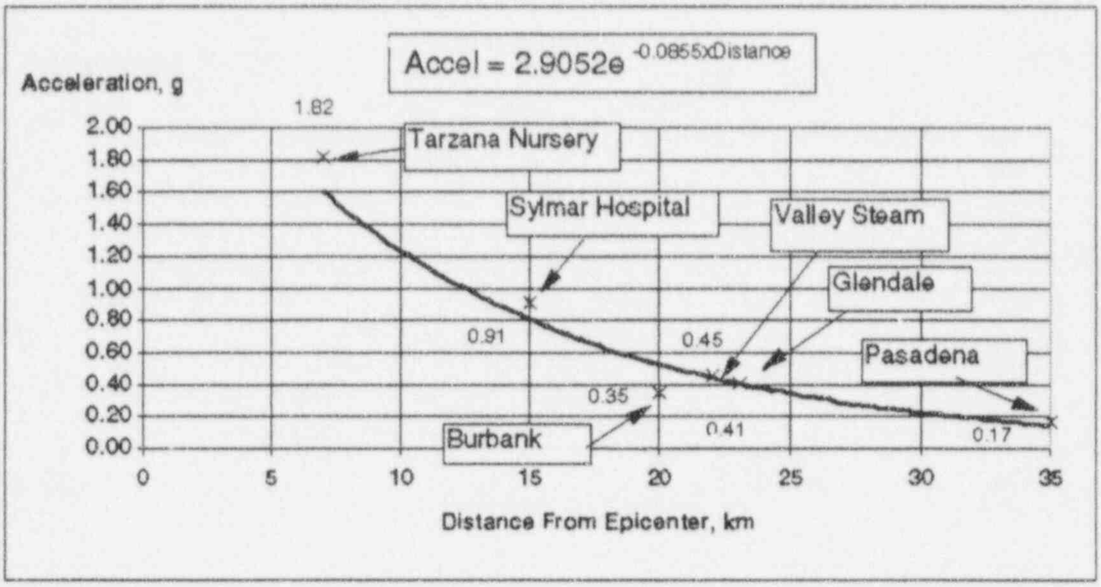


Figure A2.1 Site Acceleration Levels

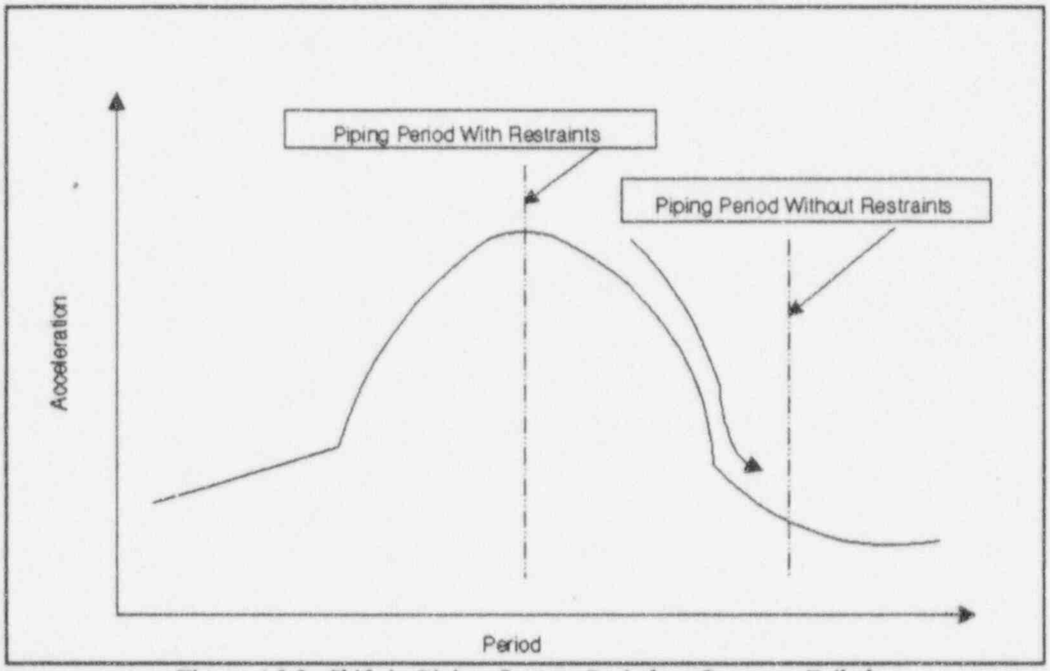


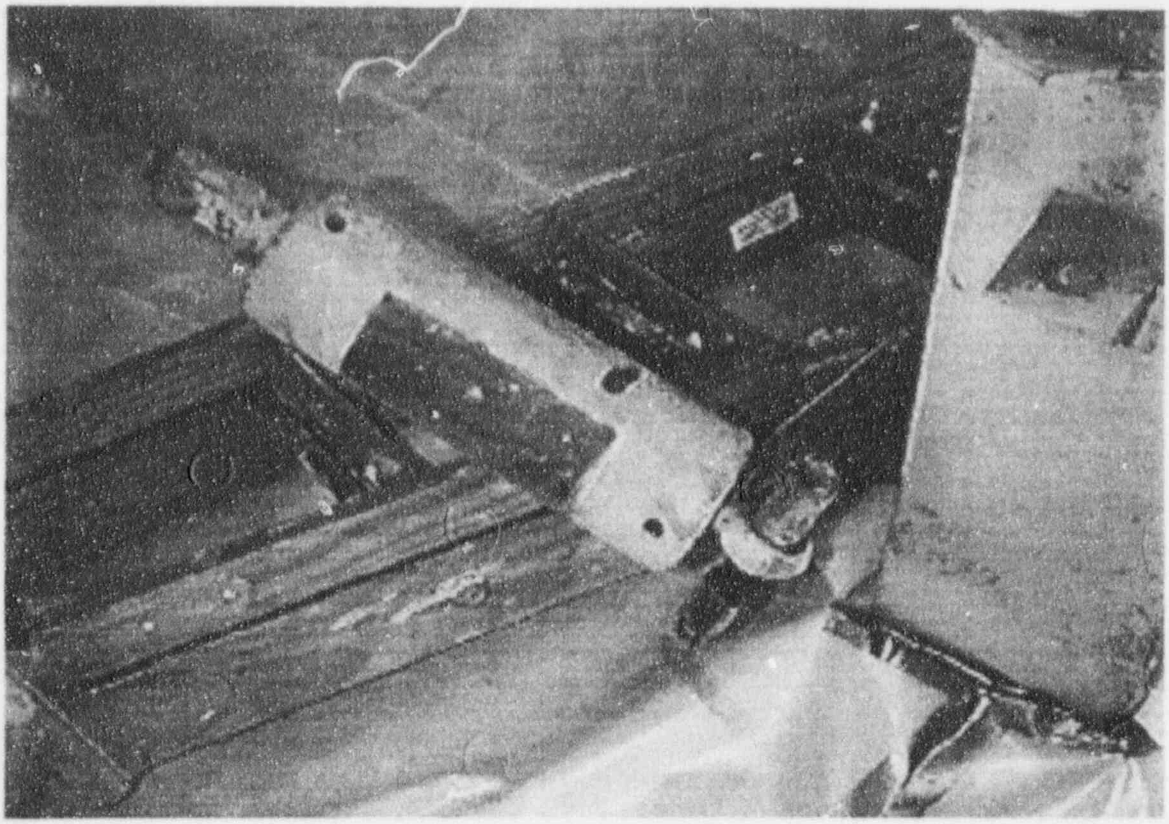
Figure A2.2 Shift in Piping System Period as Supports Failed

Appendix A2: Survey of Damage to Fossil Plant Piping and Piping Supports Due to the 1994 Northridge Earthquake

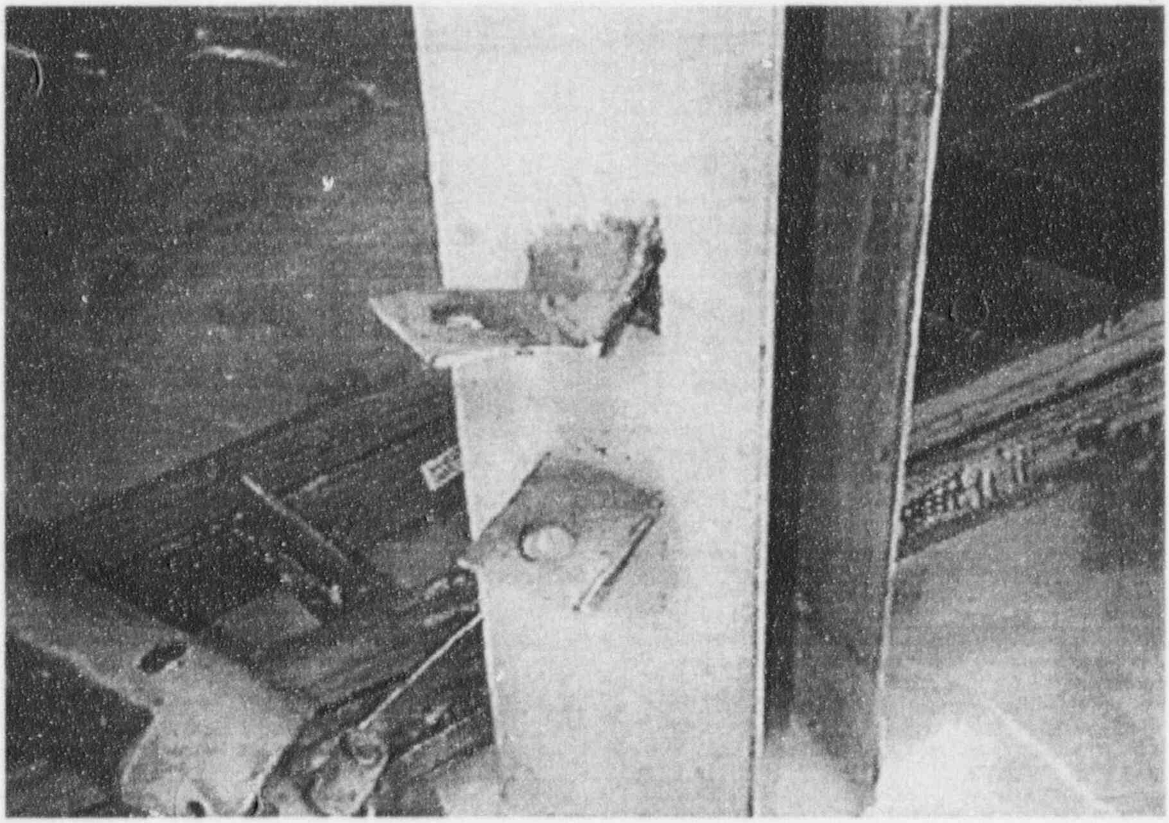
Photographs

Appendix A2: Survey of Damage to Fossil Plant Piping and Piping Supports Due to the 1994 Northridge Earthquake

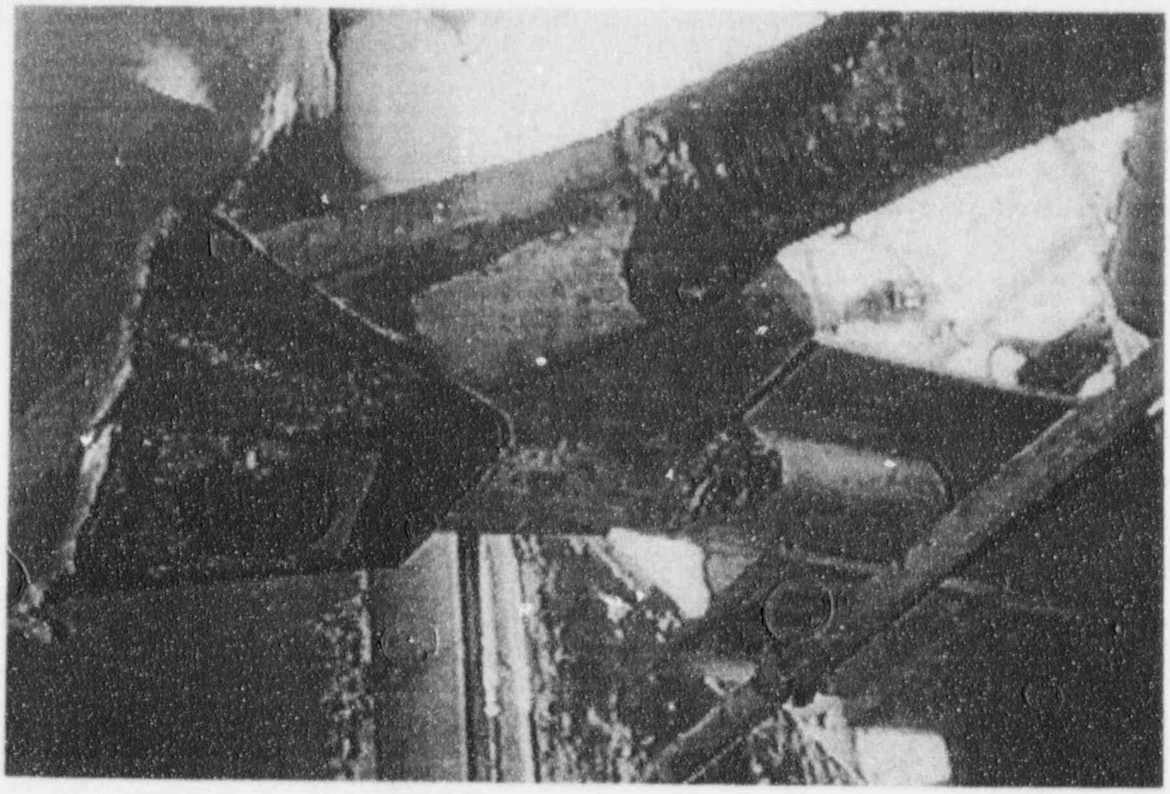
Valley Steam Plant
Pictures 1-23
Sway Brace Failures



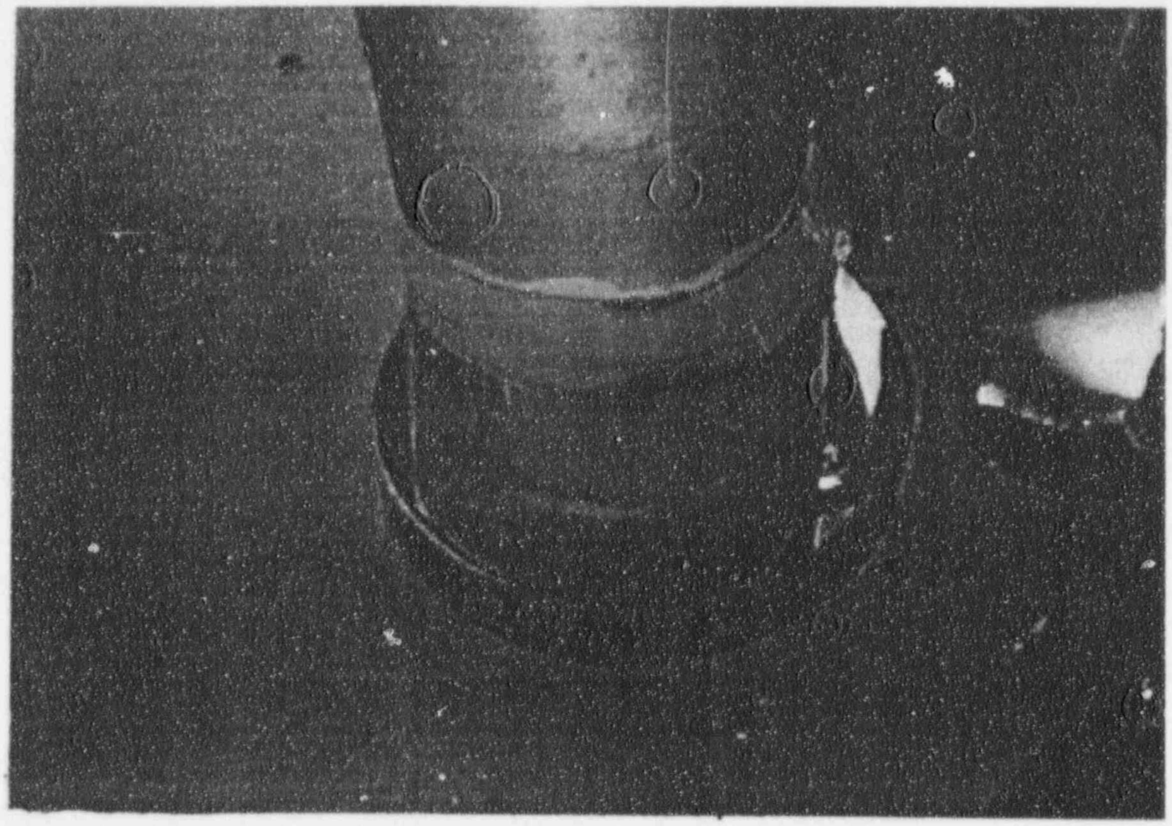
VALLEY STEAM: Picture1



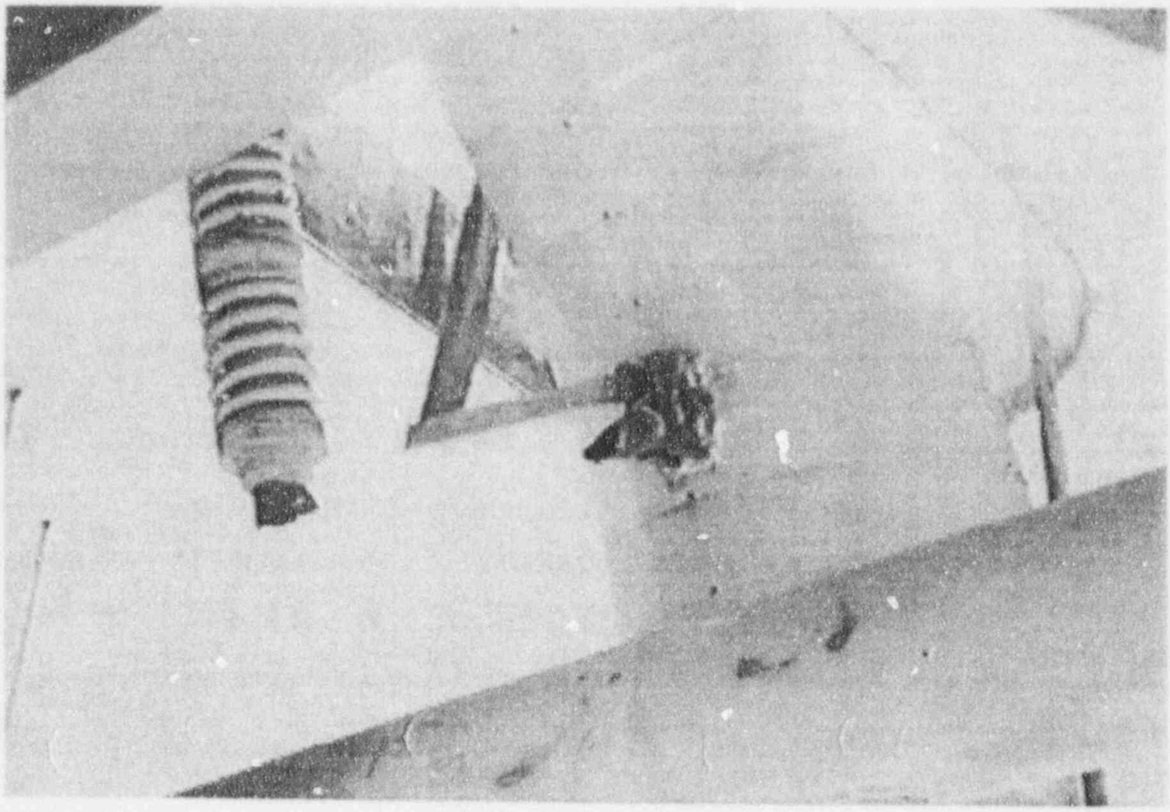
VALLEY STEAM: Picture2



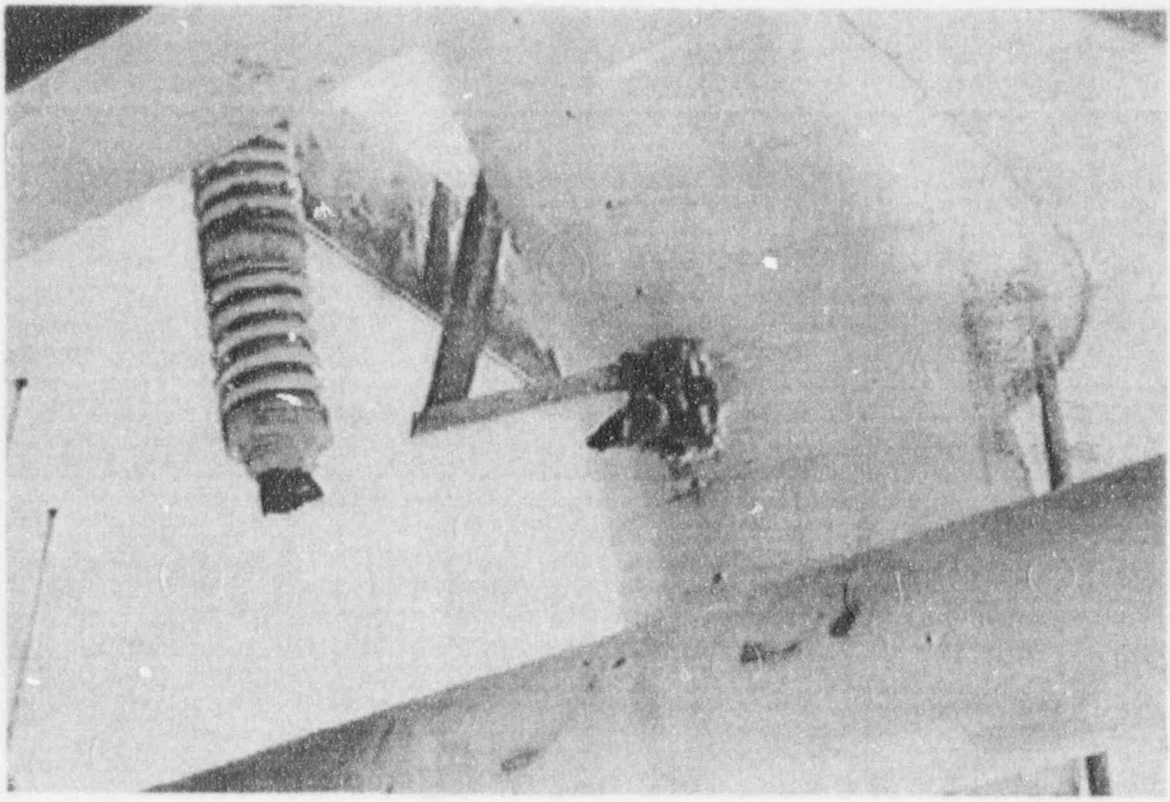
VALLEY STEAM: Picture 3



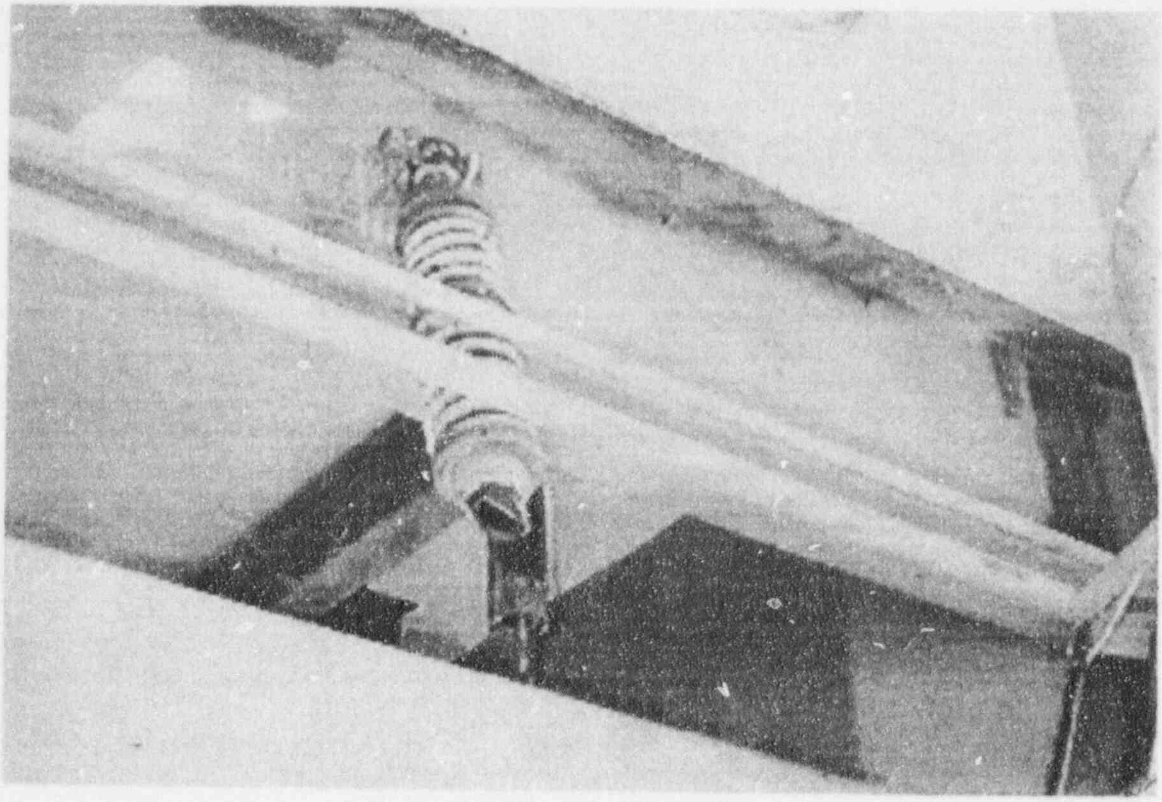
VALLEY STEAM: Picture 4



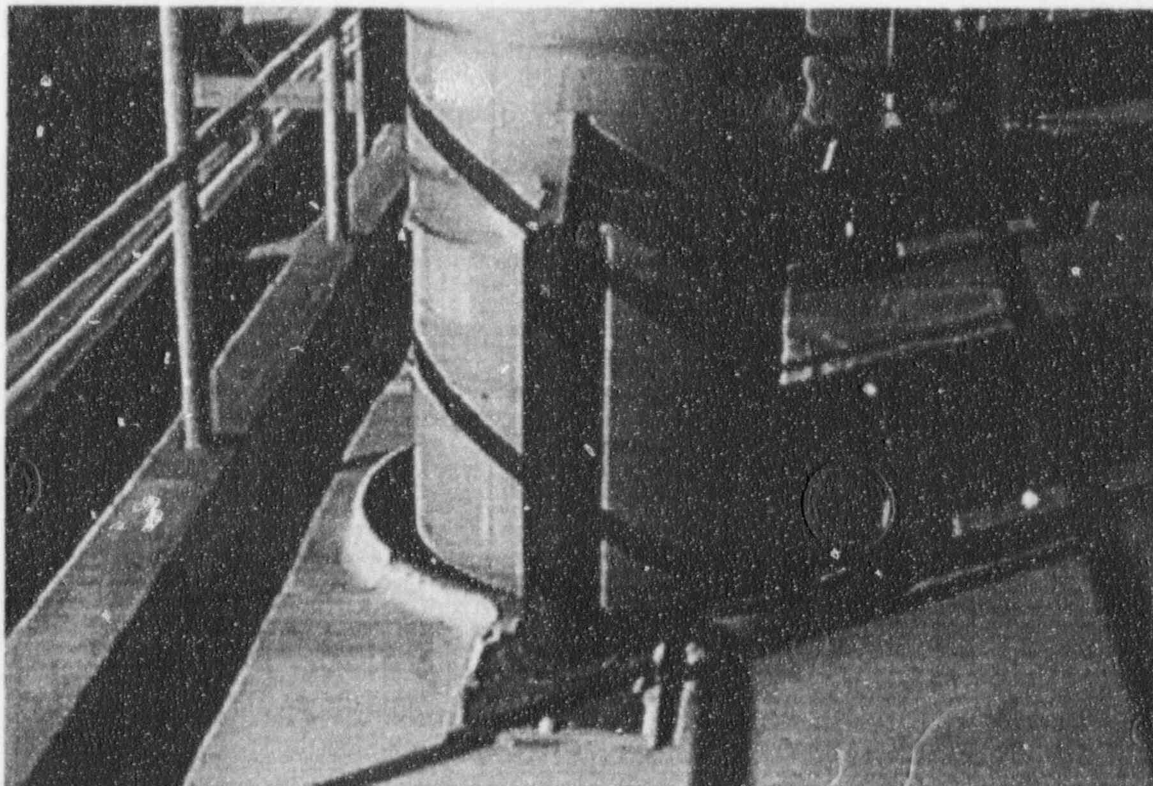
VALLEY STEAM: Picture 5



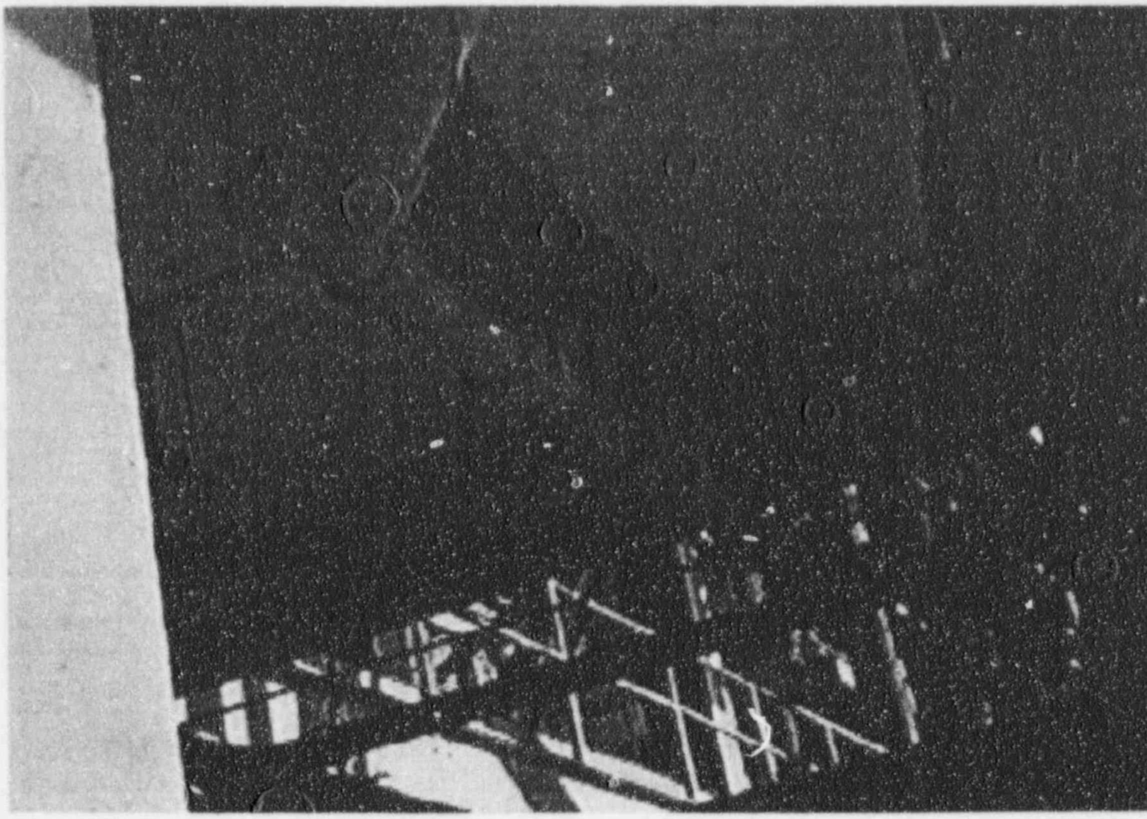
VALLEY STEAM: Picture 6



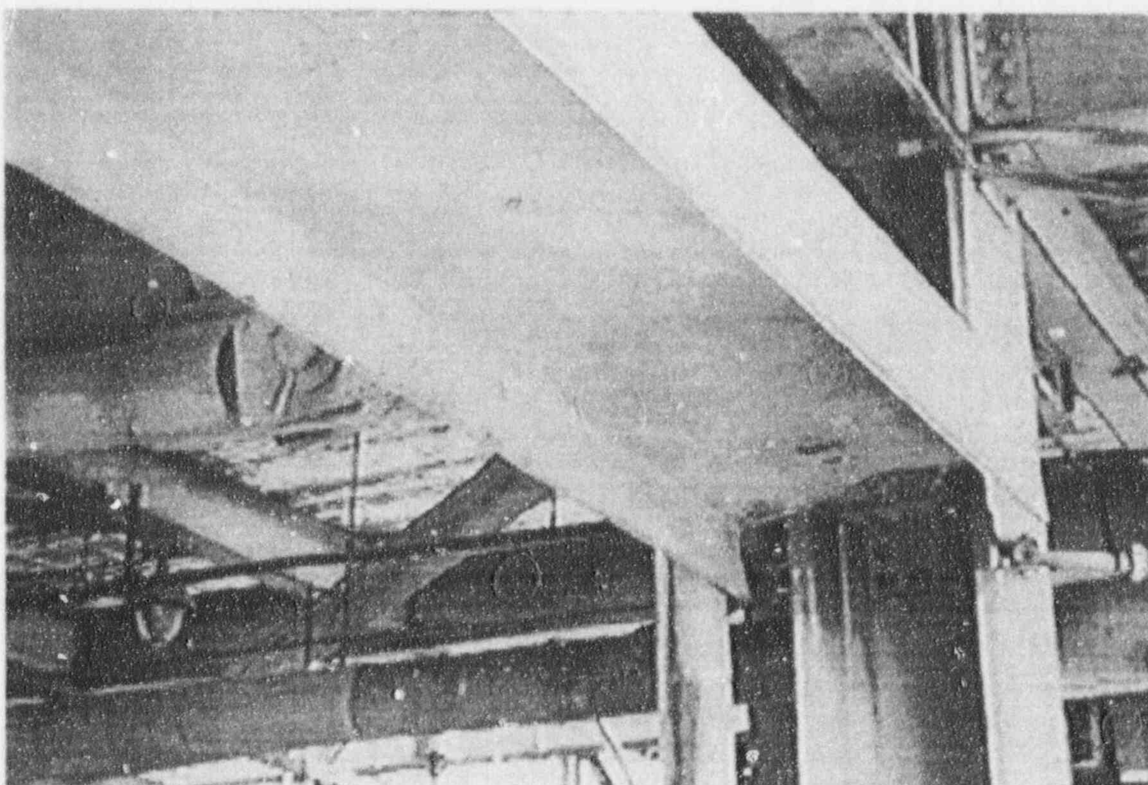
VALLEY STEAM: Picture 7



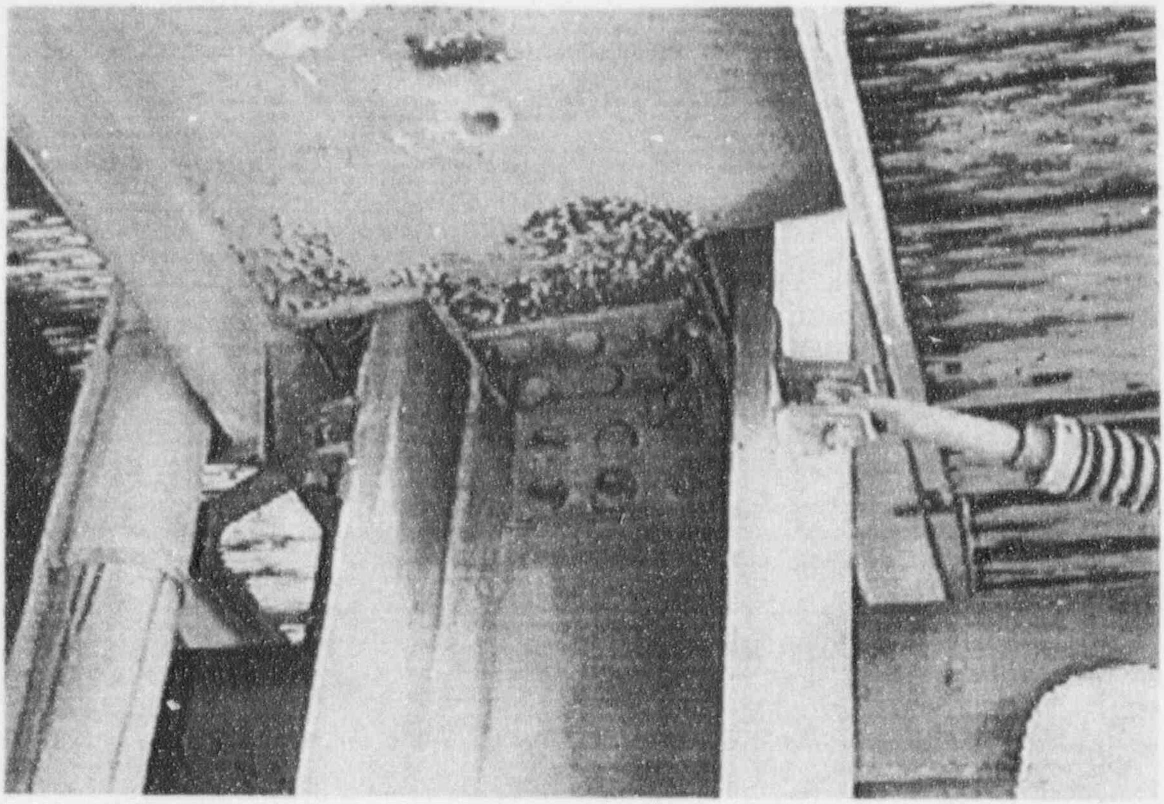
VALLEY STEAM: Picture 8



VALLEY STEAM: Picture 9



VALLEY STEAM: Picture 10



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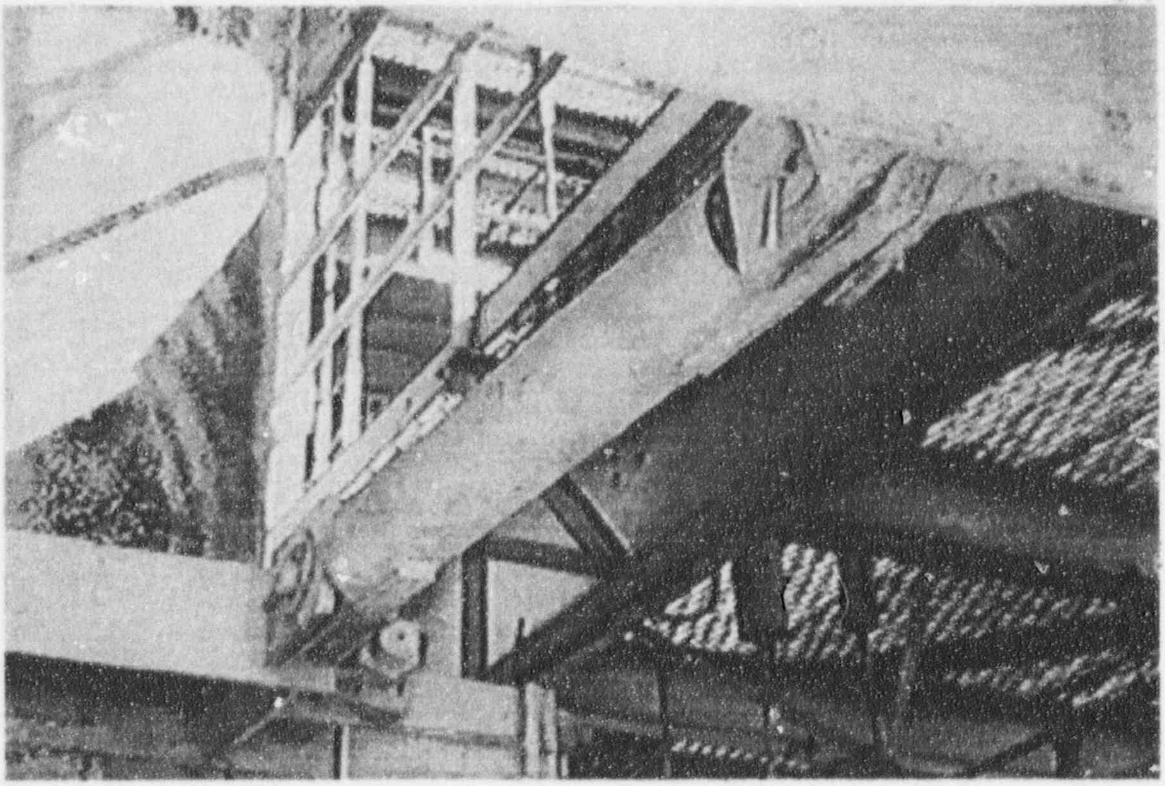
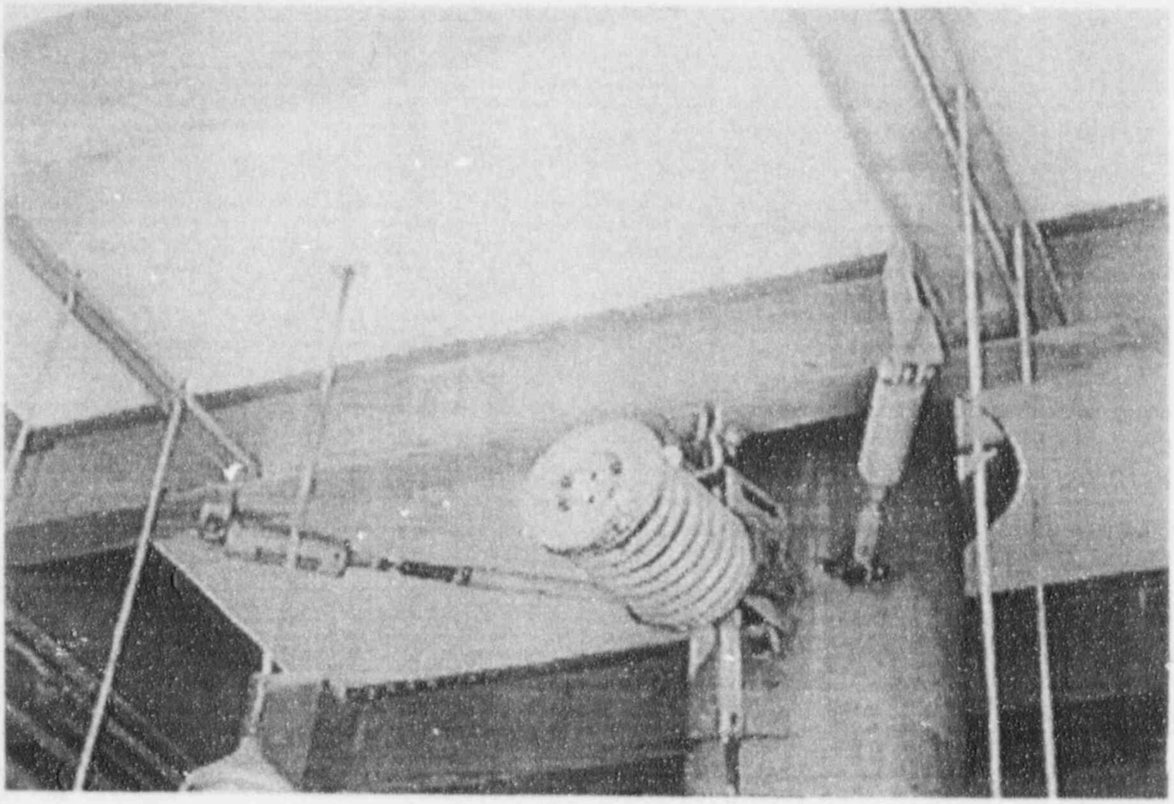
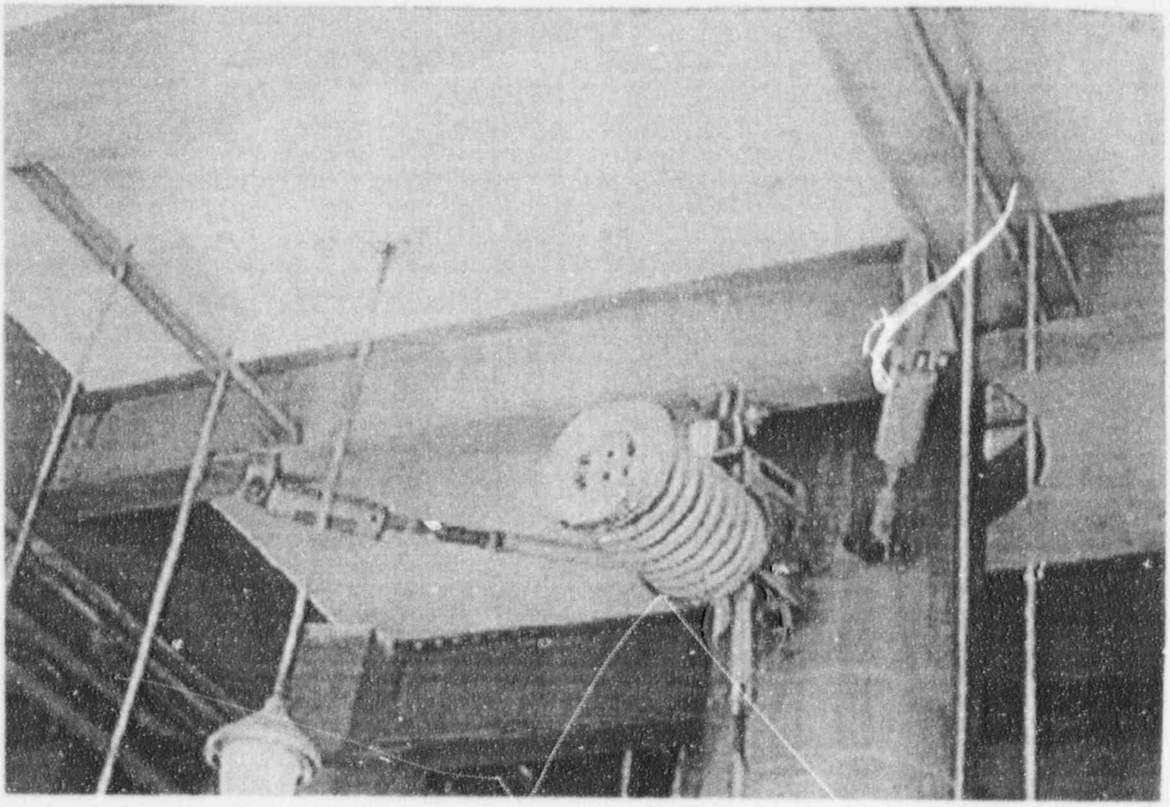


VALLEY STEAM: Picture 12



VALLEY STEAM: Picture 13



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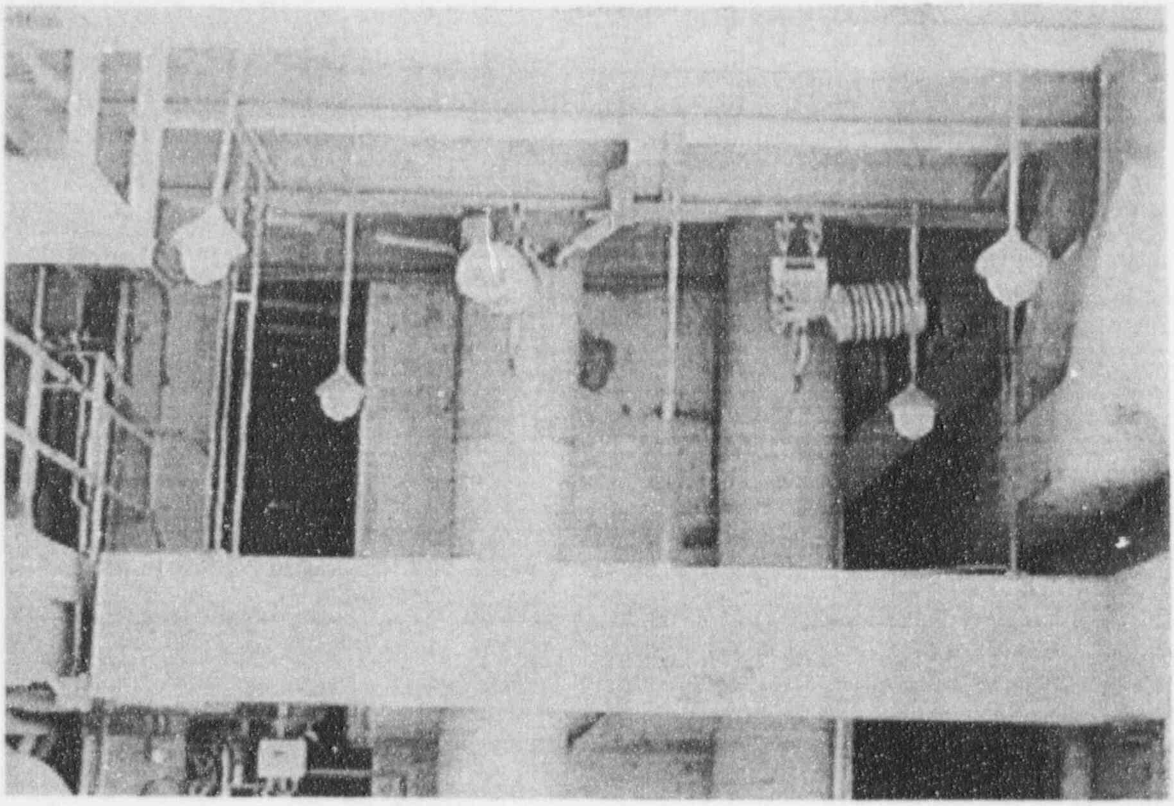
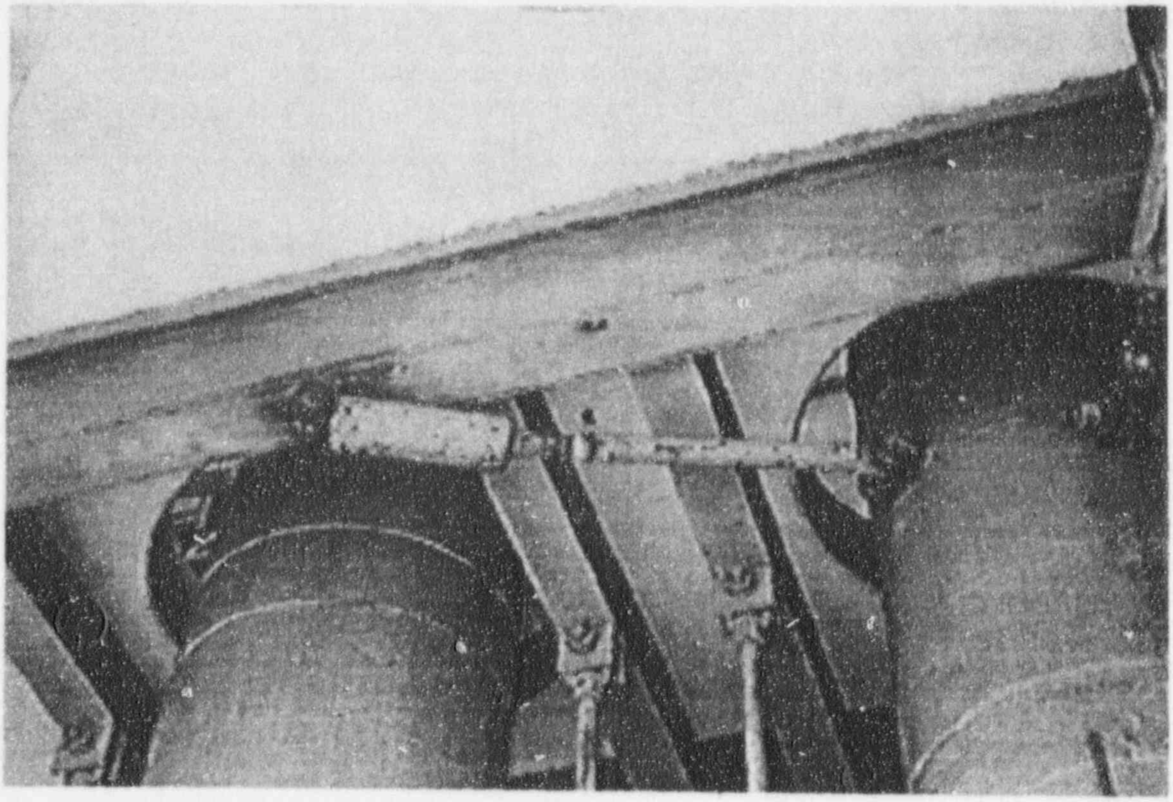
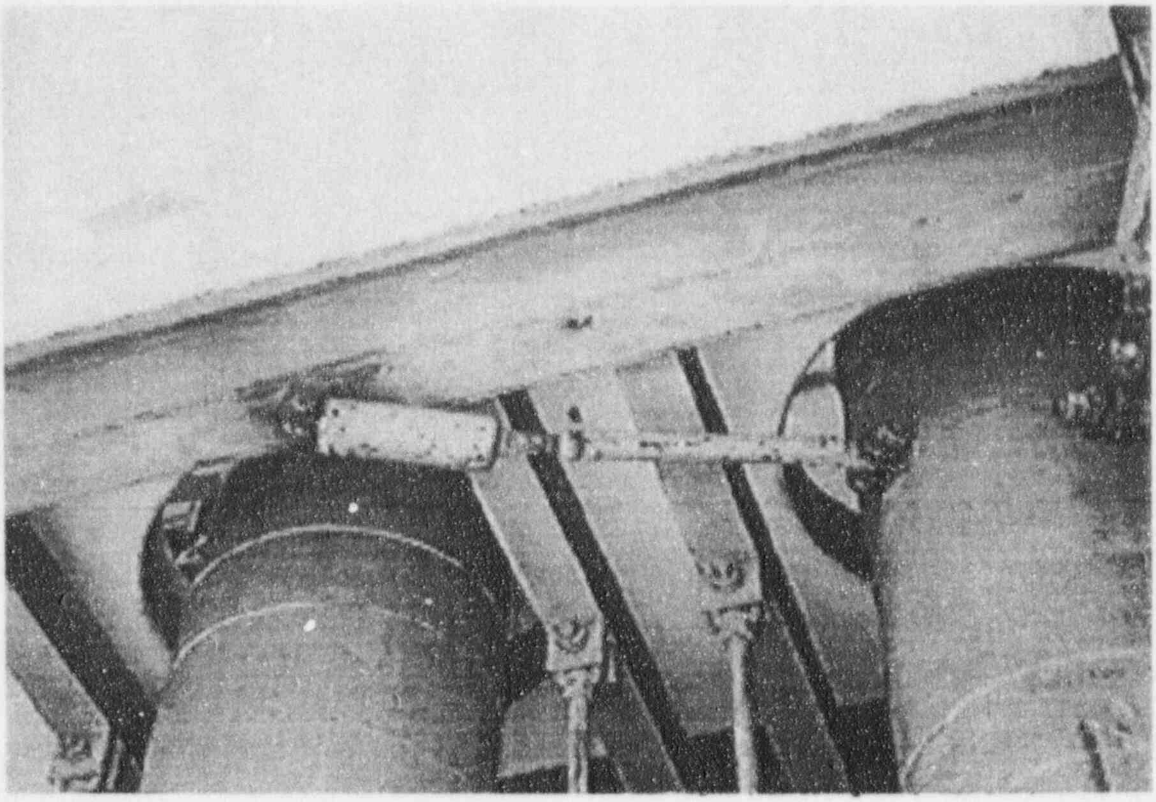


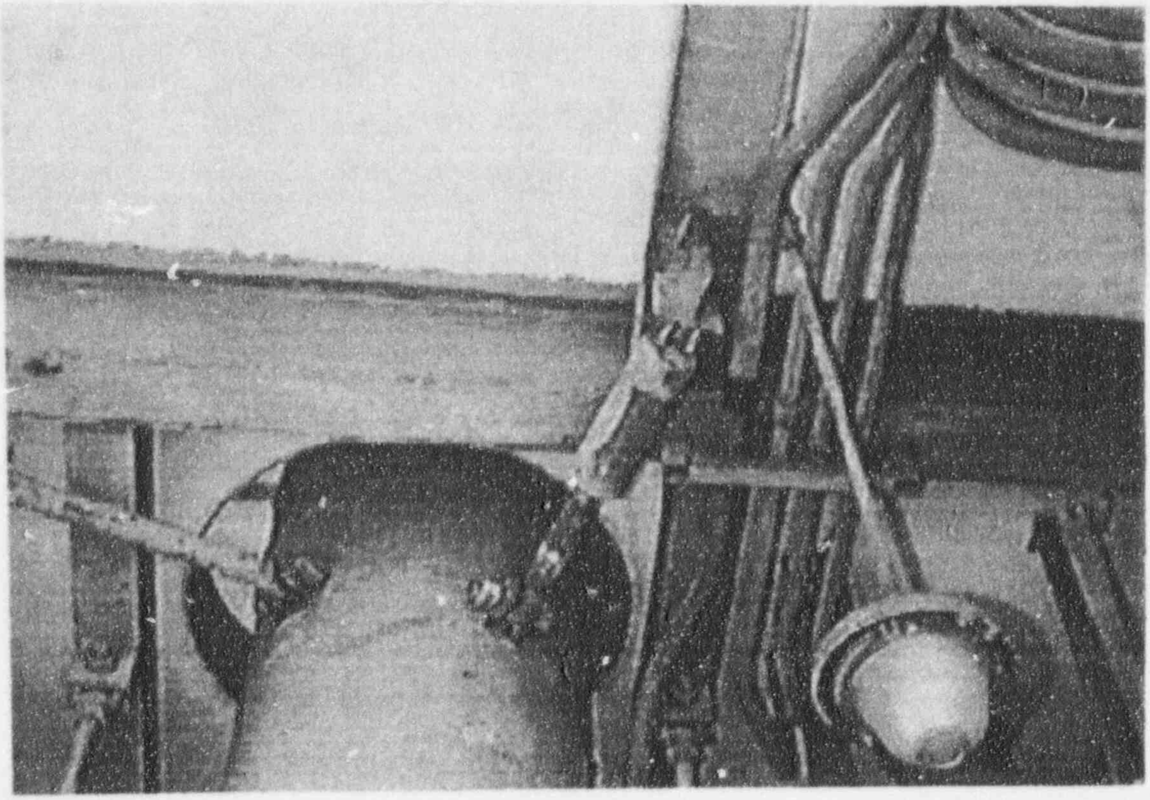
VALLEY STEAM: Picture 15



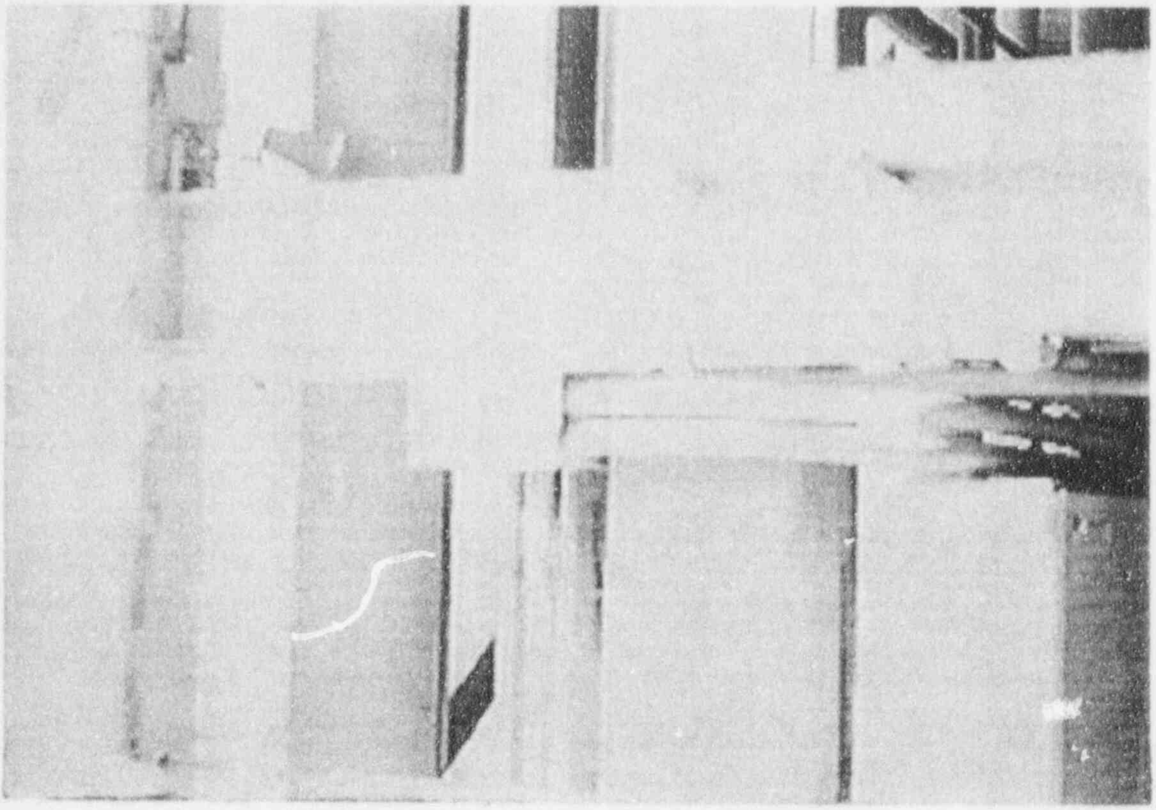
VALLEY STEAM: Picture 16



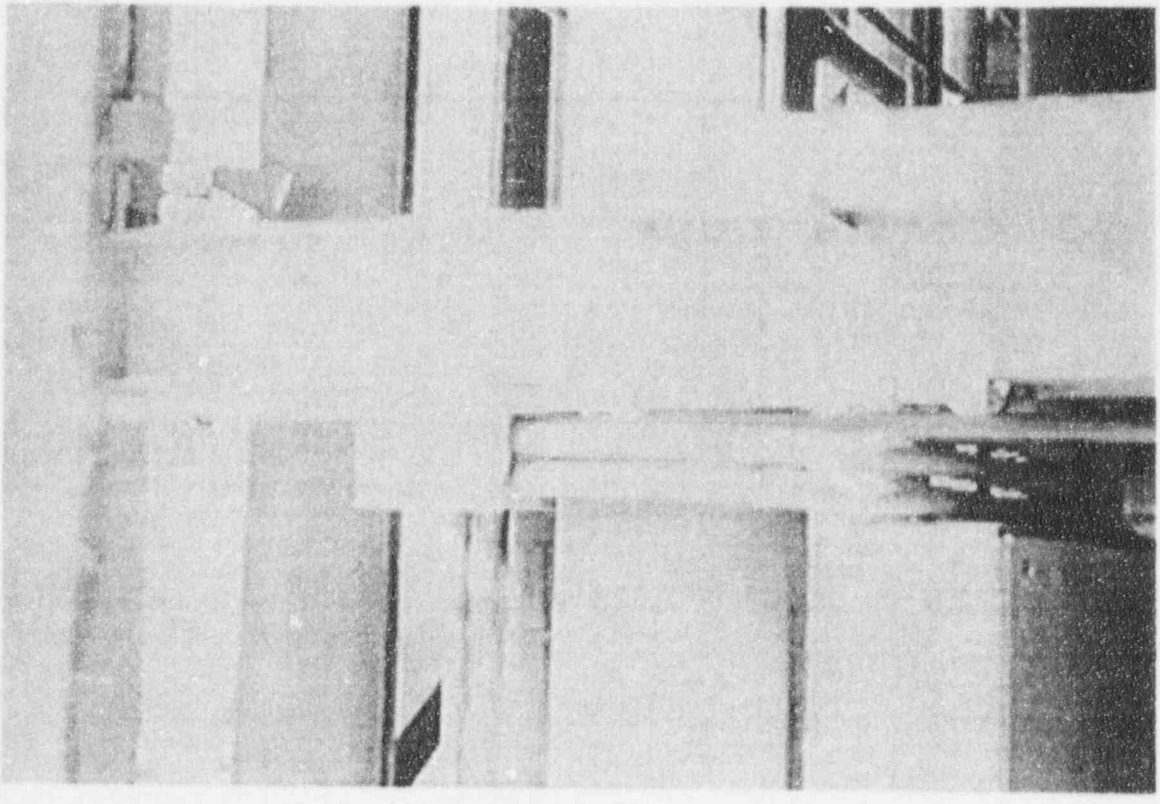
VALLEY STEAM: Picture 17



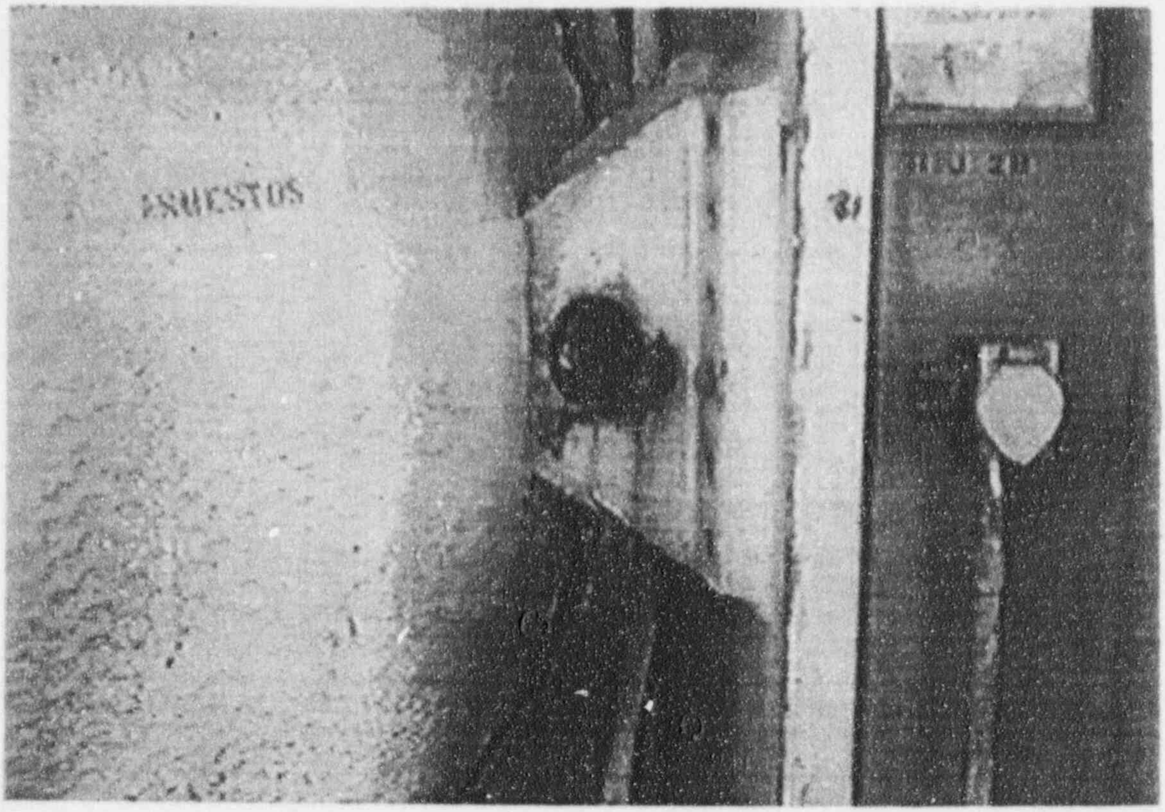
VALLEY STEAM: Picture 18



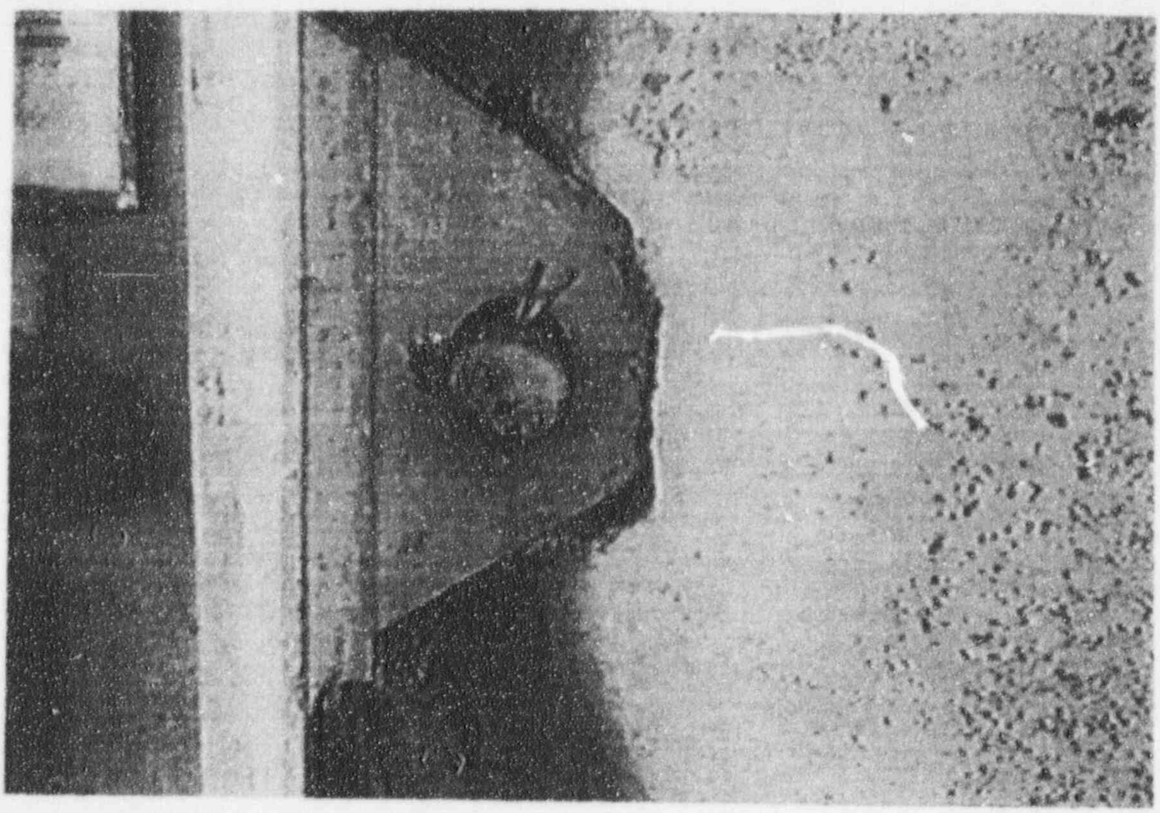
VALLEY STEAM: Picture 19



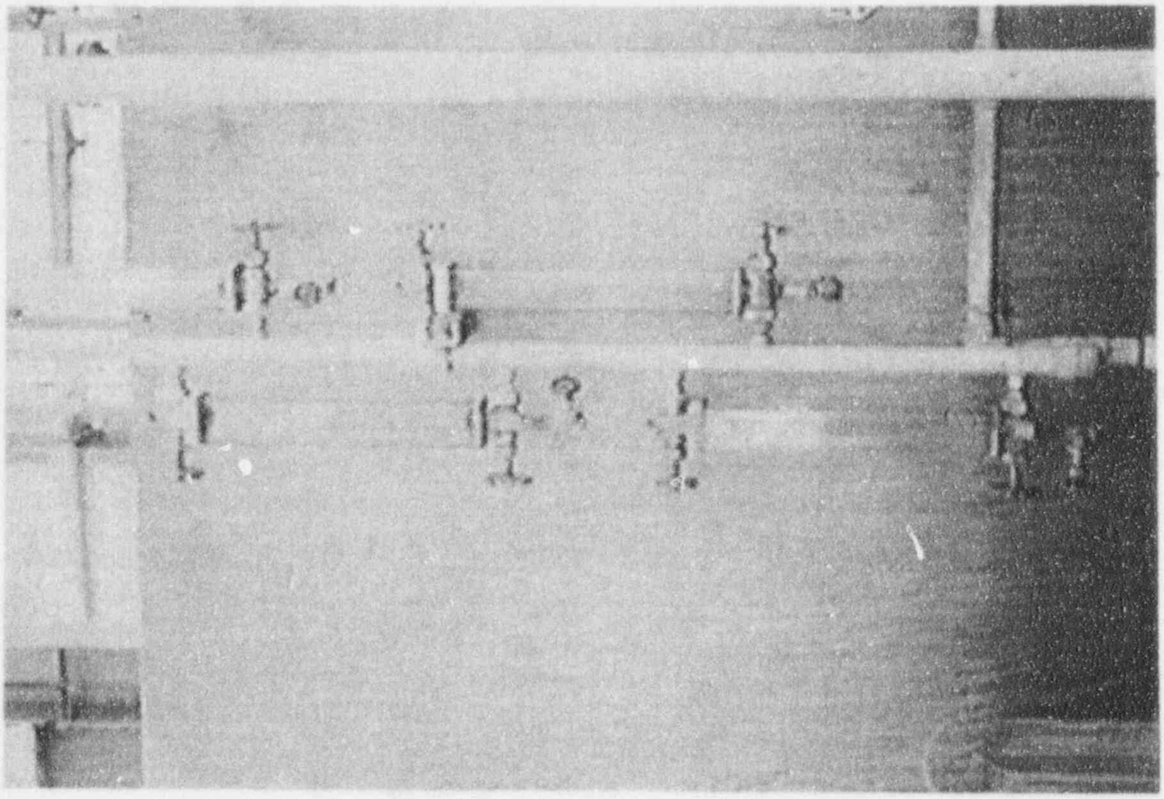
VALLEY STEAM: Picture 20



VALLEY STEAM: Picture 21



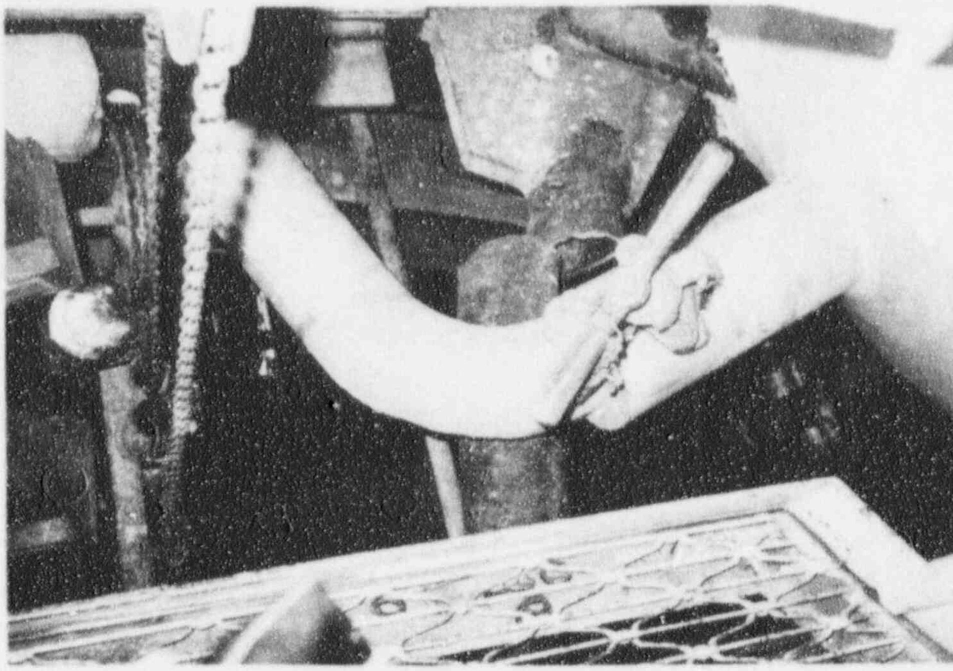
VALLEY STEAM: Picture 22



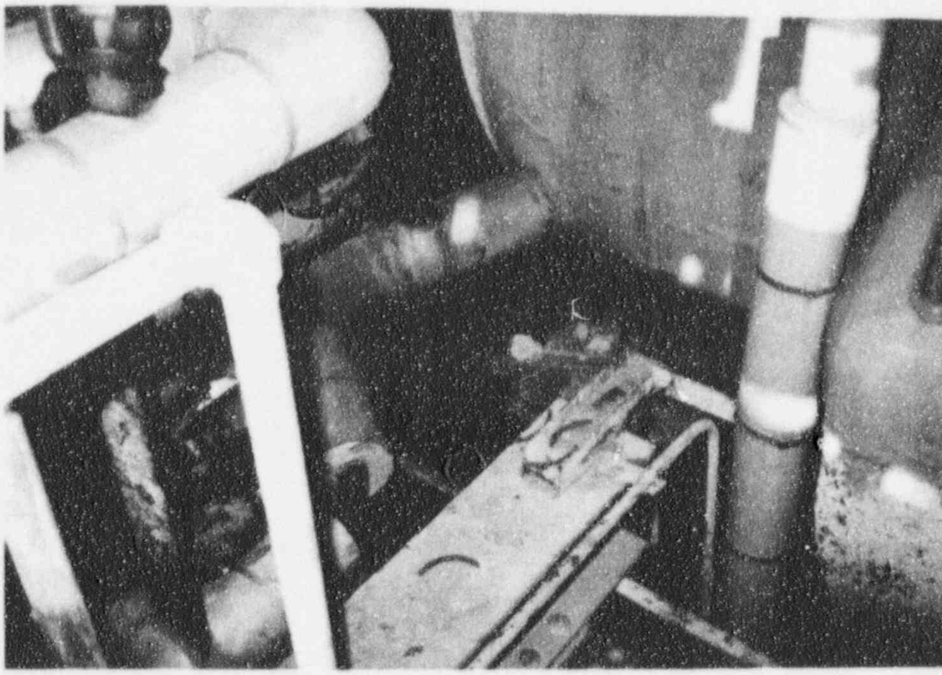
VALLEY STEAM: Picture 23

Appendix A2: Survey of Damage to Fossil Plant Piping and Piping Supports Due to the 1994 Northridge Earthquake

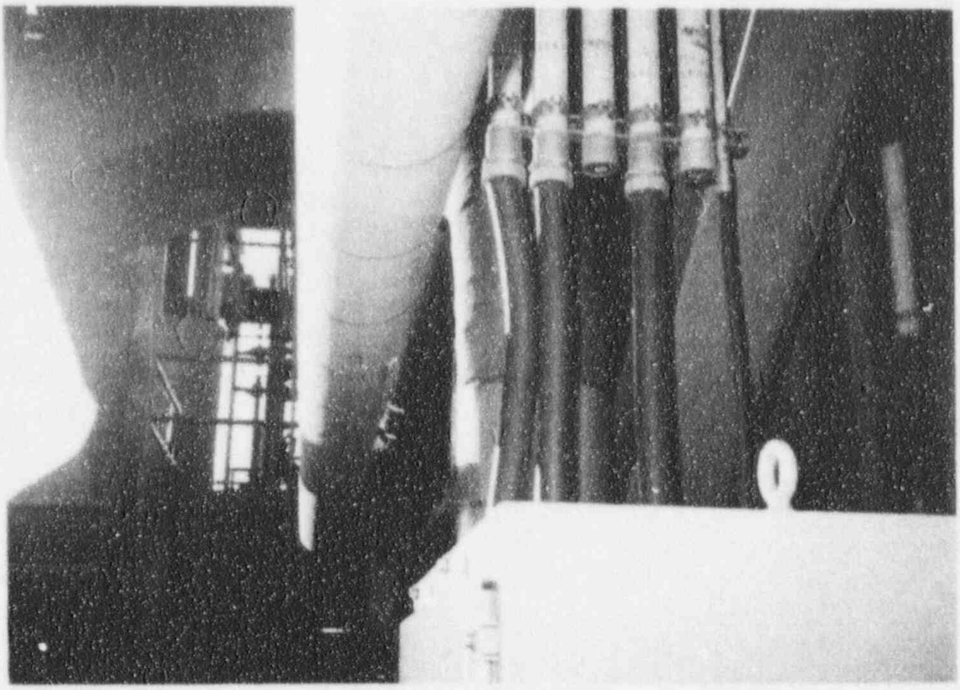
Valley Steam Plant
Items 18-50, 62, 63, 80-81, 83-85
Piping Support Failures, Steam and Condensate Drain Line Damage, Piping Insulation Damage, Gage Glass Shield Damage, Boiler Probe Damage, Boiler Buck Stay Damage, Boiler Drum Support Pin Damage, Ground Cable damage, Conduit Damage



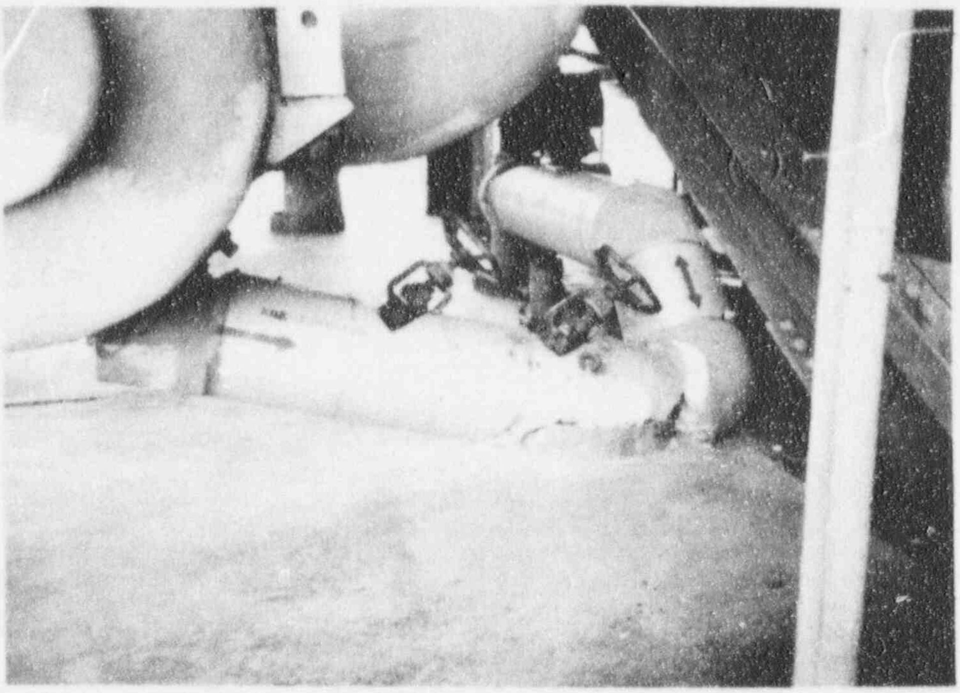
Item 18 - Unit 1 Elev 1006 Column G6 Lateral Seismic Supports Broken at Steam Drum



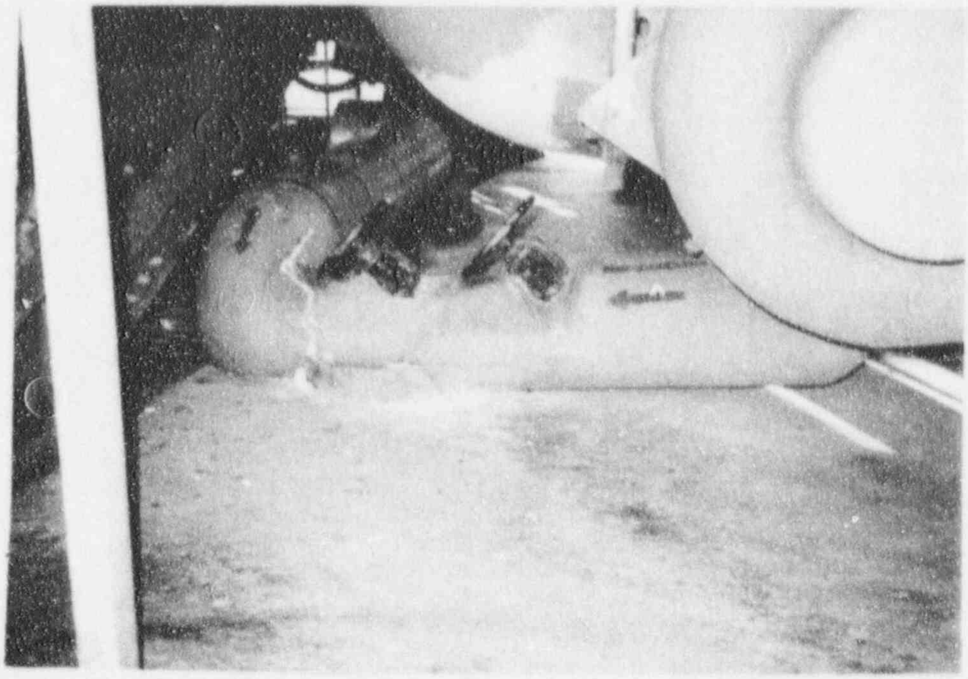
Item 19 - Unit 2 Elev 1006 Column G12 Lateral Seismic Supports Broken at Steam Drum



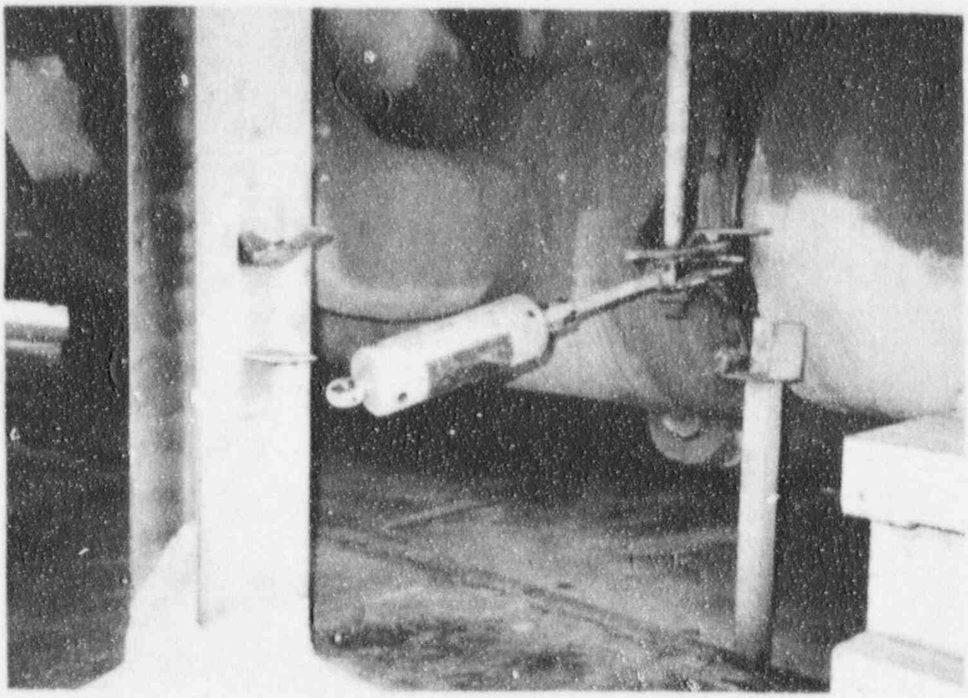
Item 20 - Unit 1 Elev 1006 Column J6 Flex Conduit Hit by Adjacent Pipe



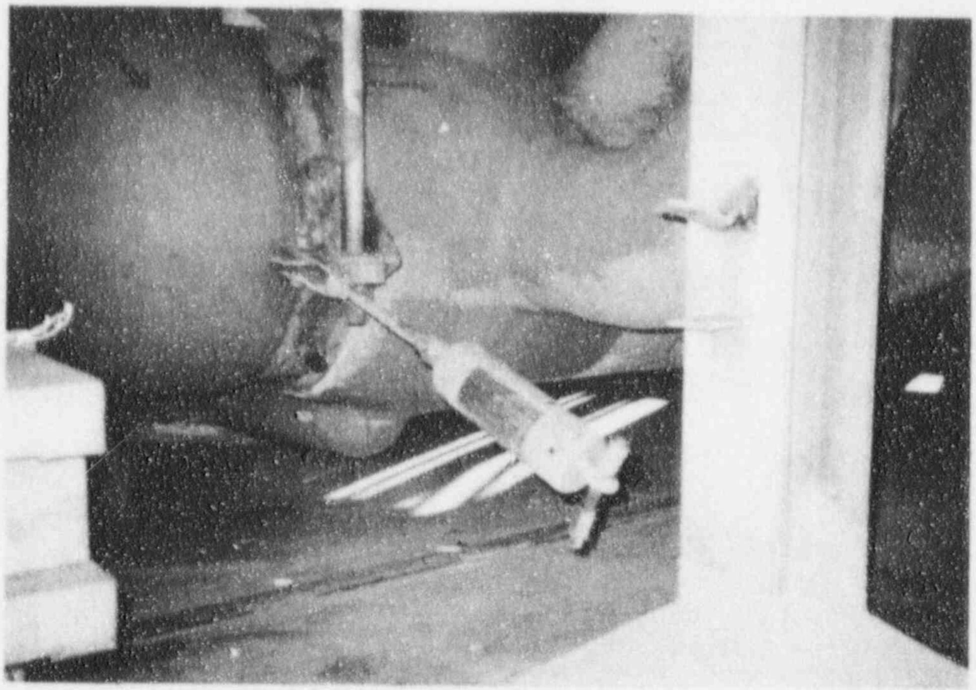
Item 21 - Unit 1 Elev 1006 Main Steam Bottle Drains Damaged



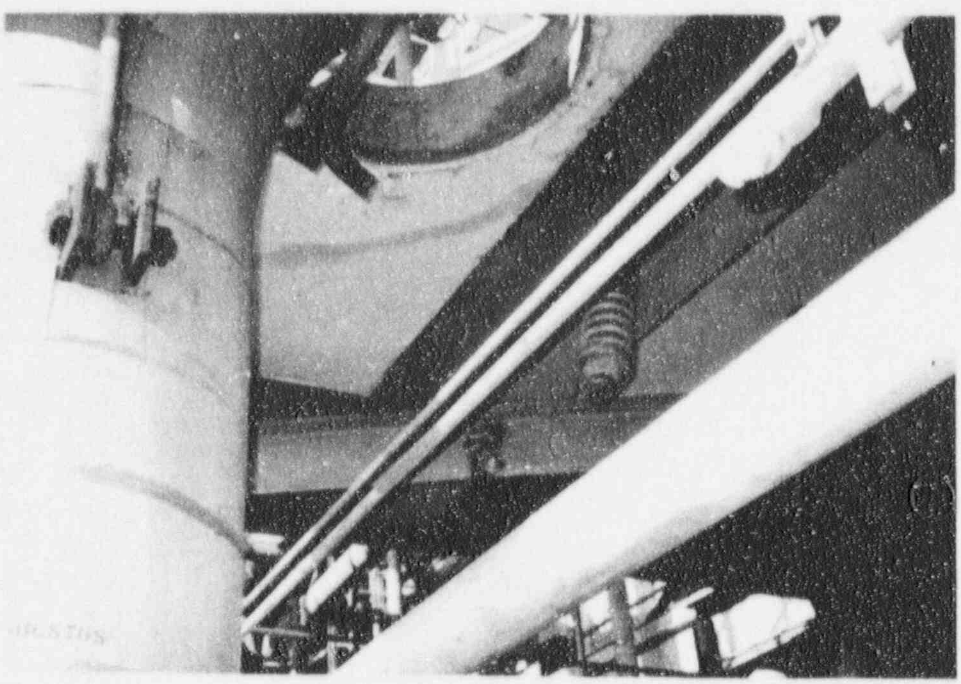
Item 22 - Unit 2 Elev 1006 Main Steam Bottle Drains Damaged



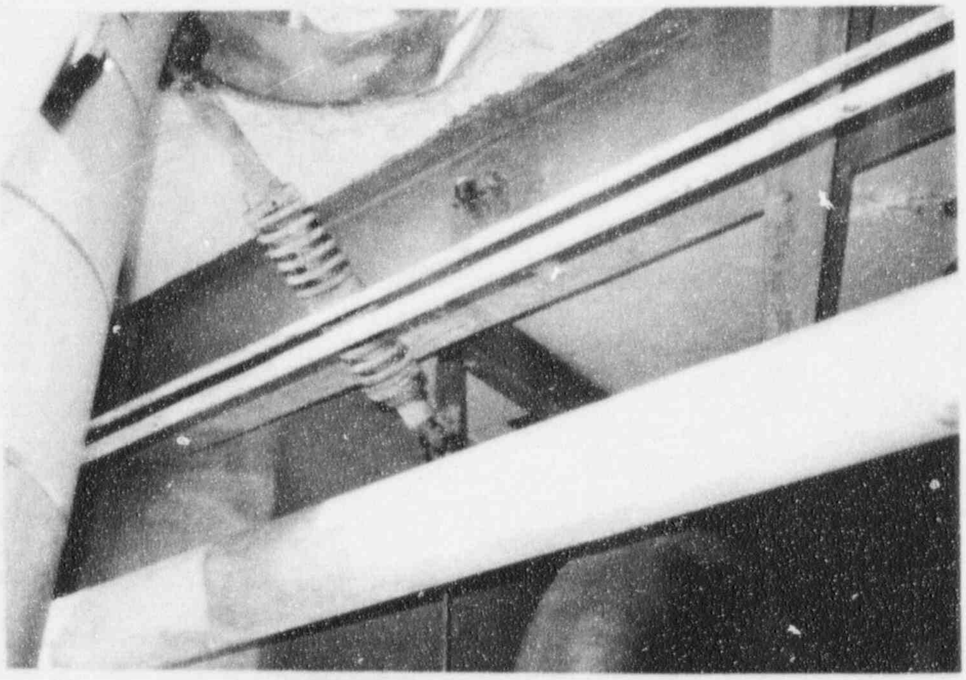
Item 23 - Unit 1 Elev 1006 Main Steam Bottles Broken Snubbers at North End



Item 24 - Unit 2 Elev 1006 Main Steam Bottles Broken Snubbers at North End

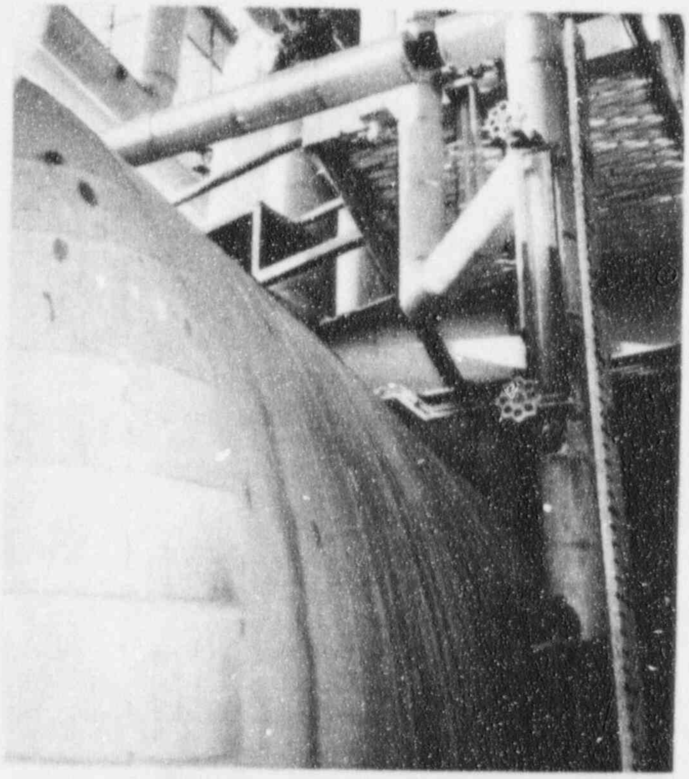


Item 25 - Unit 1 Elev 992 Snubbers Broken to Main Steam Line Where It Comes Through the Floor of 1006

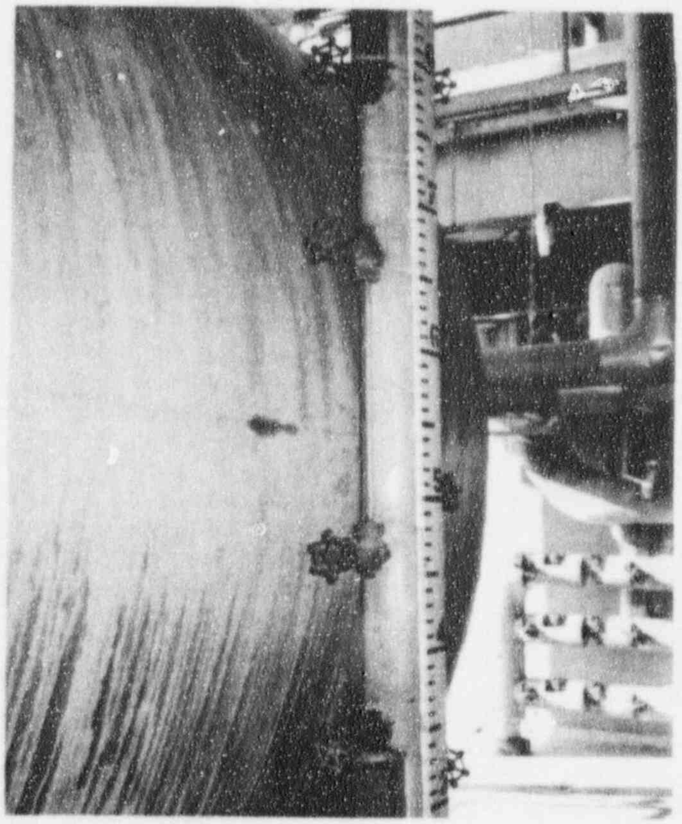


Item 26 - Unit 2 Elev 992 Snubbers Broken to Main Steam Line Where It Comes through the Floor 1006

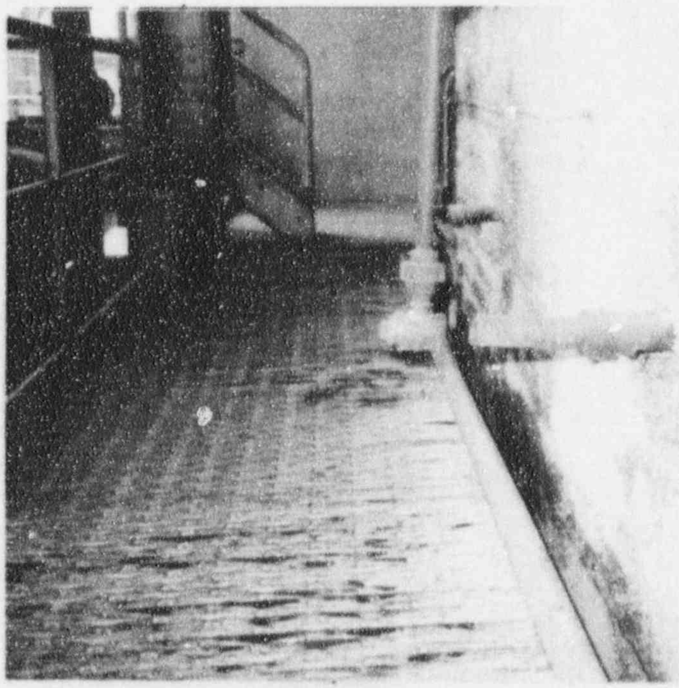
Item 27 - Unit 2 Elev 992 Column H12 Furnace Probe Pipe Broken Off



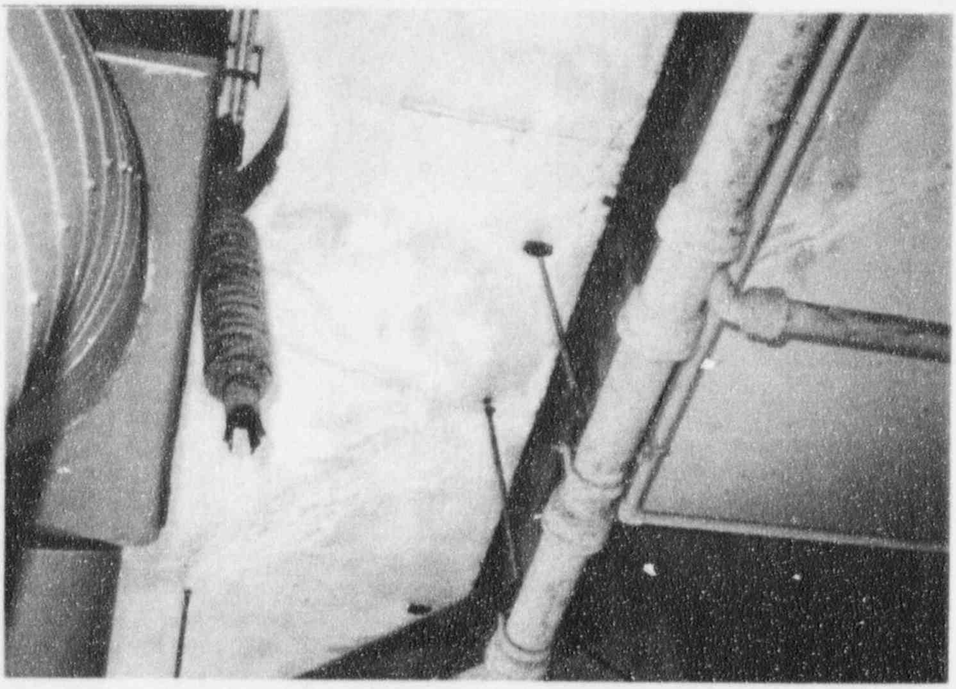
Item 28 - Unit 1 Elev 999 Dearator Gage Glass Shields Broken



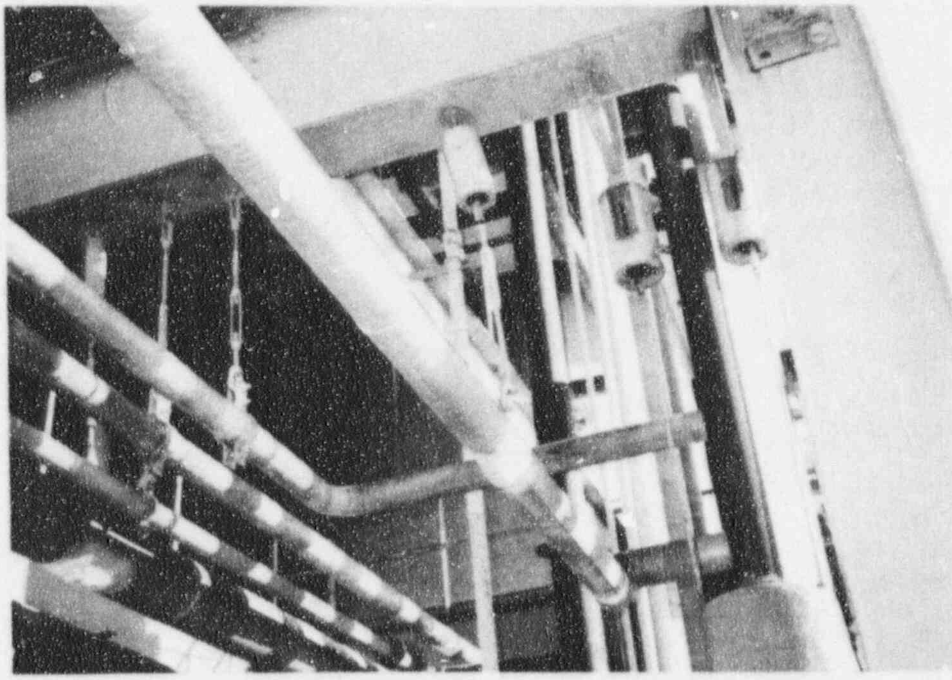
Item 29 - Unit 2 Elev 999 Dearator Gage Glass Shields Broken



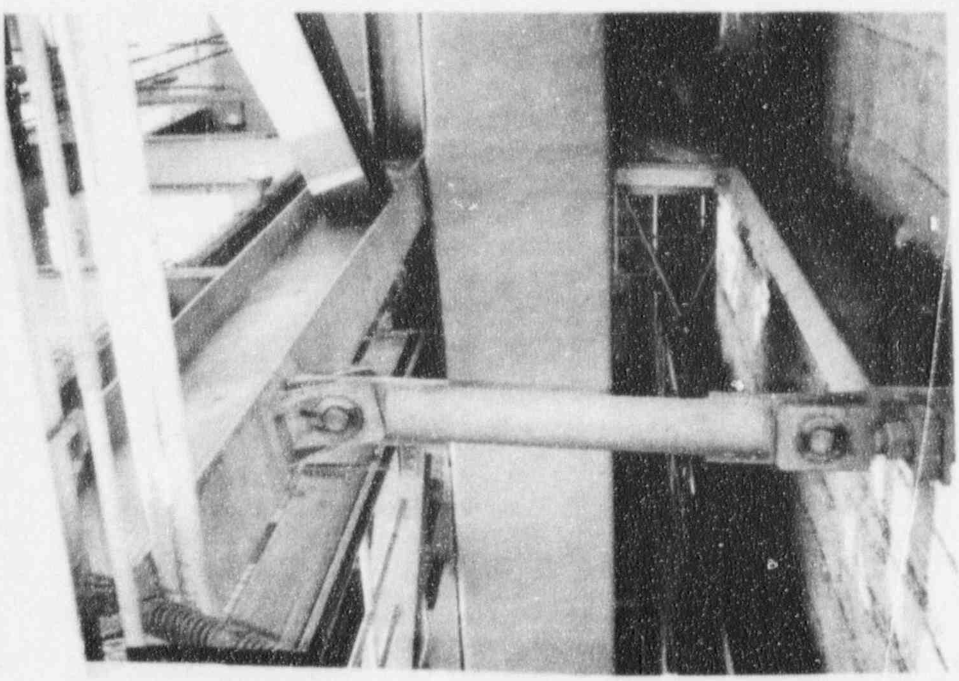
Item 30 - Unit 1 Elev 975 Column J5 Boiler Probe Pipe Broken Off



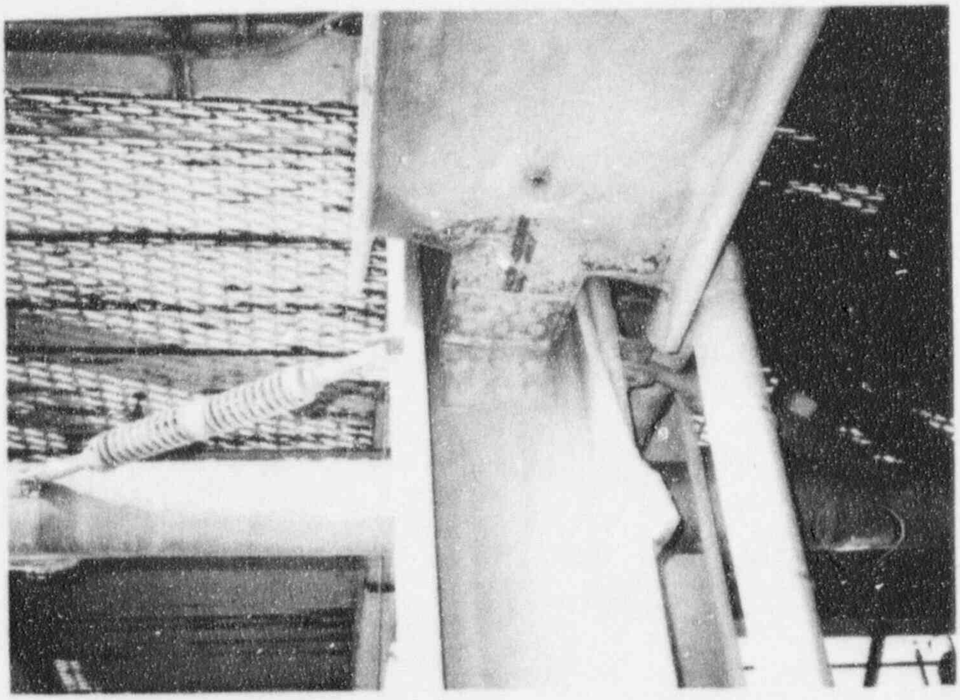
Item 31 - Unit 2 Elev 960 Column F12 Main Steam Line Snubber Broken



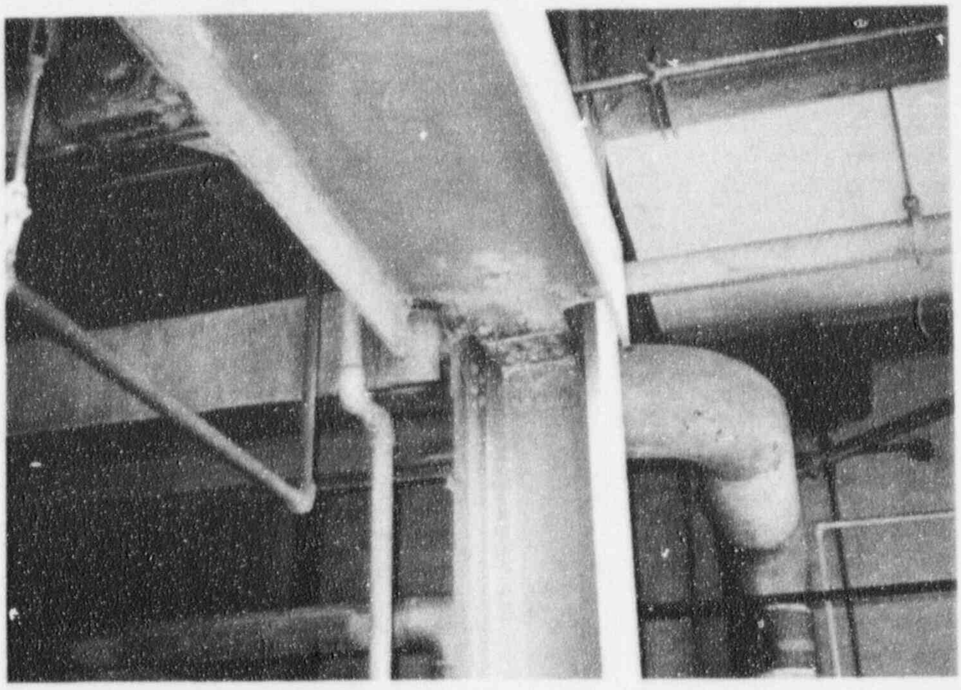
Item 32 - Unit 1 Elev 960 Column F5 Bent Pipe Hanger



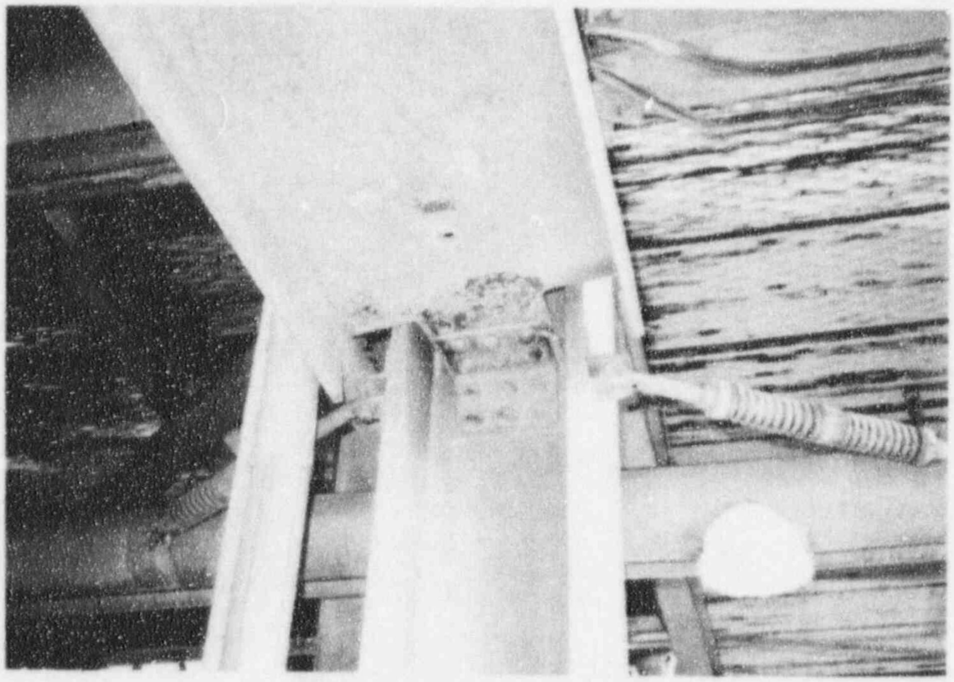
Item 33 - Unit 1 Elev 960 Front Boiler Buckstays Bent - Plate 1



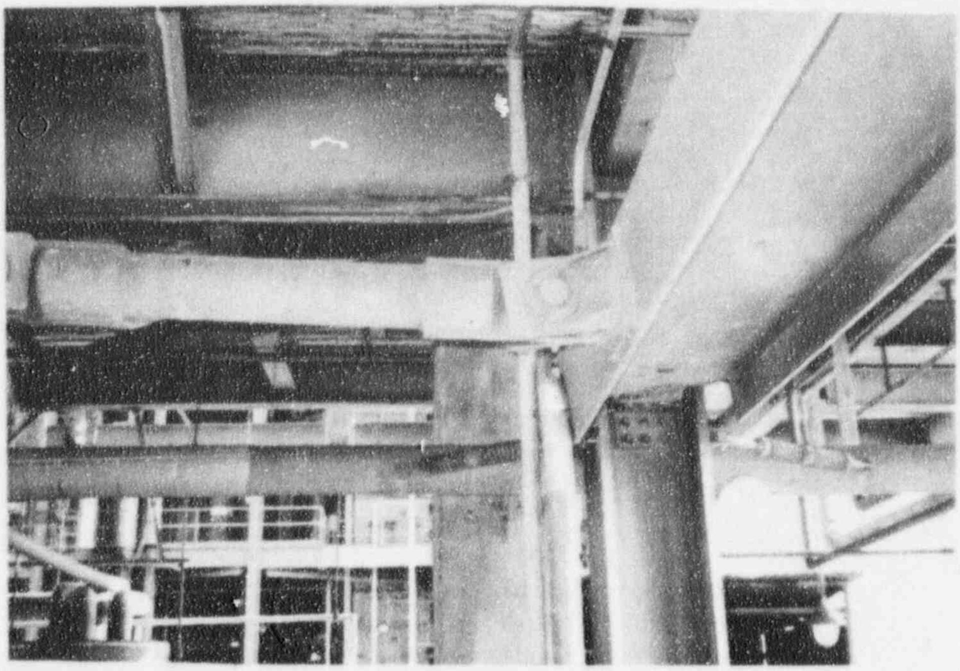
Item 33 - Unit 1 Elev 960 Front Boiler Buckstays Bent - Plate 2



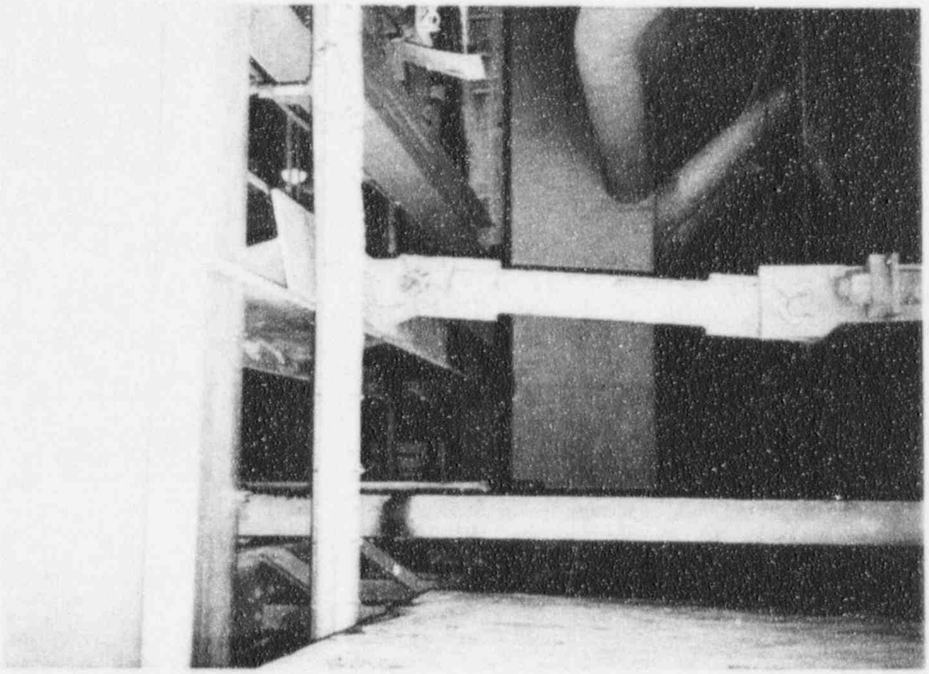
Item 33 - Unit 1 Elev 960 Front Boiler Buckstays Bent - Plate 3



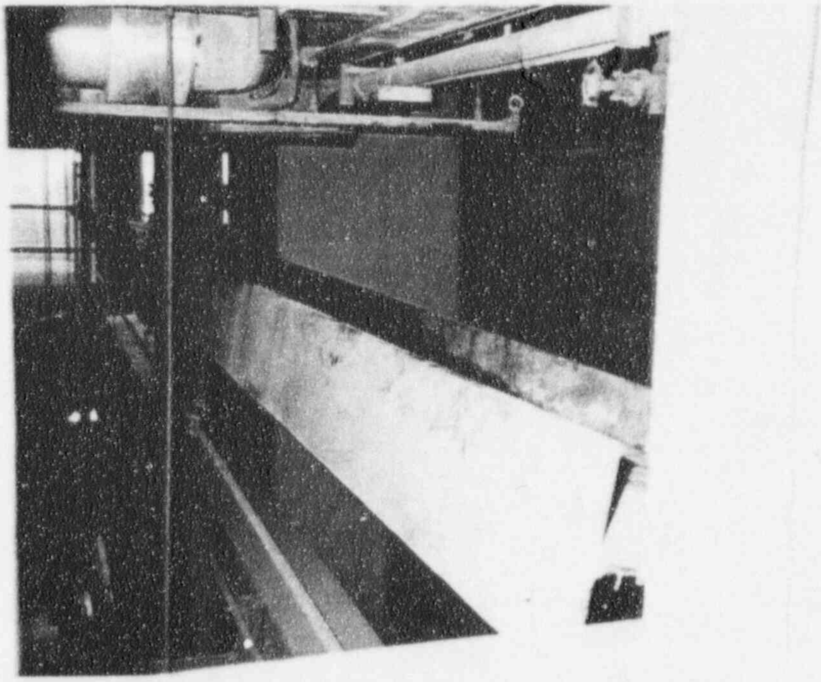
Item 34 - Unit 2 Elev 960 Front Boiler Buckstays Bent - Plate 1



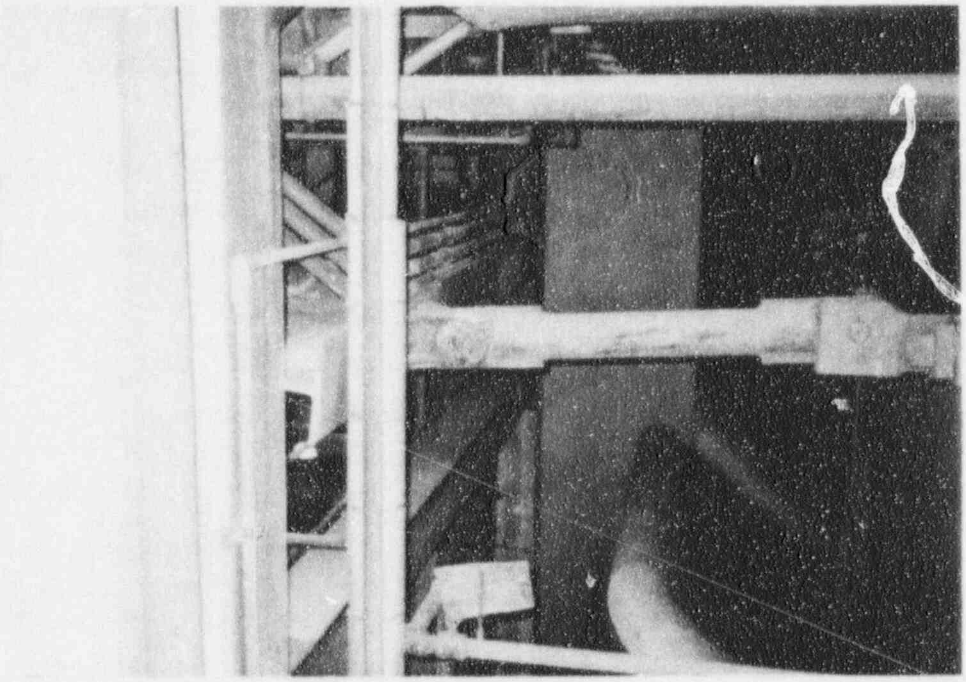
Item 34 - Unit 2 Elev 960 Front Boiler Buckstays Bent - Plate 2



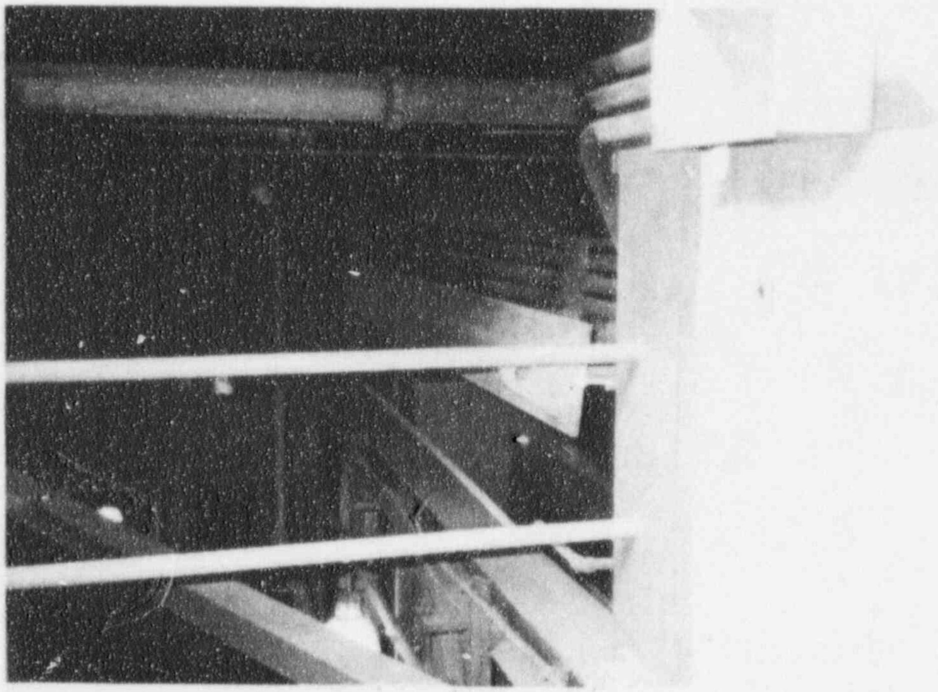
Item 35 - Unit 1 Elev 930 Front Boiler Buckstays Bent - Plate 1



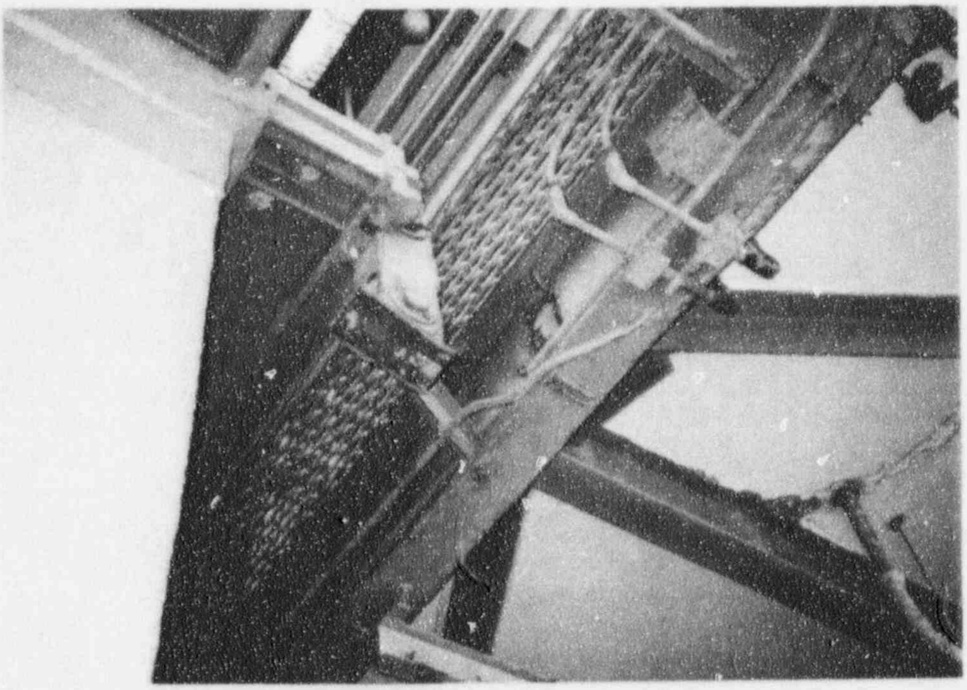
Item 35 - Unit 1 Elev 930 Front Boiler Buckstays Bent - Plate 2



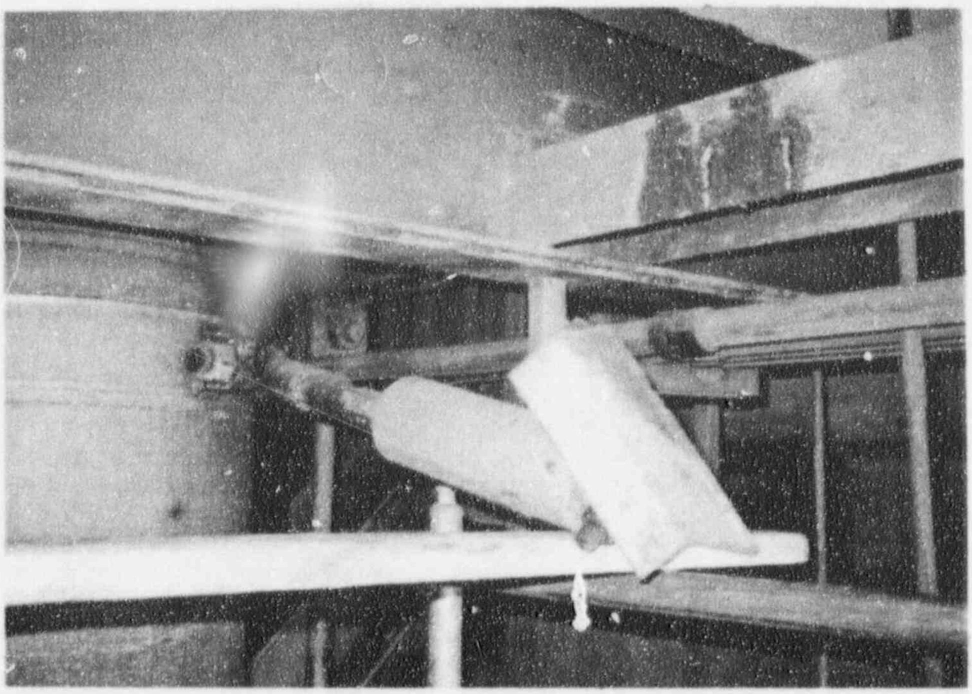
Item 36 - Unit 2 Elev 930 Front Boiler Buckstays Bent - Plate 1



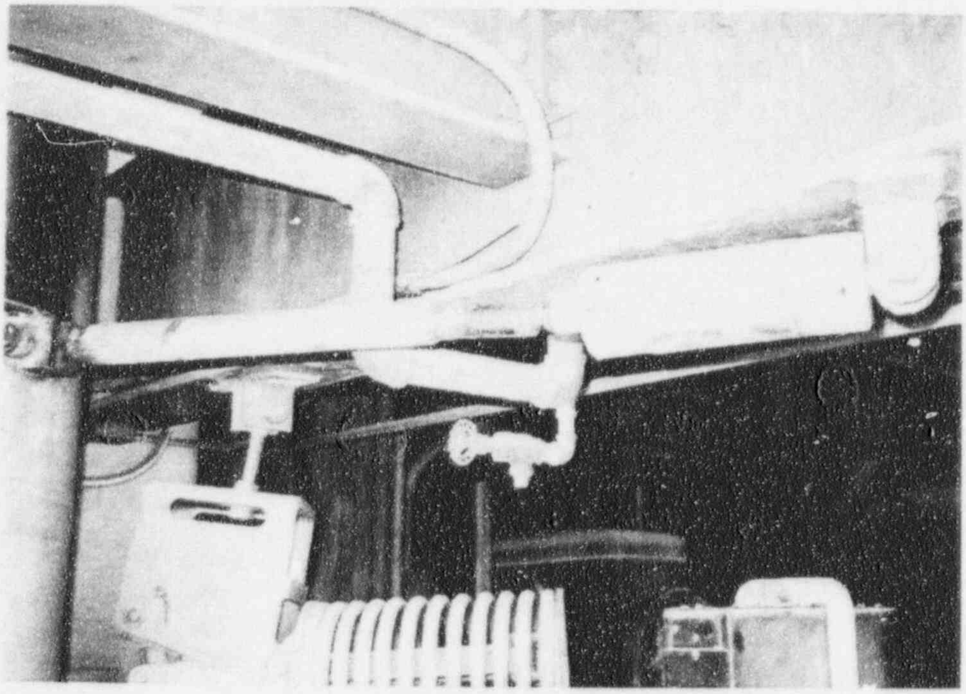
Item 36 - Unit 2 Elev 930 Front Boiler Buckstays Bent - Plate 2



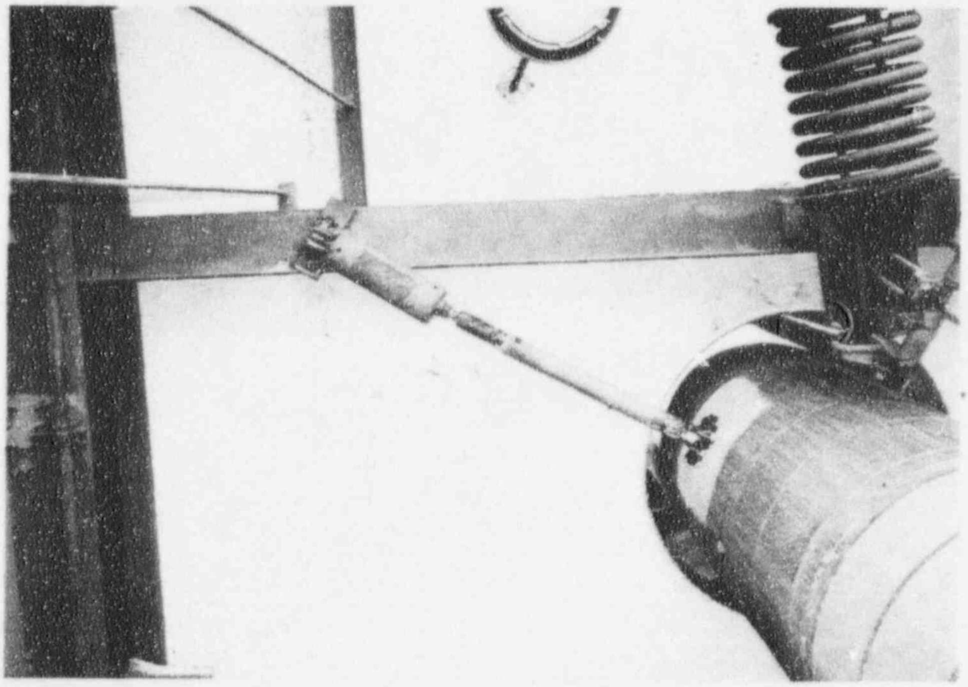
Item 37 - Unit 2 Elev 975 Rear Corner Buckstay Bent



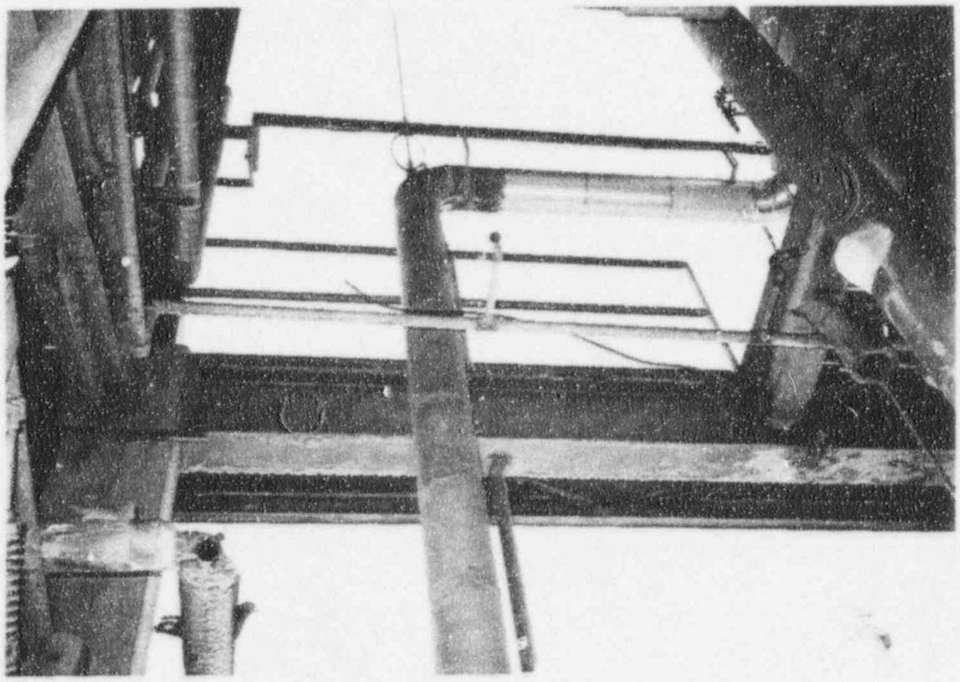
Item 38 - Unit 3 Elev 964 Broken Steam Line Snubber Between Locker Room and Burner Duct at Ceiling



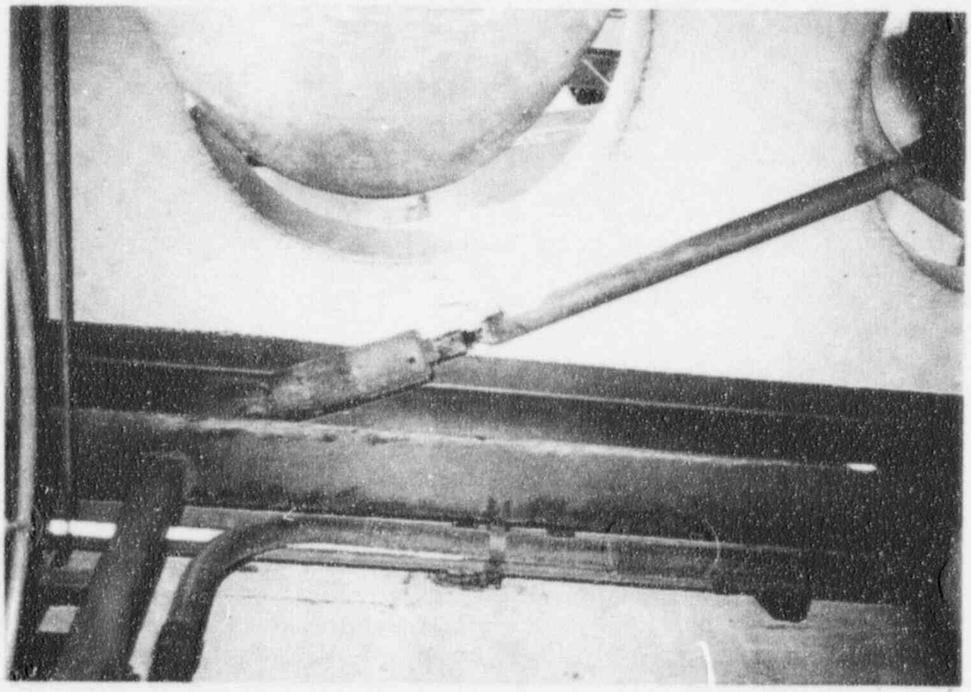
Item 39 - Unit 3 Elev 954 by Fuel Oil Differential Pumps Steam Line Snubber Badly Bent



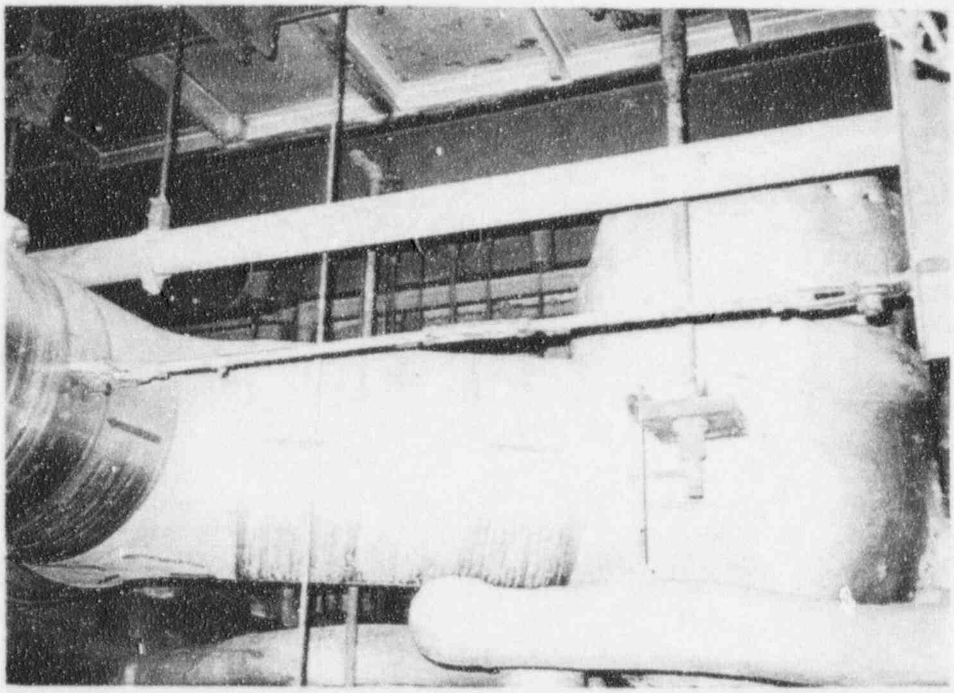
Item 40 - Unit 3 Elev 945 Outside Control Room Hot Reheat Line Broken Snubber



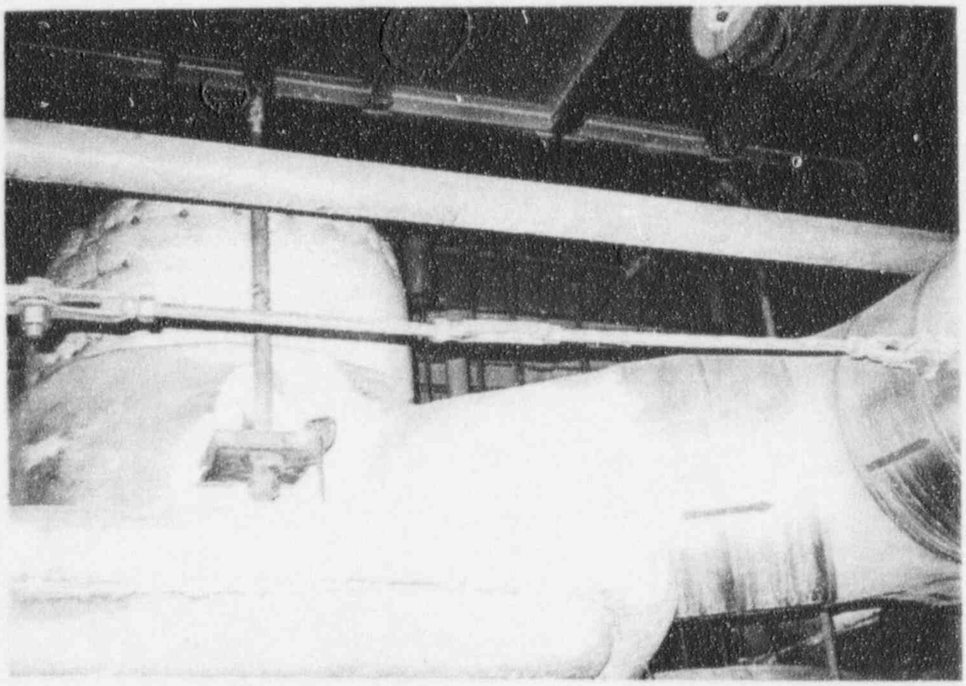
Item 41 - Unit 3 Elev 945 at Fuel Oil Heaters in Overhead Broken Ground Cable to Structure



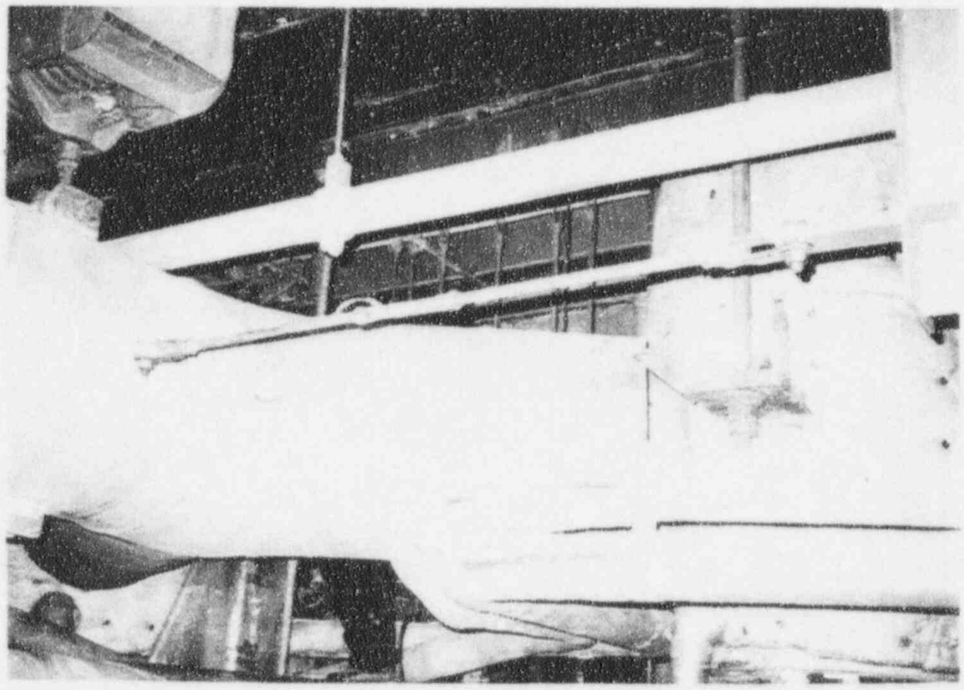
Item 42 - Unit 3 Elev 930 Over Aux Steam Station Broken Snubber to Steam Line



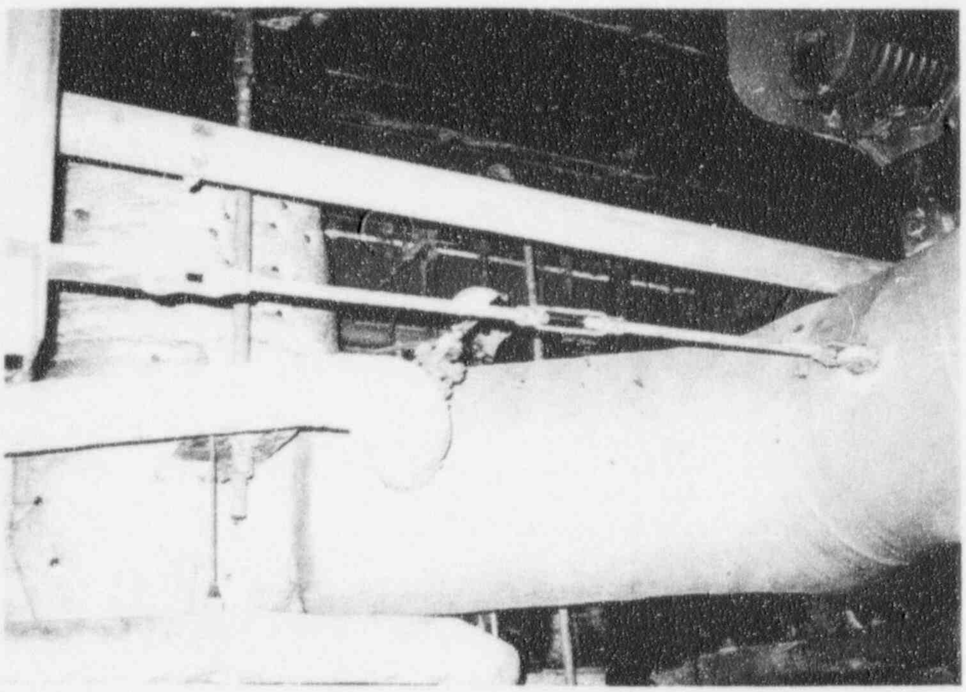
Item 43 - Unit 3 Elev 930 Main Steam Line at Main Steam Stop by Lube Oil Reservoir Line Stabilizers with Turnbuckles Badly Bent - Plate 1



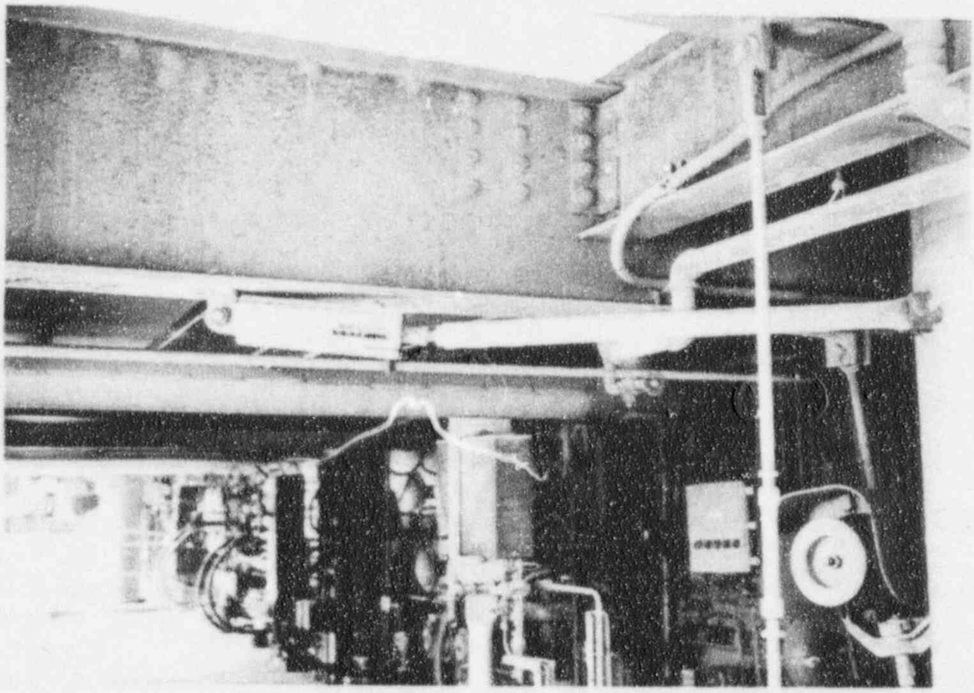
Item 43 - Unit 3 Elev 930 Main Steam Line at Main Steam Stop by Lube Oil Reservoir Line Stabilizers with Turnbuckles Badly Bent - Plate 2



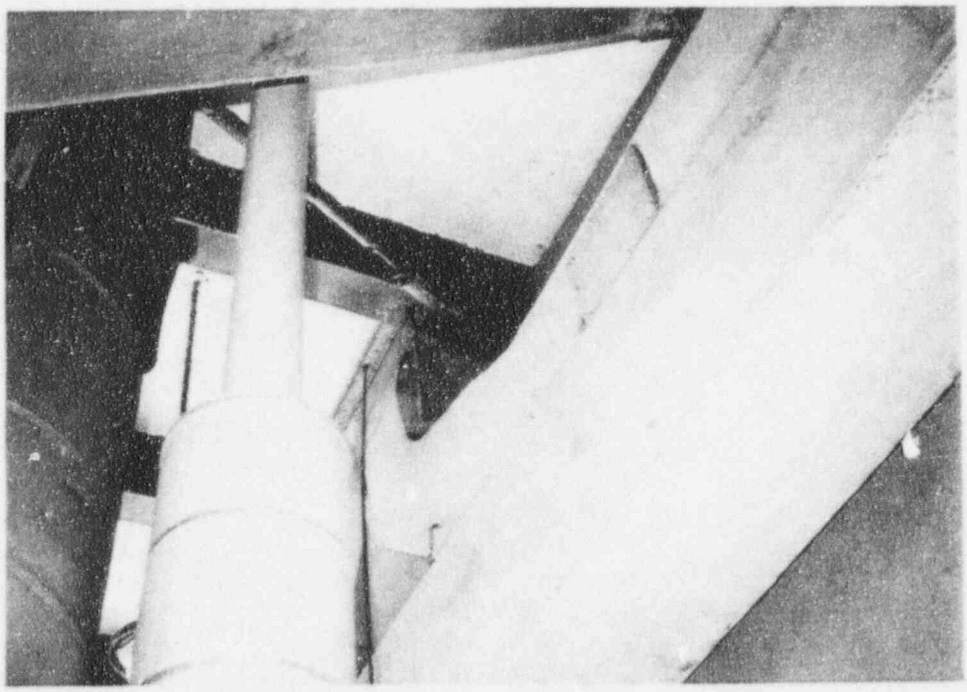
Item 44 - Unit 4 Elev 930 Stabilizers to Main Steam Line at Main Stops by Lube Oil Reservoir are Broken - Plate 1



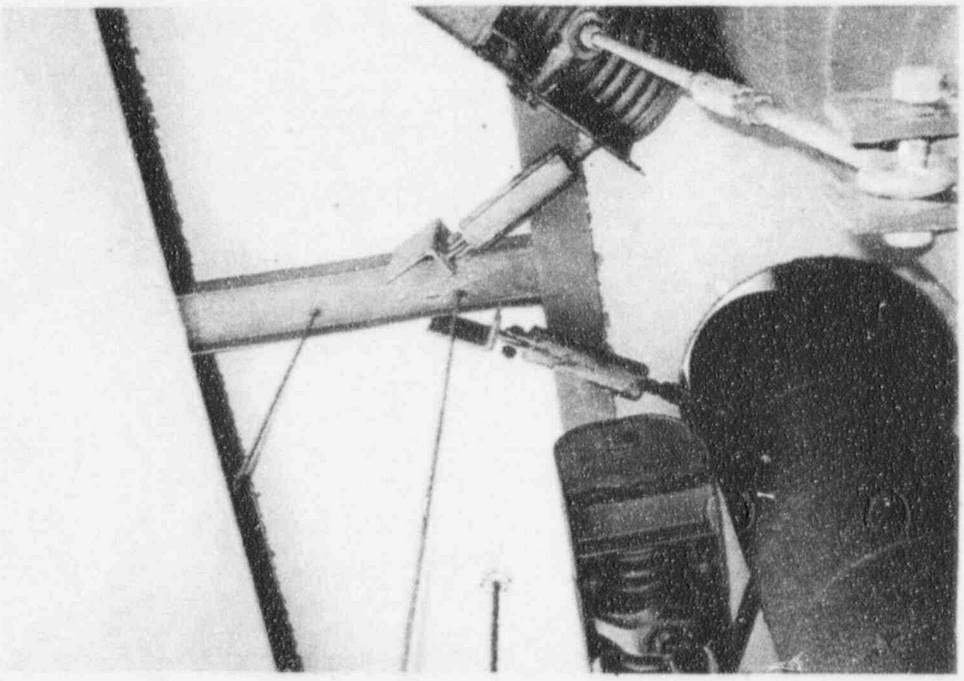
Item 44 - Unit 4 Elev 930 Stabilizers to Main Steam Line at Main Stops by Lube Oil Reservoir are Broken - Plate 2



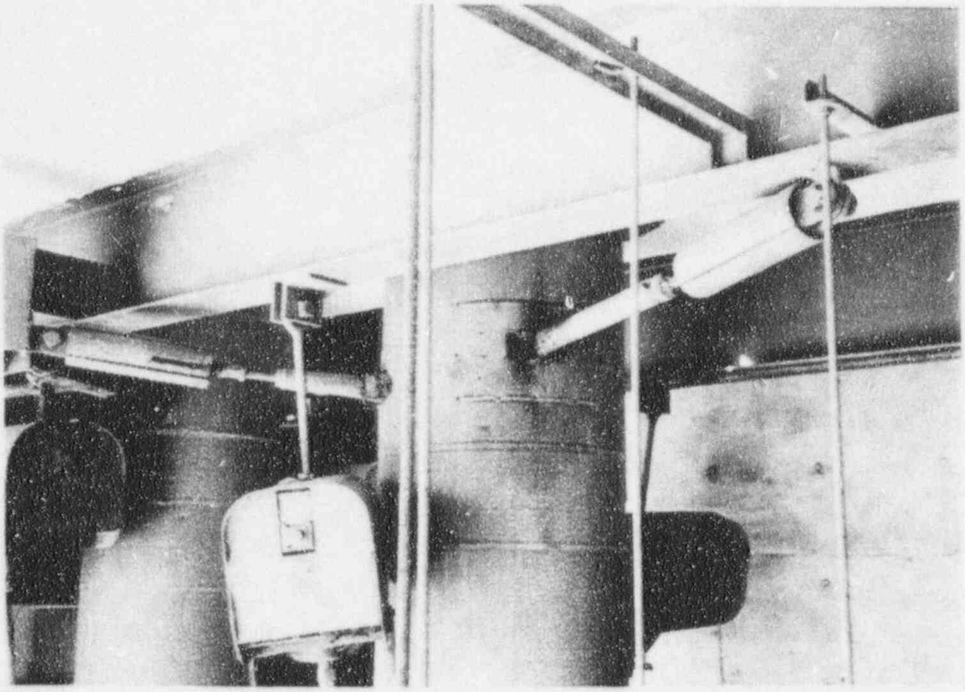
Item 45 - Unit 4 Elev 945 Hot Reheat Steam Line Snubber by Fuel Oil Differential Pumps Bent



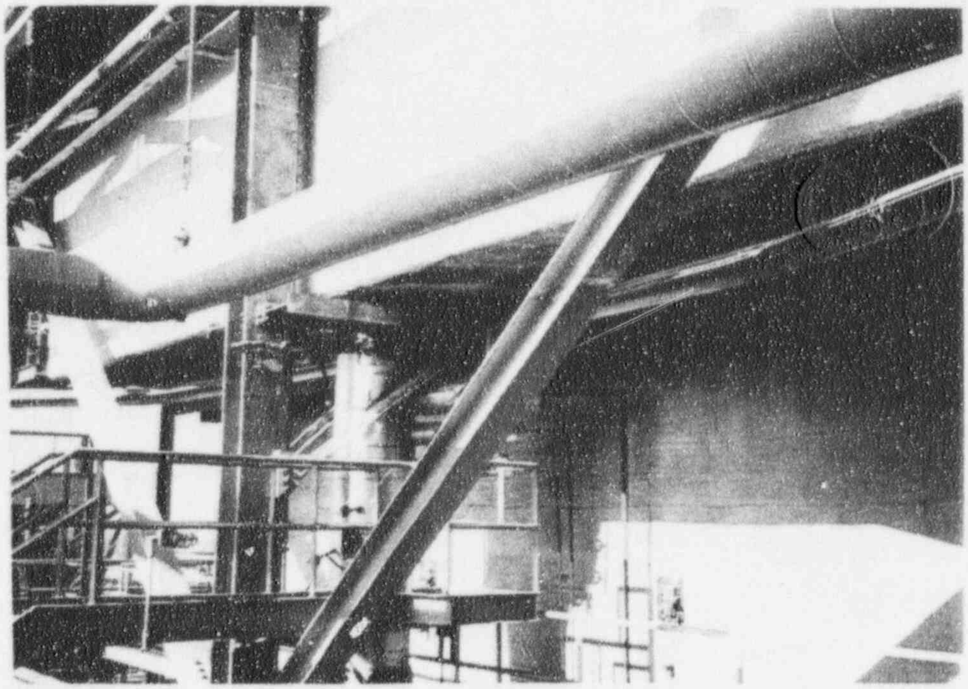
Item 46 - Unit 4 Elev 945 Outside Control Room Main Steam Line One Broken Snubber, One Bent Snubber - Plate 1



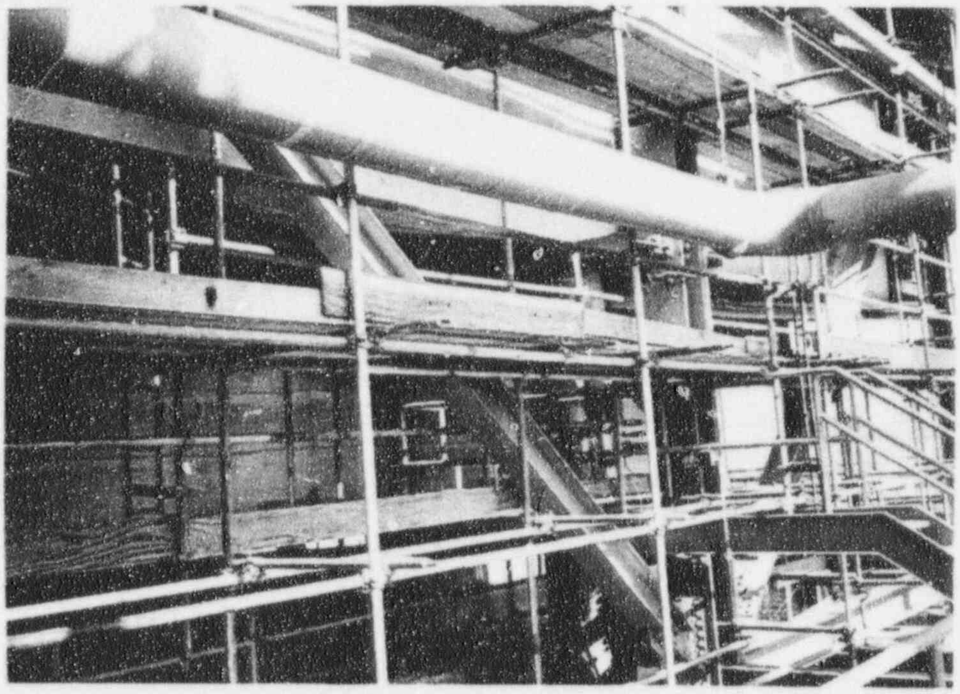
Item 46 - Unit 4 Elev 945 Outside Control Room Main Steam Line One Broken Snubber, One Bent Snubber - Plate 2



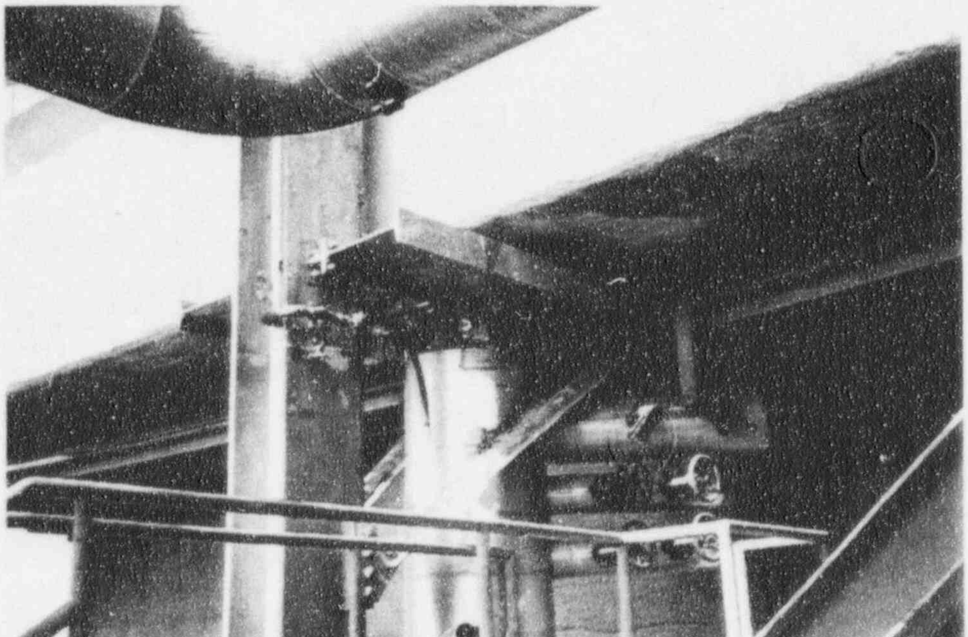
Item 47 - Unit 4 Elev 945 Hot Reheat Steam Line One Bent Snubber



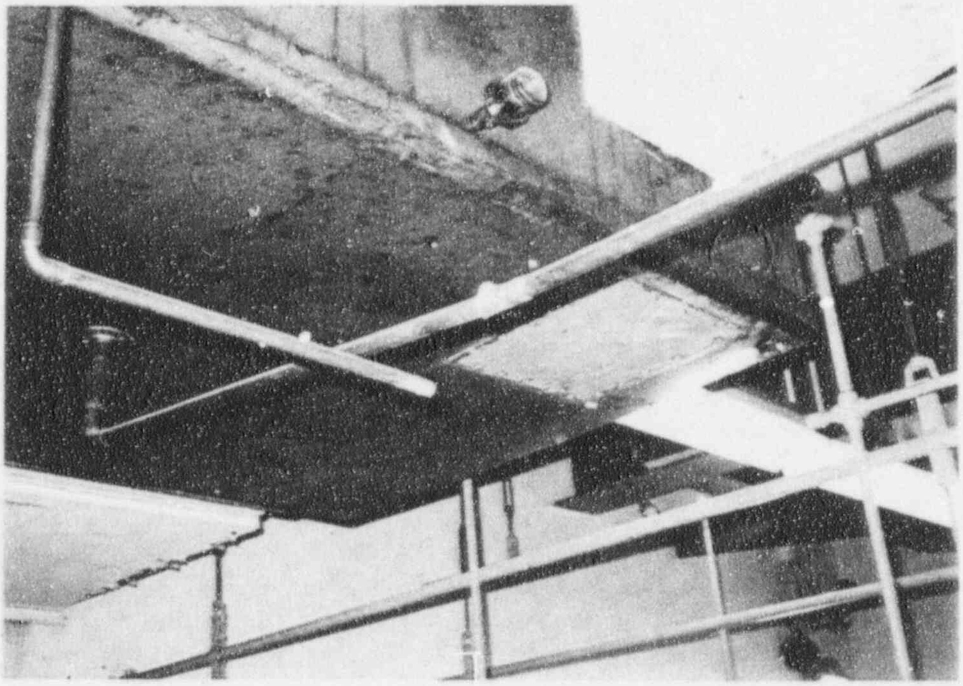
Item 48 - Unit 3 Elec 1018 Penthouse Front Overhang Seismic Restraint Lateral Ties Bent



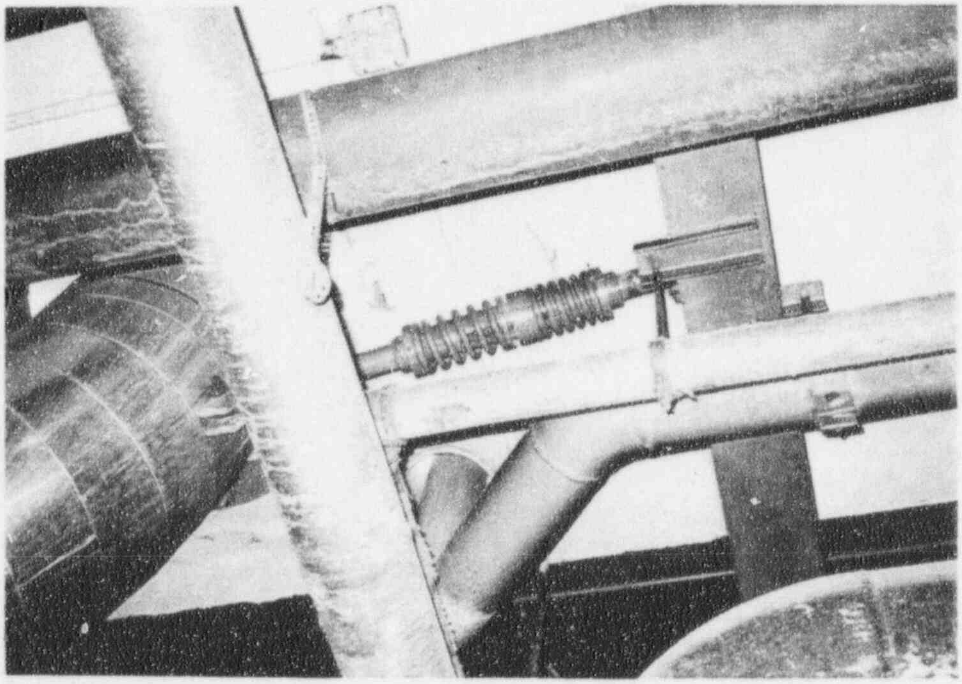
Item 49 - Unit 4 Elev 10108 Penthouse Front Overhang Seismic Restraint Lateral Ties Bent



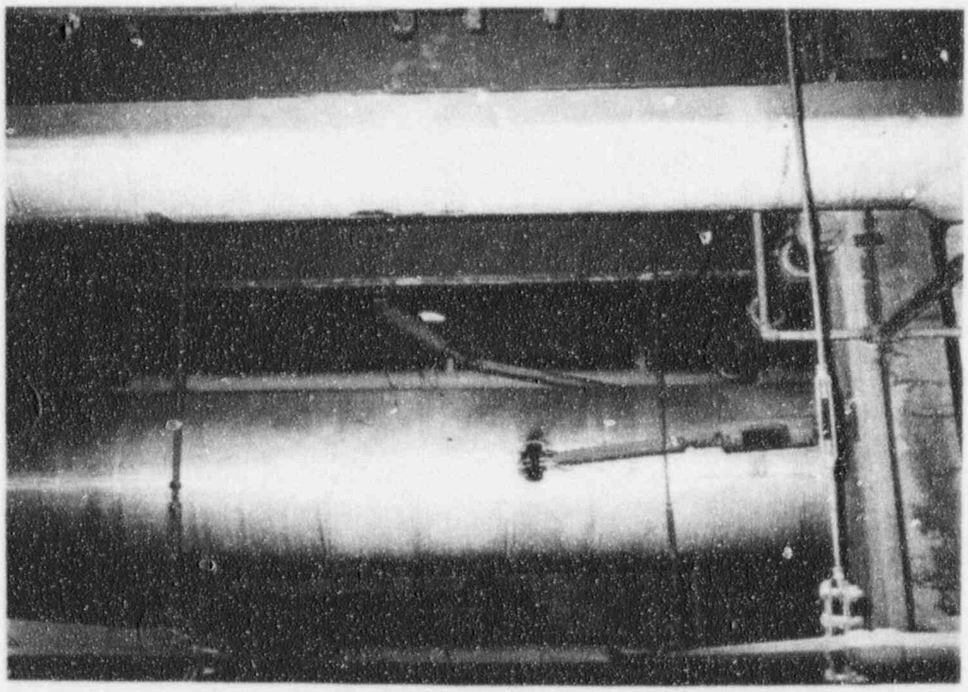
Item 50 - Unit 3 Main Steam Line Exit from Penthouse Overhang Insulation and Lagging Damaged



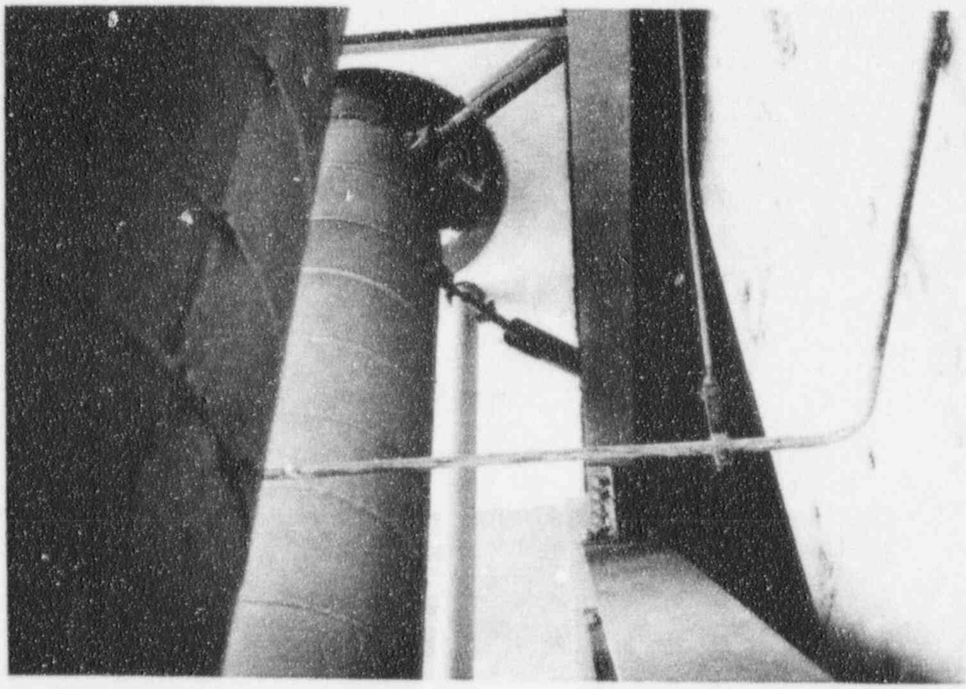
Item 62 - Unit 1 & 2 Elev 992 Column G9 Condensate Drain to Air Conditioner in Chem Feed Room Broken



Item 63 - Unit 1 Elev 930 Column F6 Main Steam Line Snubber Show that Main Steam Line May Have Moved South, Spring Tension has Shifted All to One Side

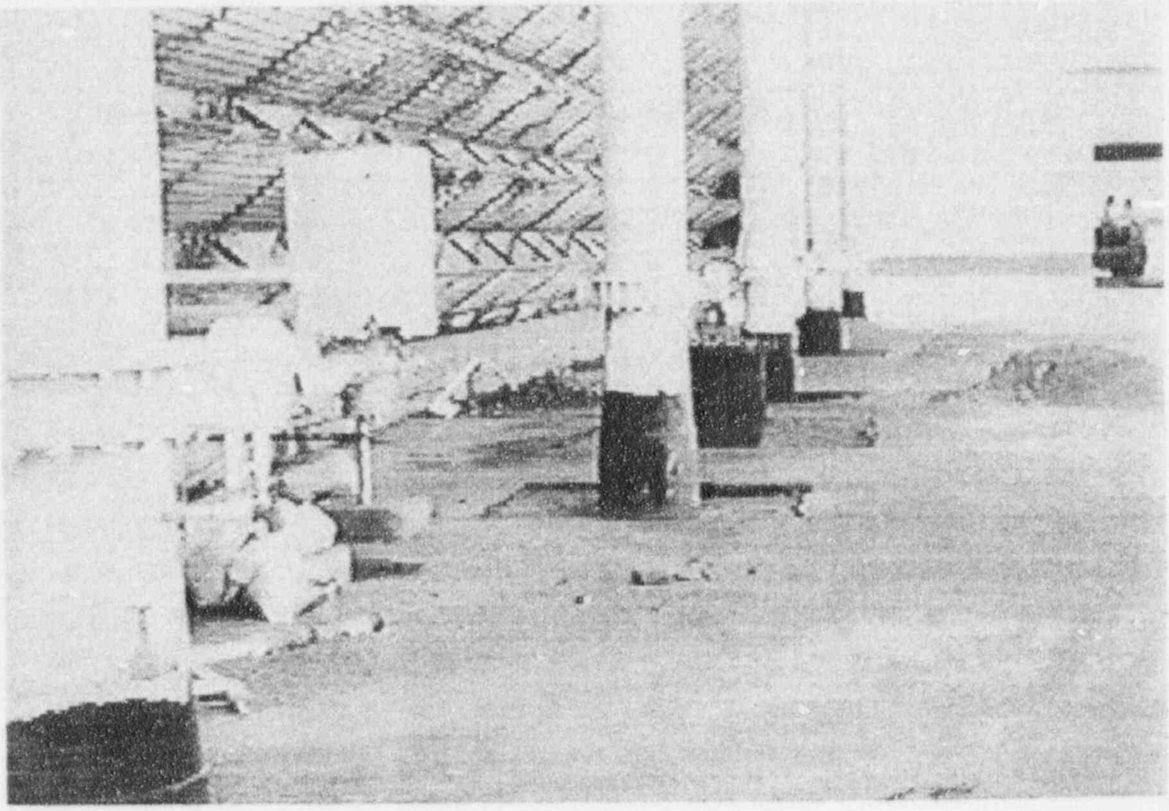


Item 80 - Unit 3 Elev 930 Cold Reheat Steam Line Snubber Bend Above "A" Condensate Water Box

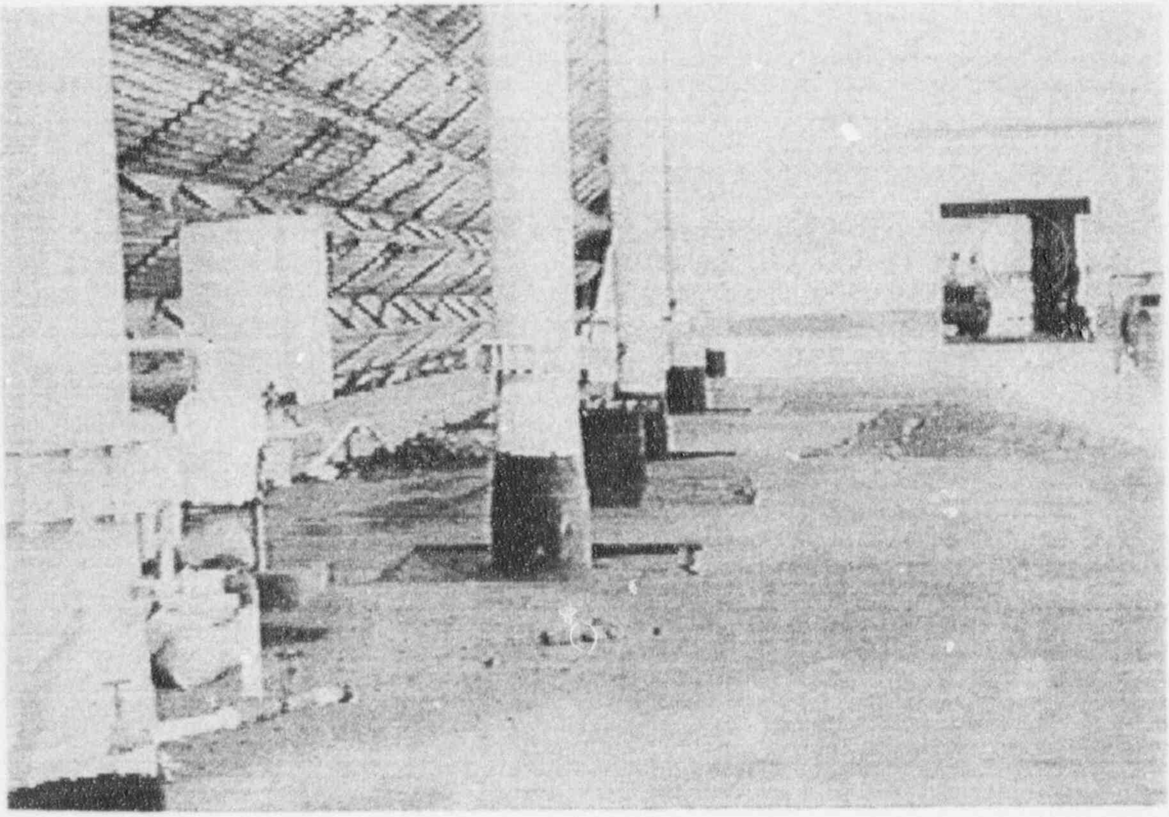


Item 81 - Unit 4 Elev 983 Main Steam Line Snubber Over Extended

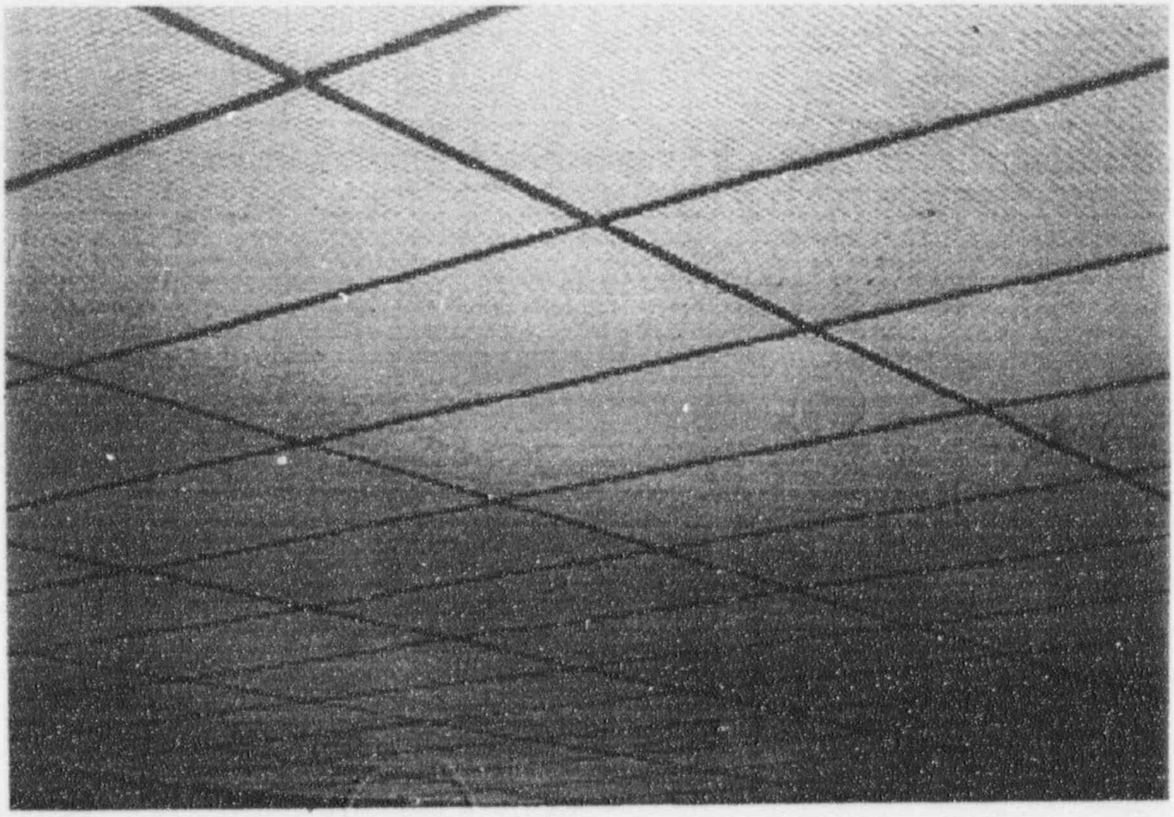
Glendale Plant
Pictures 31-37



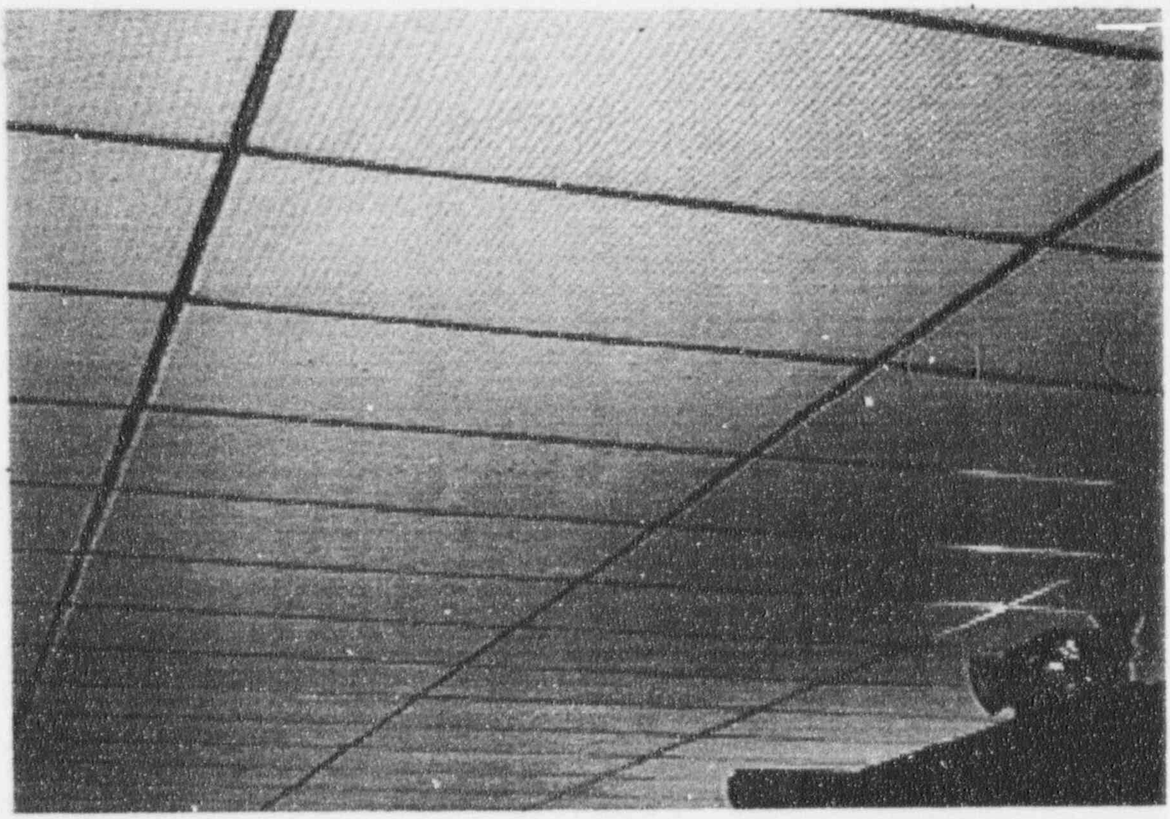
GLENDALE: Picture 31



GLENDALE: Picture 32

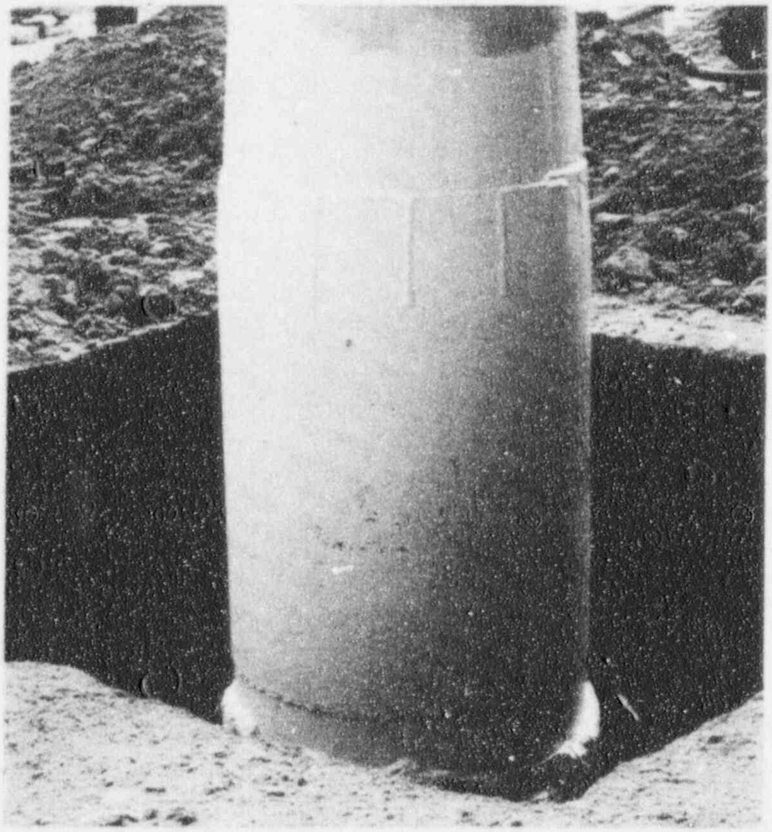


GLENDALE: Picture 33

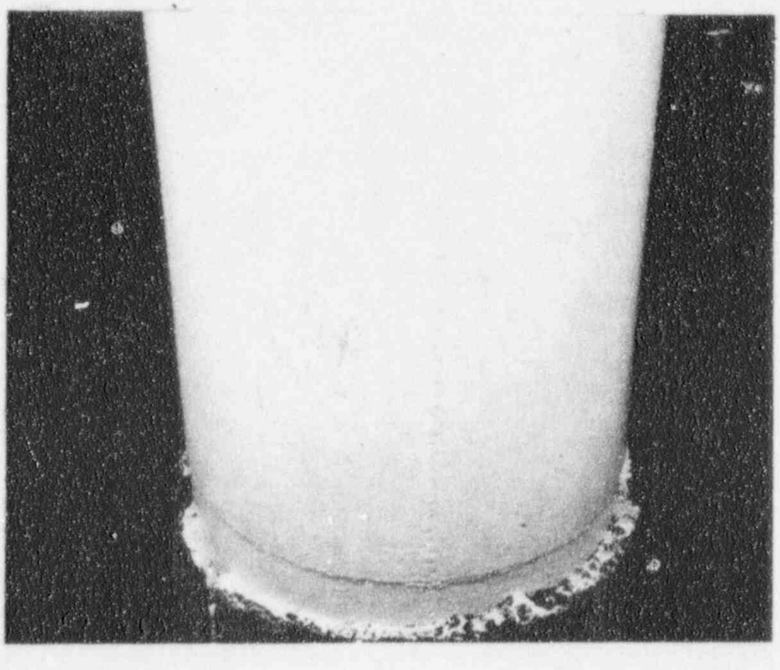


GLENDALE: Picture 34

Glendale: Picture 35 (20″ Vertical Riser to Cooling Tower Damage)



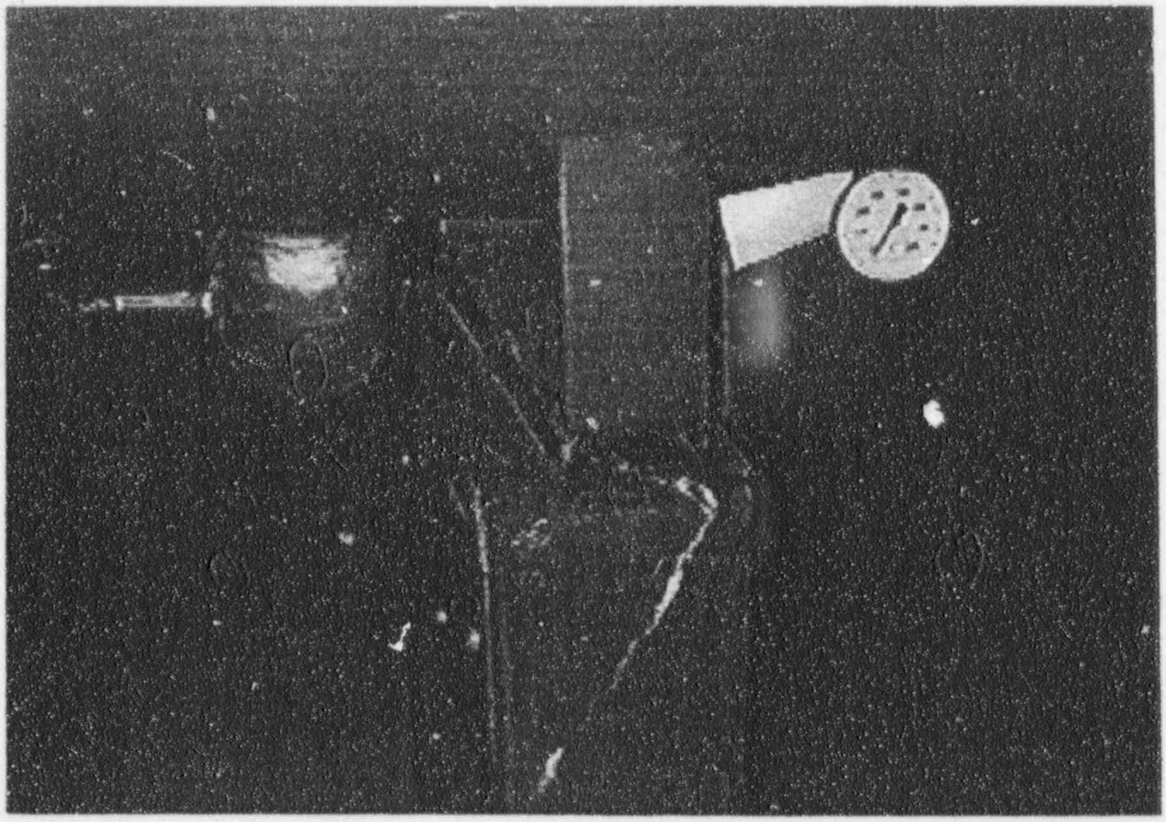
Glendale: Picture 36



Glendale: Picture 37

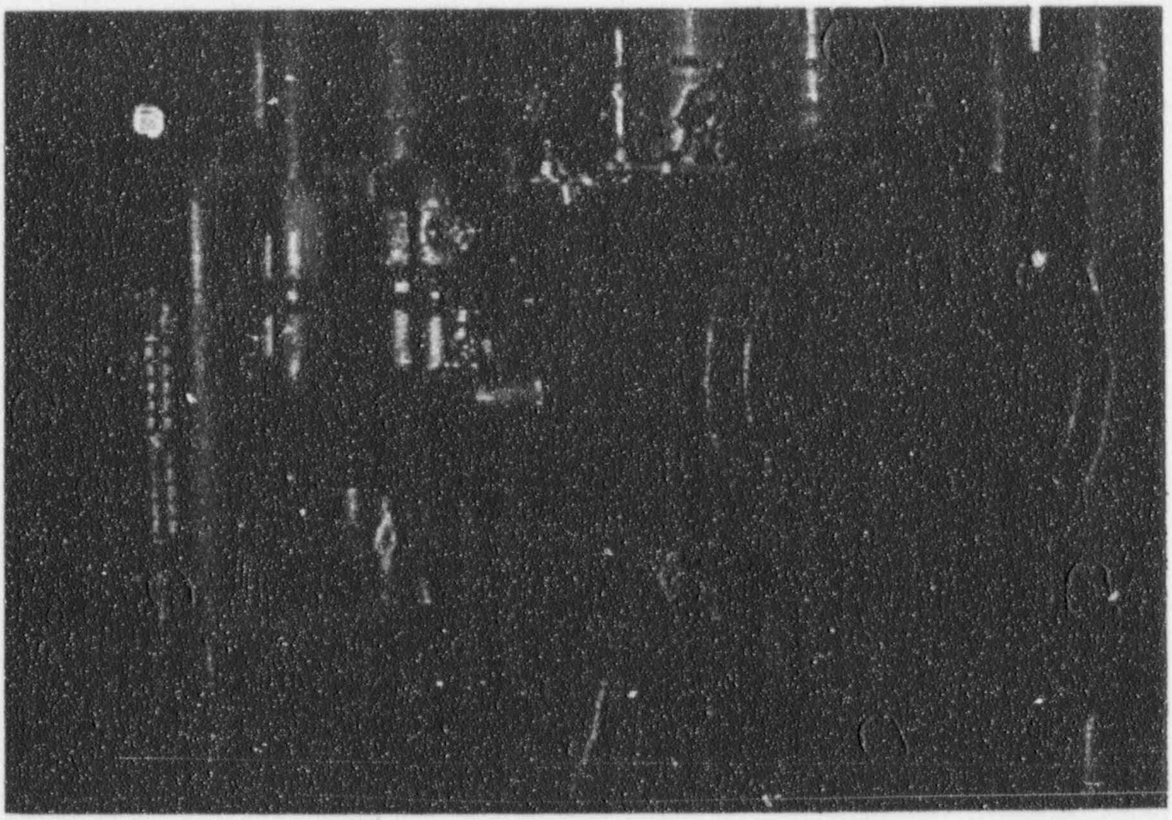
Appendix A2: Survey of Damage to Fossil Plant Piping and Piping Supports Due to the 1994 Northridge Earthquake

Burbank Plant
Pictures 1-20

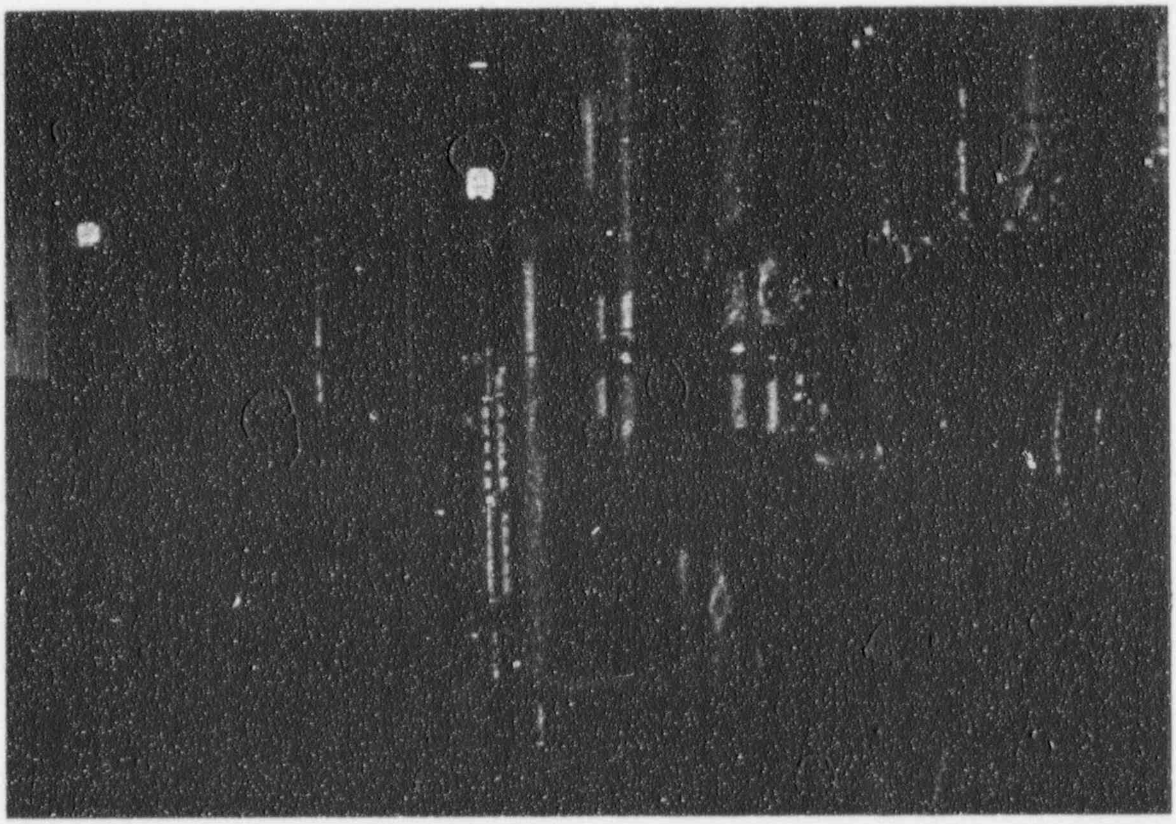


Burbank Plant: Picture 1

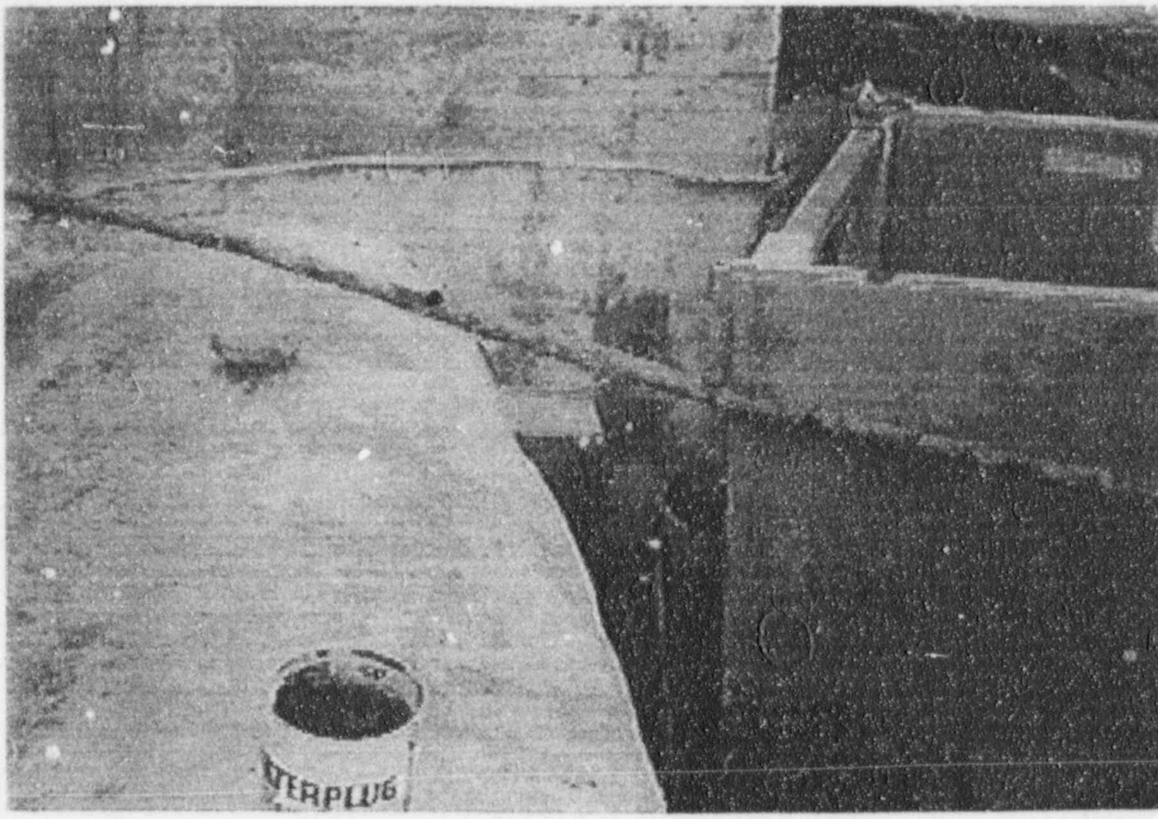
Burbank Plant: Picture 2



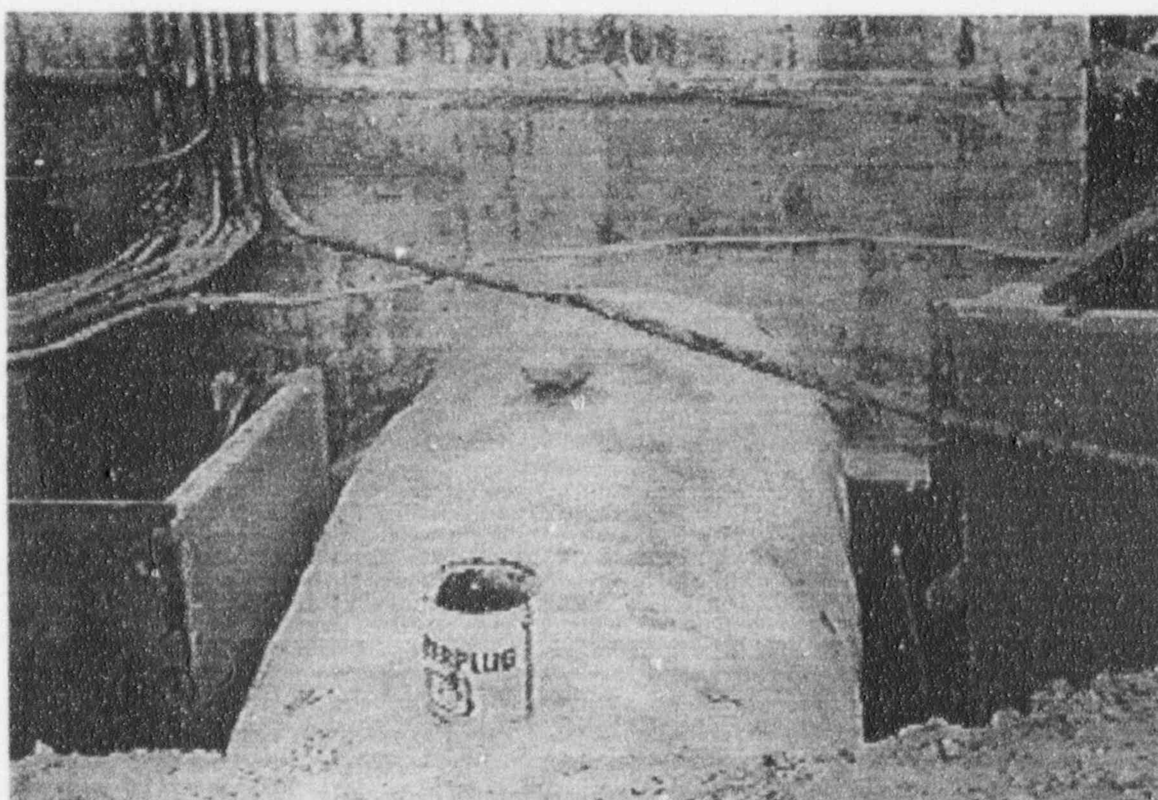
Burbank Plant: Picture 3



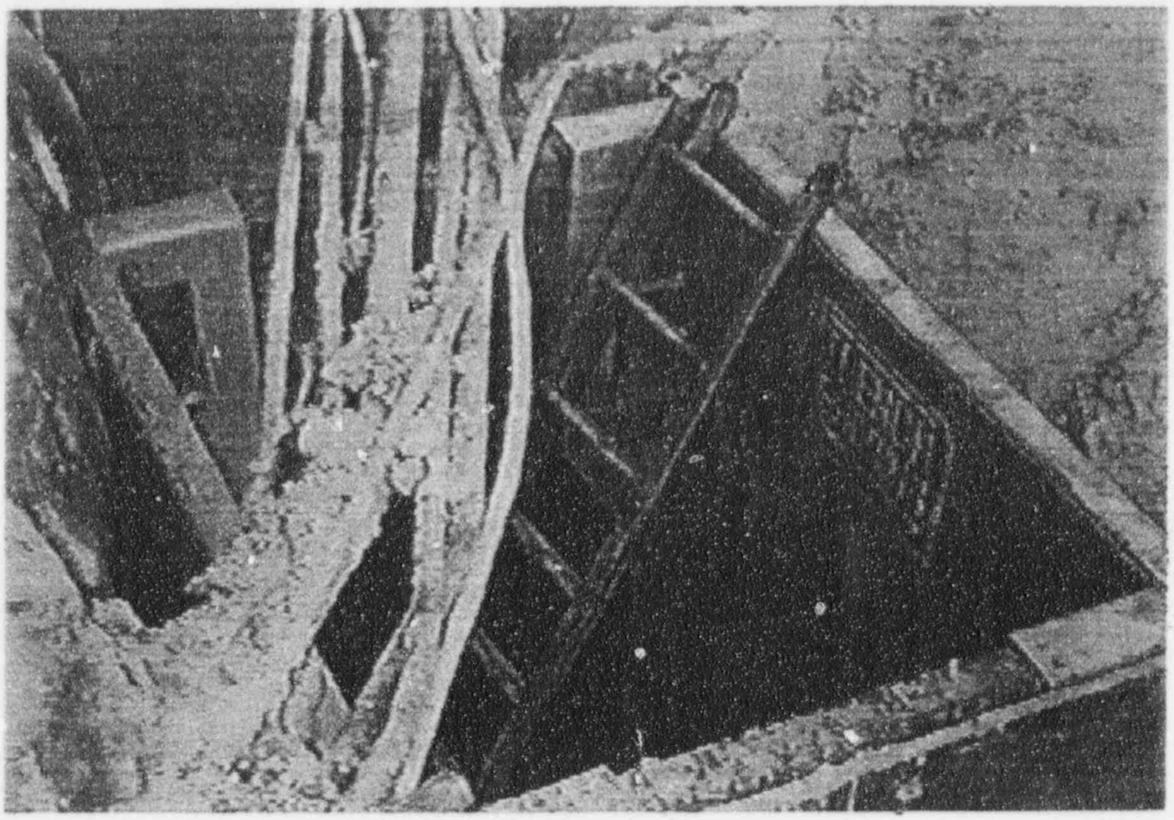
Burbank Plant: Picture 4



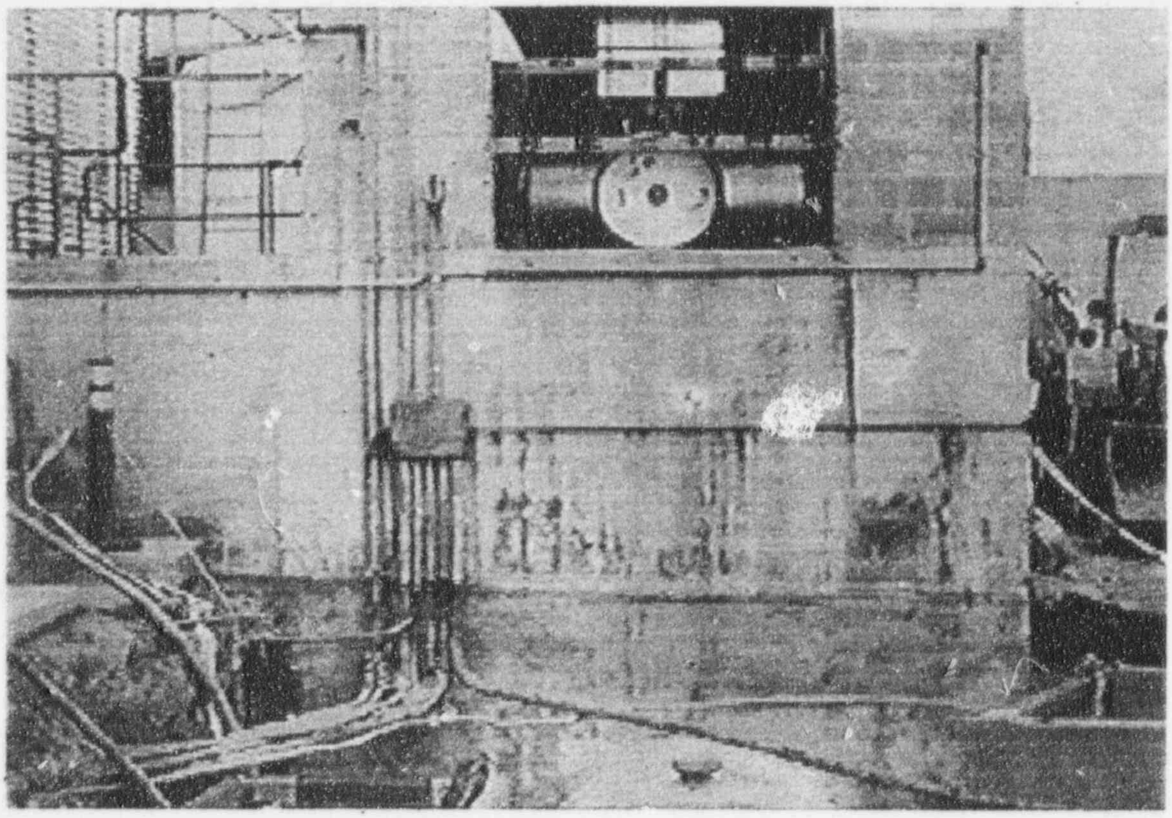
Burbank Plant: Picture 5



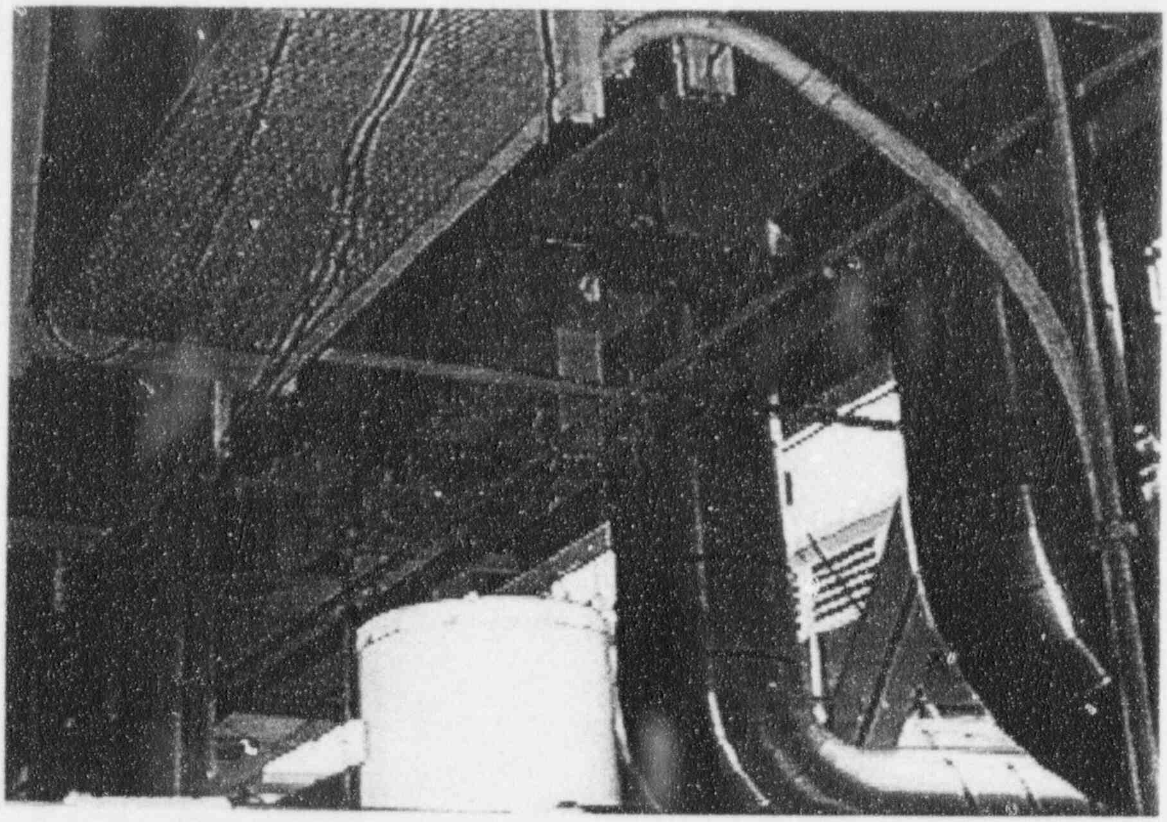
Burbank Plant: Picture 6



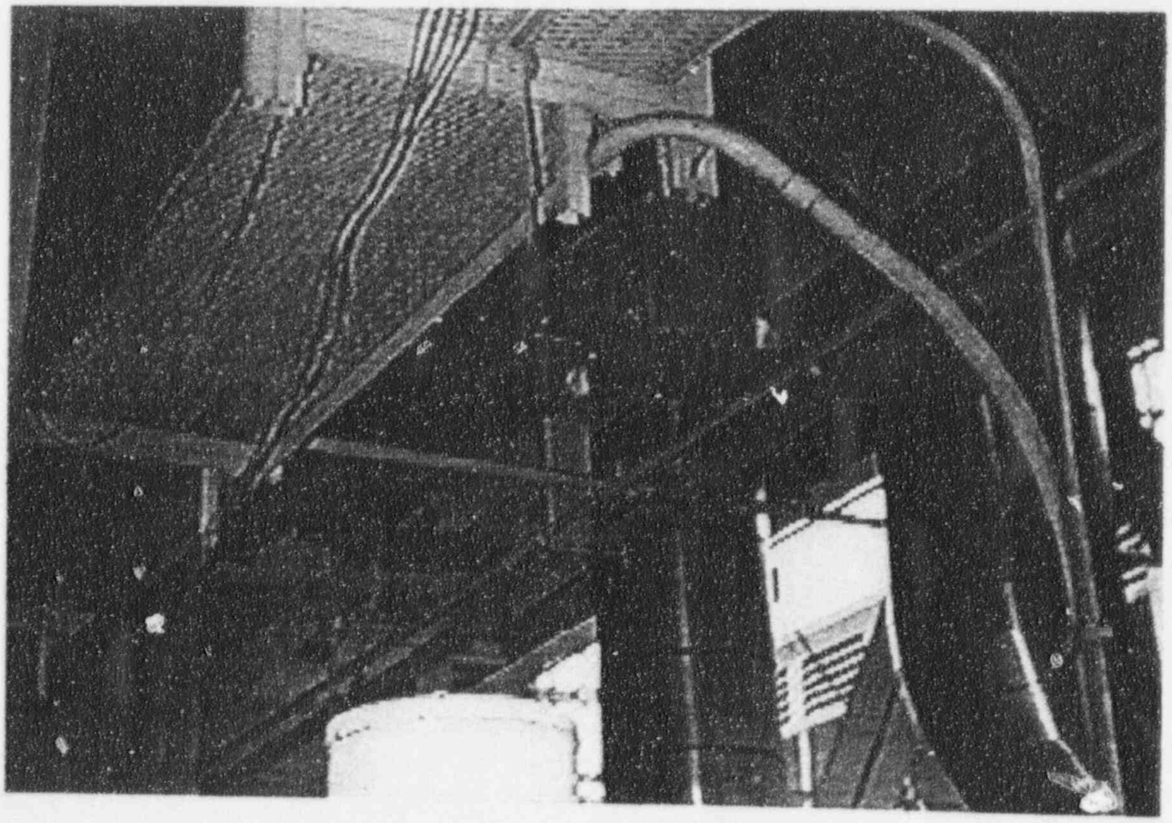
Burbank Plant: Picture 7



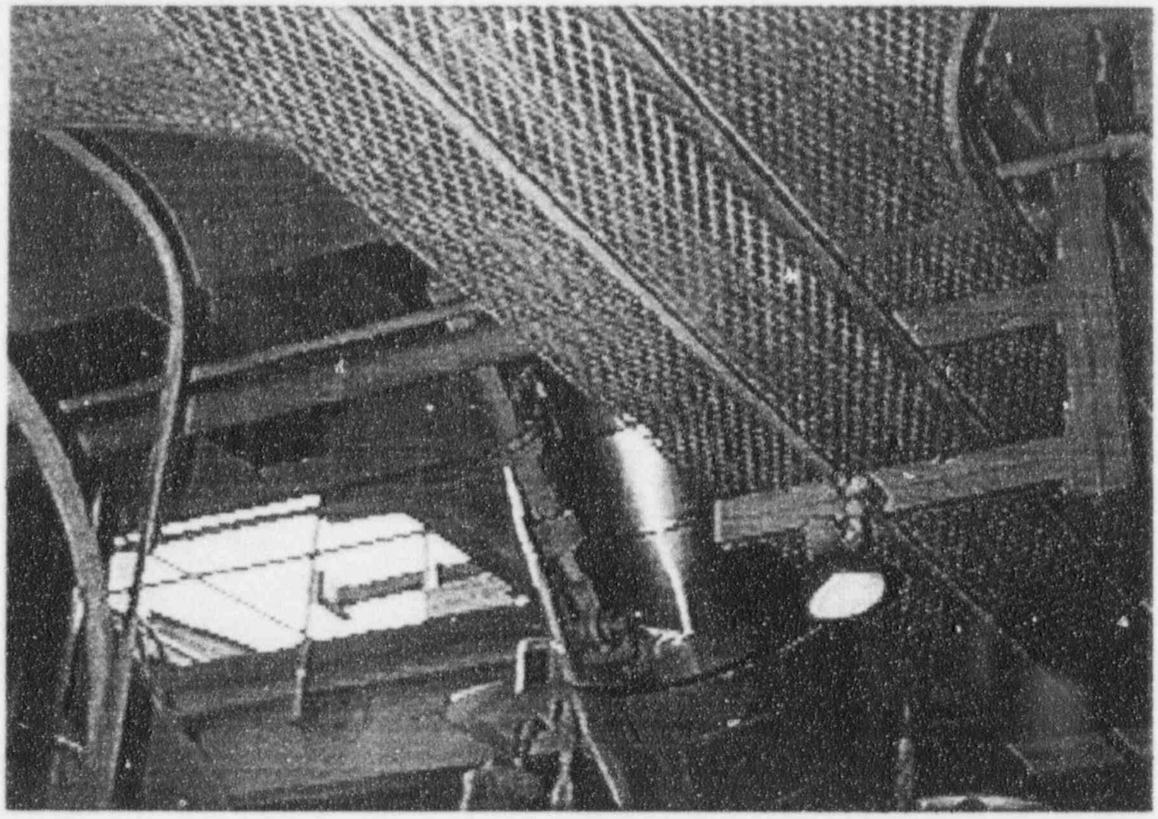
Burbank Plant: Picture 8



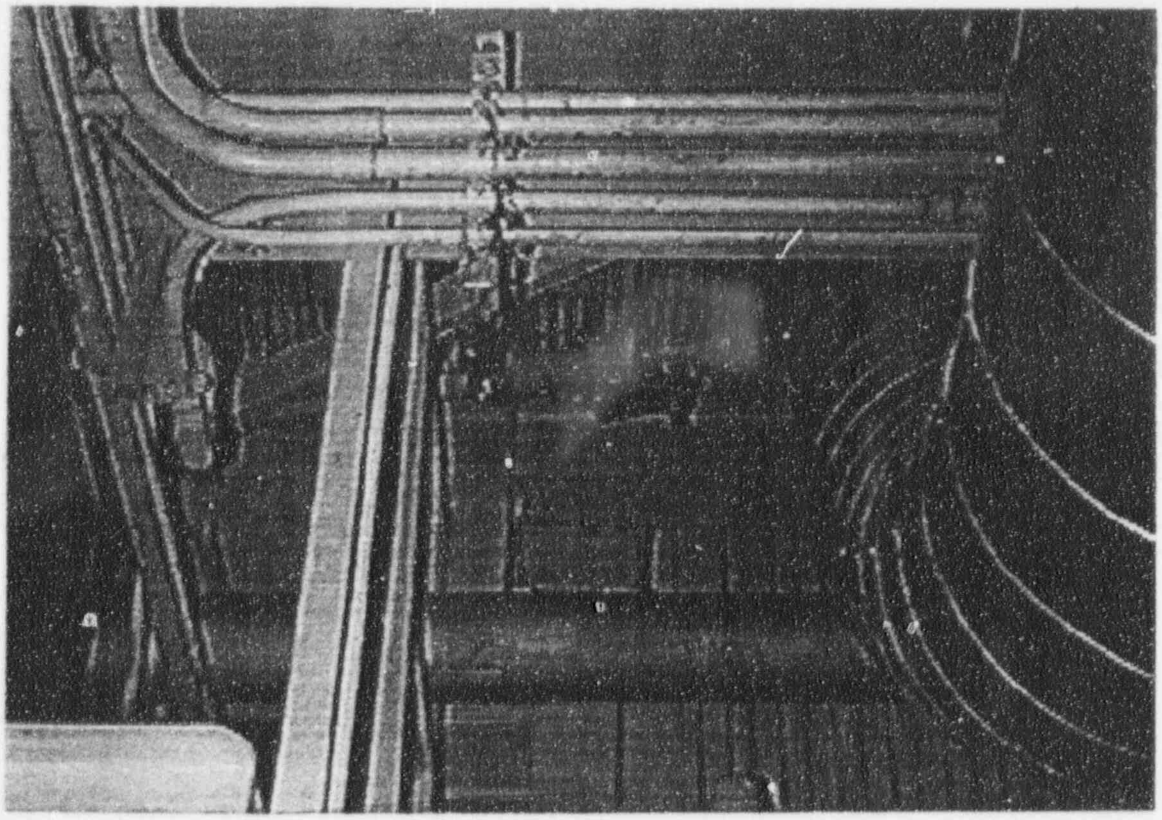
Burbank Plant: Picture 9



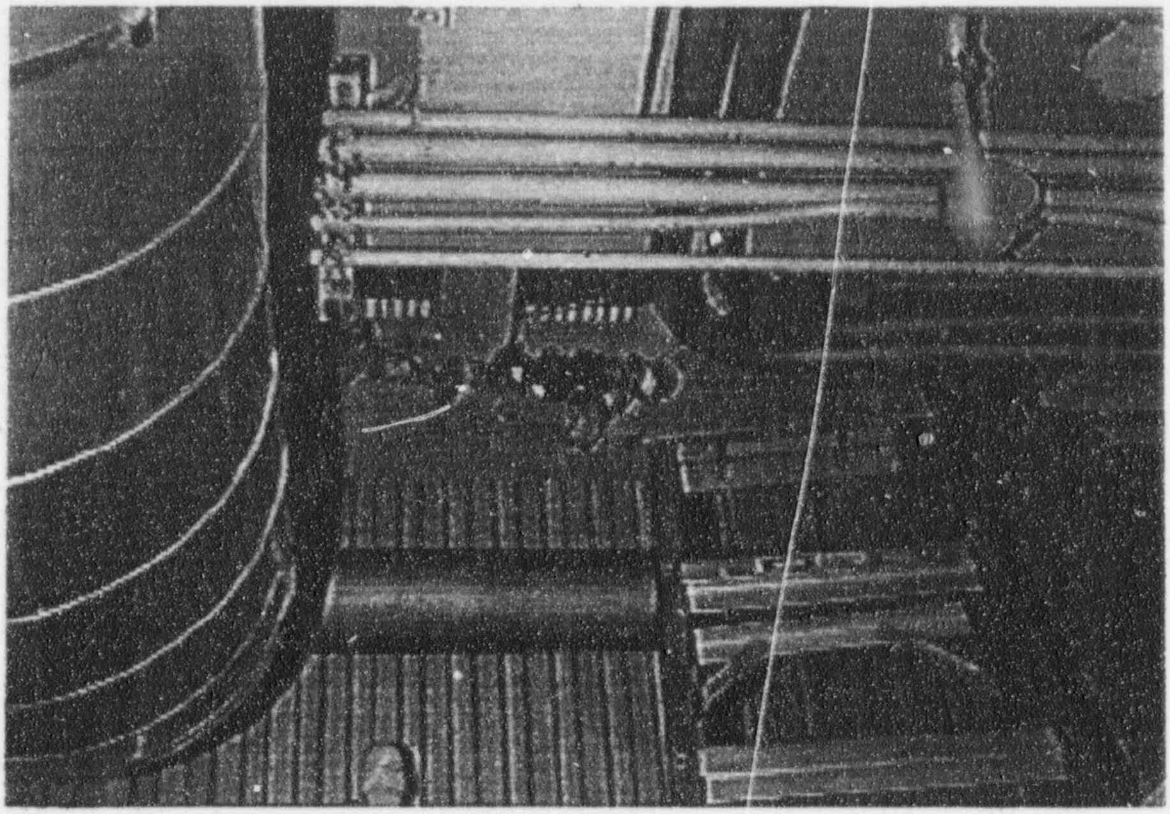
Burbank Plant: Picture 10



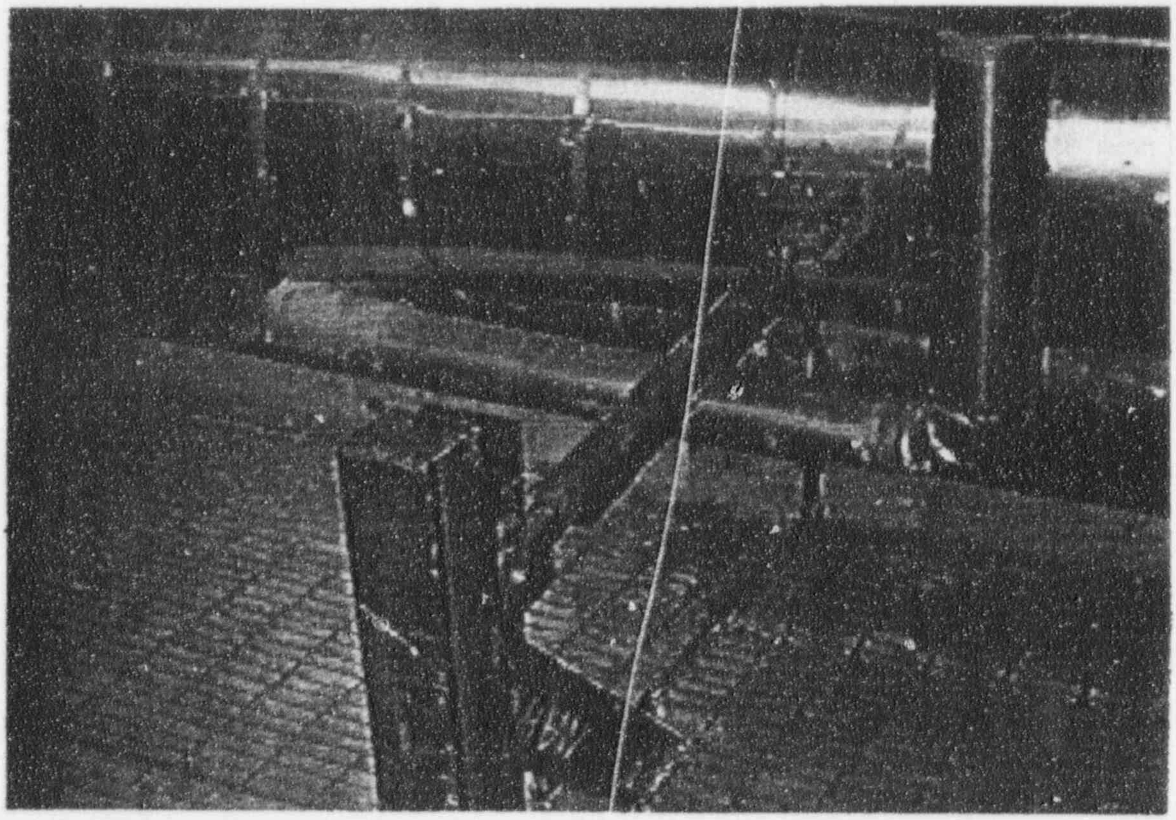
Burbank Plant: Picture 11



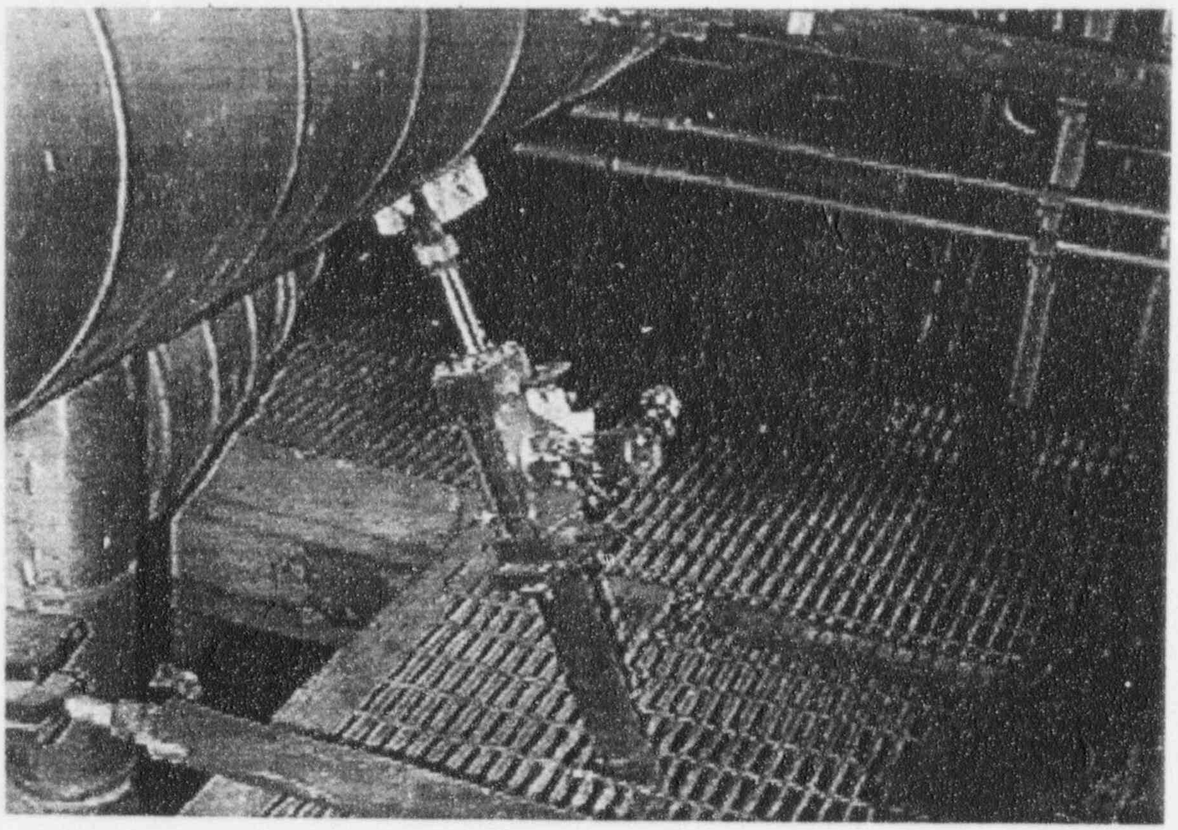
Burbank Plant: Picture 12



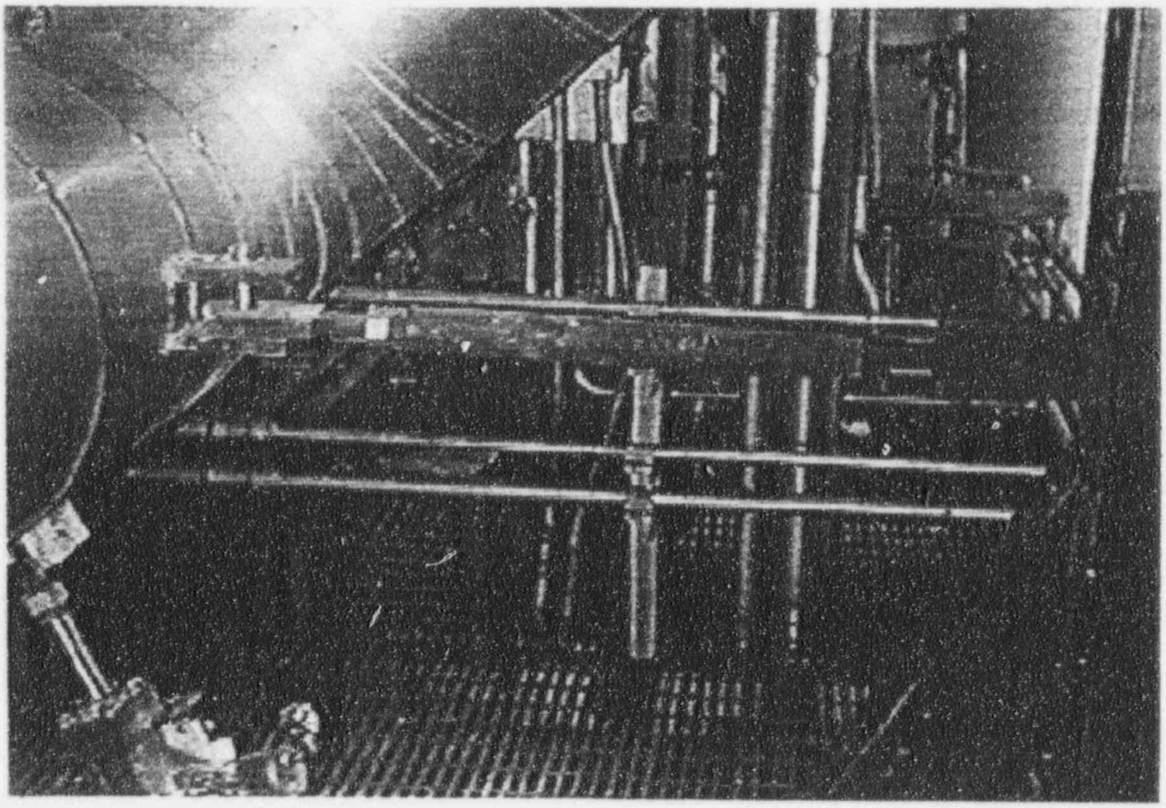
Burbank Plant: Picture 13



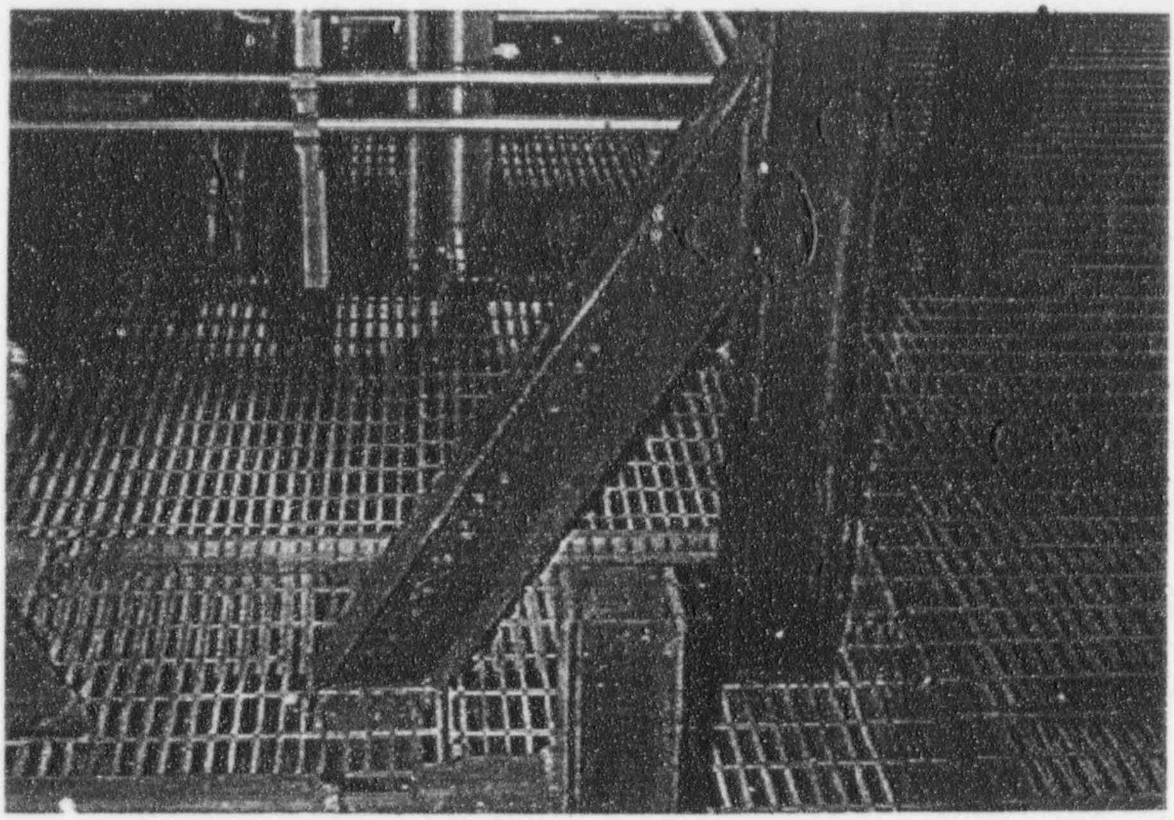
Burbank Plant: Picture 14



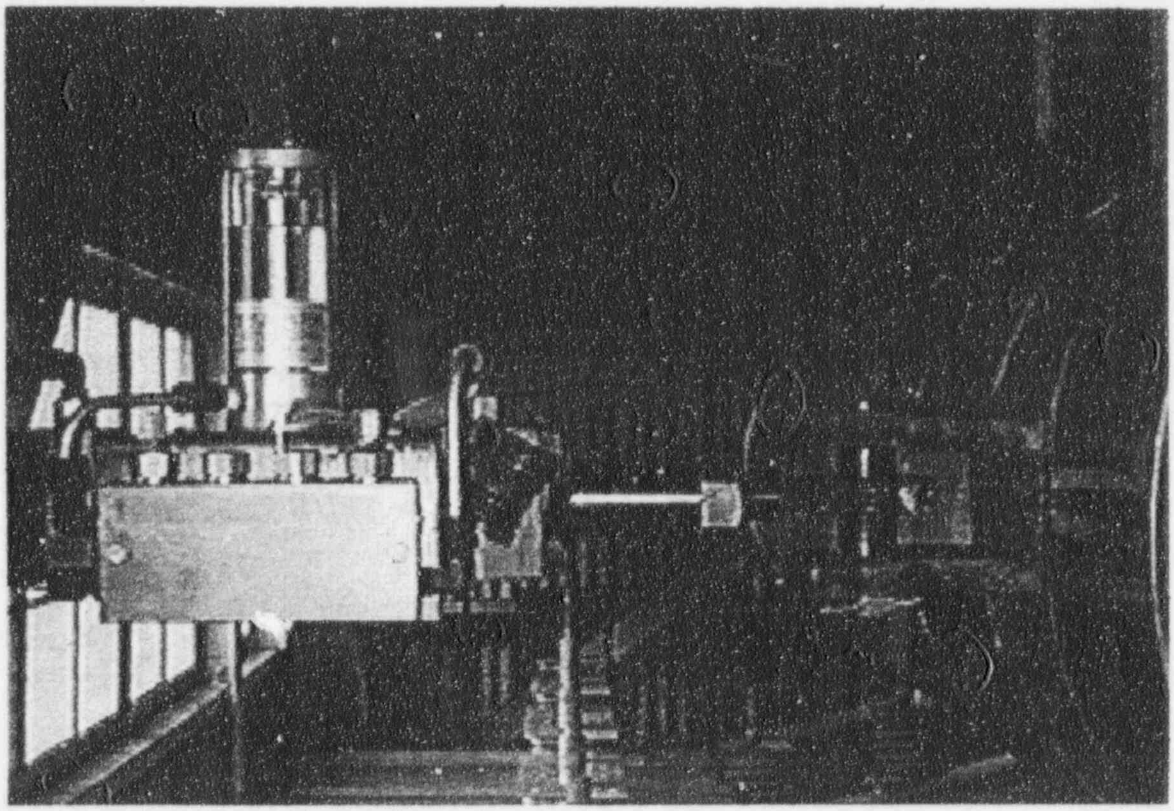
Burbank Plant: Picture 15



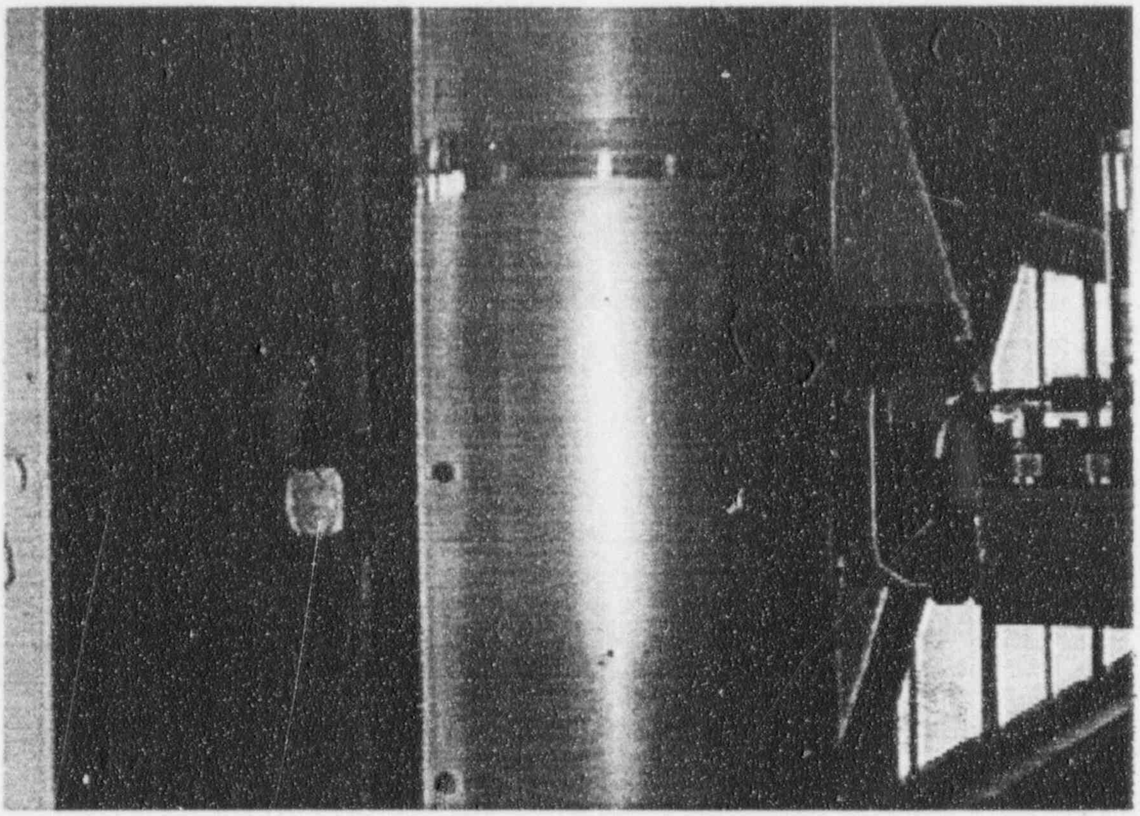
Burbank Plant: Picture 16



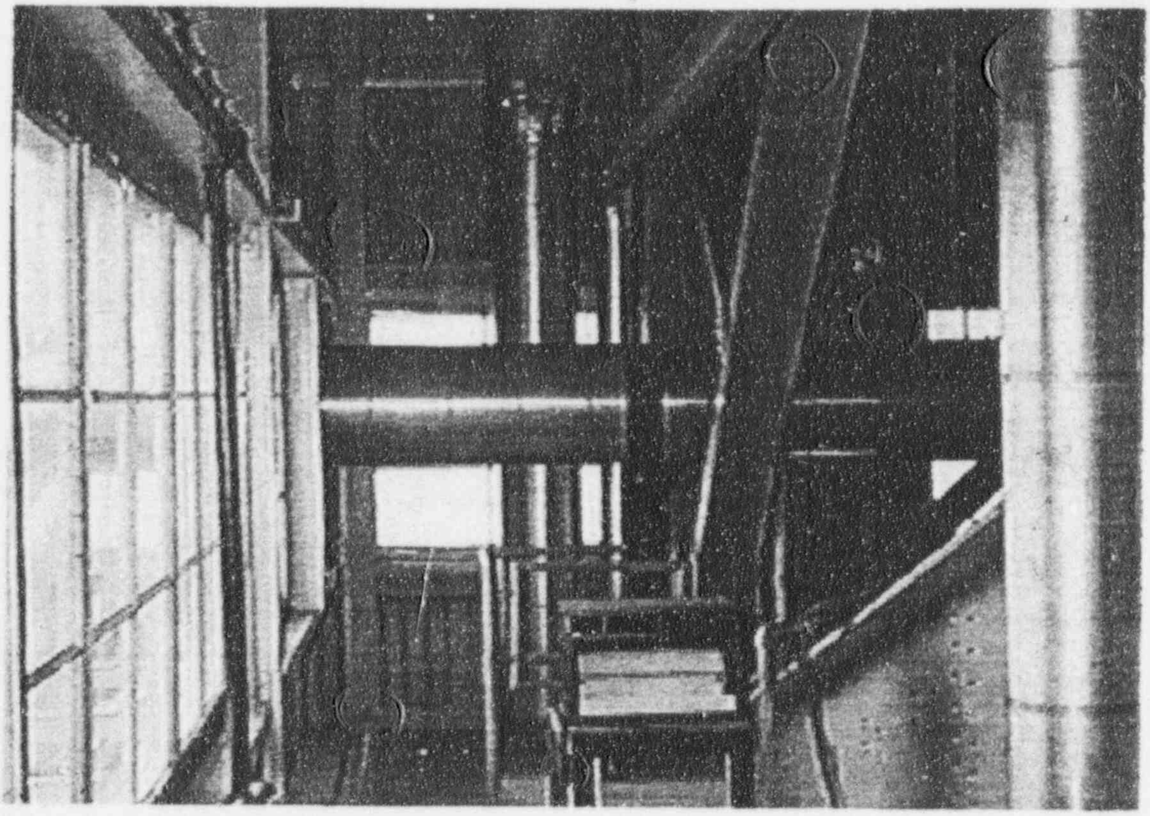
Burbank Plant: Picture 17



Burbank Plant: Picture 18



Burbank Plant: Picture 19



Burbank Plant: Picture 20

Appendix A3: Survey of Damage due to the 1995 Hyogo-Ken Nanbu Earthquake (Kobe)

A3.1 Introduction

Most large devastating earthquakes are measured by the degree of damage they cause and the loss of life. The 1995 Kobe earthquake is no exception. However, to a considerable degree the amount of damage and loss of life are related to the amount, type and quality of residential construction in the immediate proximity of the epicenter and faults that moved during the earthquake. In this regard by far most of the loss of life and total destruction were in traditional older Japanese single family homes and small apartments built before modern building materials were available.

The unusually large lateral ground and building displacements and their associated P-Δ resulting from the KOBE earthquake may also have contributed significantly to the observed damage. Newer prefabricated construction of dwellings performed quite well with relatively little damage reported. However, such construction tended to be in newer neighborhoods which were removed some distance from the regions of high intensity.

A3.2 Seismic Intensities

Earthquake accelerations of more than 0.82g were recorded in the Kobe earthquake high intensity region near the fault line that moved. This value is 2 to 3 times the Standard 0.3g to 0.4g typically used in structural design of engineered structures in this region.

The design of conventional structures at ground accelerations of 0.4 g using modern engineering materials and designs with high ductilities increase cost by about 5 percent for new construction. Design for 0.8g even if it is feasible when foundation phenomena such as liquefaction are concerned would increase the cost differential by a factor of about 4 or 20 percent.

In Figure A3.1 can be found maximum measured seismic acceleration in cm/sec/sec (1.0 g equals 980cm/sec/sec) and velocities in cm/sec as a result of the Kobe Earthquake. Associated with the 818 cm/sec/sec peak ground acceleration instrument location shown in Figure A3.1 are the acceleration time history motion shown in Figure A3.2 and more importantly the Fourier Spectrum plots for the 0.81g location shown in Figure A3.3. It is important to note from Figure A3.3 that the dominant energy of the earthquake is in the 0.8 to 1.4 second range. This suggests that the dominant frequency of the earthquake is much lower than are used in standard design spectra and that ground motion velocities and in particular displacement velocities are much higher than those used in standard seismic design spectra. These results also support the conclusion reached by Iwan [A17] with regard to near-field seismic design motions. This conclusion concerning relatively large ground velocities and displacements in high intensity regions near epicenters and fault movements could have far reaching impact on the parameters used in seismic design.

A3.3 Impact of Larger than Expected Velocity and Displacement Motions on Design

In general the only displacement limit associated with design of structures, systems and components is that associated with story drift. The story drift limit from the U.S. UBC for structures having frequencies greater than 1.4 Hz is 0.5 percent. Iwan has given the means for determining the maximum drift ratio as a function of the dynamic characteristic of a building and the velocity time history applied to the structure.

In Table A3.1 is a comparison between the recorded motions of the Sylmar Converter Stations (SCS) in the Northridge earthquake and the .81g peak recorded acceleration at Kobe, KOB. For 5 percent damping the KOB earthquake would result in a maximum story drift ratio for the heights associated with a nuclear power plant of about 2 percent.

Reinforced concrete beams for nuclear power plants which typically are not designed using the ductile detailing requirements of ACI-318 do not have a drift capacity greater than about 0.7 to 1.0 percent prior to significant damage and potential failure. This suggests that a maximum story drift spectral evaluation should be performed in addition to response spectral analysis. The recommendation made by Iwan concerning the Northridge Earthquake appear to be supported by the Kobe Earthquake. These recommendations somewhat modified are as follows:

1. The shape of the response spectrum for near-field

thrust-fault generated earthquakes may not differ greatly from that of standard design earthquakes.

2. The shape of the time history of near-field earthquake ground motion is as important for the seismic design of some structures as the spectral content of the motion.

3. The time history of near-field ground motion is characterized by potentially damaging distinct large-amplitude velocity and displacement pulses.

4. An additional measure of damage potential for near-field earthquakes may be needed. The *Drift Demand Spectrum* is recommended for this purpose to be used in conjunction with the traditional response spectrum. This is particularly true for nuclear power plant structures which typically have not employed ductile joint detailing.

5. Drift demand spectra computed for a sample of near-field records from the Northridge and Kobe earthquakes show drift demands which exceeded code recommendations, the drift demand of standard design earthquakes, and the experimentally determined drift capacity of most non-ductile design steel beam-column and reinforced concrete connections.

The concern with regards to story drift and P-Δ effects is inherent in any inverted pendulum type structure where lateral displacements tend to increase bending moments in support members. This would be true for not only building structures but also for any base supported system and component. Fortunately most distribution systems are hung from above the system hence are not subject to this type of P-Δ instability.

A3.4 Brittle Fracture

A second area of concern brought to light by the Kobe Earthquake is the potential of brittle fracture in structures which are nominally in a compression field. This type of failure suggests there may have to be more careful controls on carbon steel materials used in safety related applications in nuclear power plants with regard to their nil ductility transition temperature requirement and possibly more stringent requirements placed on weld heat treatment requirements.

A3.5 Summary of Damage to Power Generating Facilities Due to the Kobe Earthquake

Table A3.2 provides a summary description of damage to Kansai Electric Power Stations due to the Kobe earthquake. In this regard except for the large amount and extent of land subsidence observed, the earthquake induced damage to these facilities is similar to the observed earthquake induced damages to U.S. power plant facilities due to the San Fernando-1971, Northridge-1994, El Centro-1975 and Kern-1952 earthquakes at approximately the same peak ground accelerations.

A3.6 Conclusions

The Kobe earthquake supports the need to consider displacement and story drift limits as well as stress limits in structural members responding to earthquake ground motions. This is particularly true for facilities near (within 10 km) of the epicenter or fault rupture lines of thrust type faults for damaging earthquake.

A second concern raised by the Kobe earthquake is the potential of brittle fracture of carbon steel members. Current material specification or selection and past weld heat treatment requirements contained in AISC Specification N-690 should be reviewed for possible modification. Also, as part of this concern, the ductility of hot rolled structural steel shapes with respect to their ductility as function of the direction of rolling should be addressed.

Other than the two concerns just raised, the observed damage at power generating facilities were typical of those observed at U.S. power generating facilities subjected to comparable zero period ground acceleration levels and there is no other obvious need to modify current design practices.

Table A3.1 Comparison of Recorded Motion in the Northridge and Kobe Earthquakes[1]

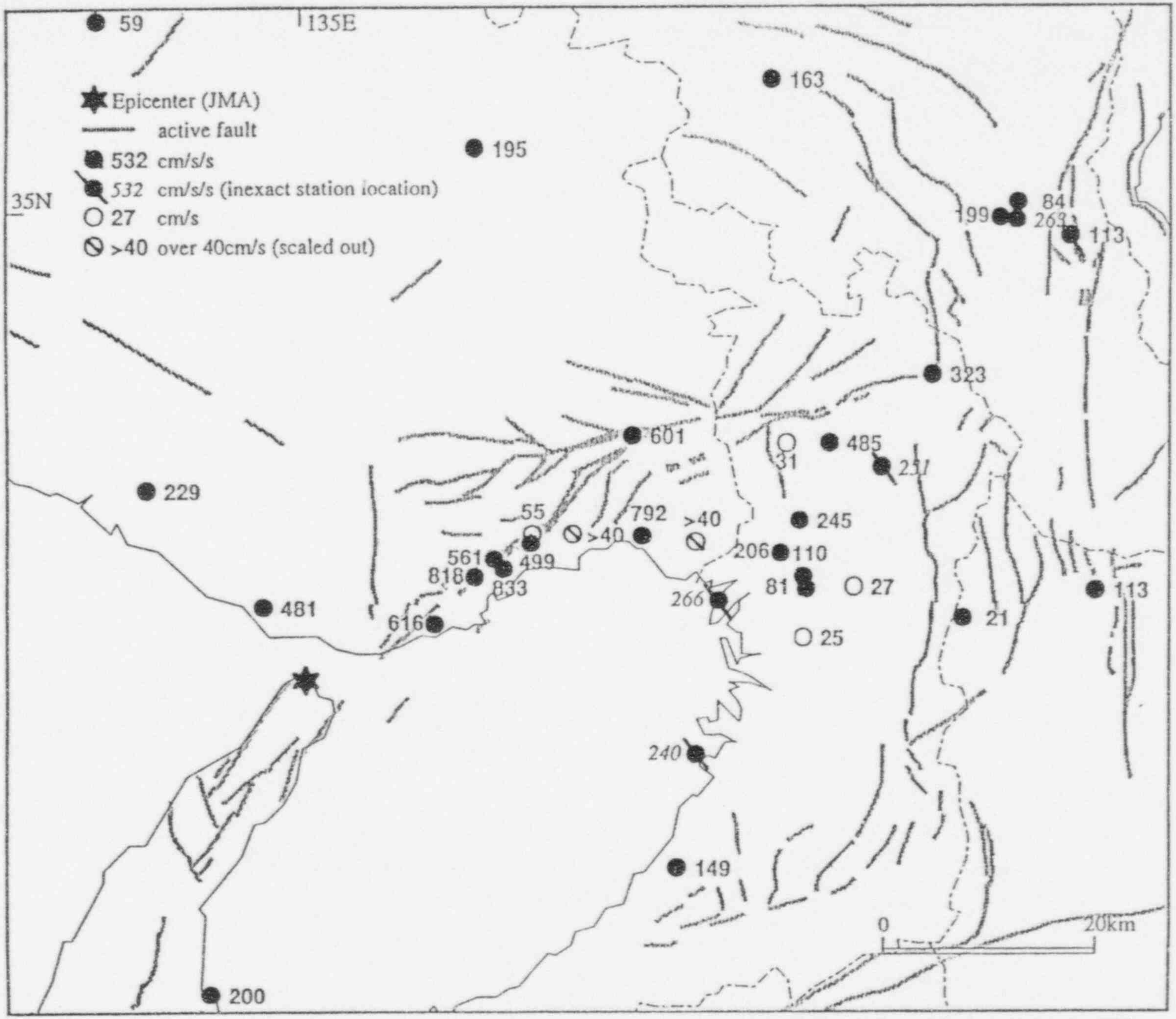
	SCS			KOB[1]		
	PGA (g)	PGV (cm/sec)	PGD (cm)	PGA (g)	PGV (cm/sec)	PGD (cm)
N-S	0.63	84	58	0.83	90	21
E-W	0.71	149	126	0.63	75	20
VERT	0.59	37	55	0.34	40	11
AVE	0.64	90	80	0.60	68	17

[1] These values are directly from recorded data and have not been base line corrected.

Table A3.2 Description of the Main Equipment Damage of the Kansai Electric Power Stations

Power station	Equipment damage
Higashi Nada gas turbine	○ Land subsidence spread across the entire yard (fissures and liquefaction occurred) Uneven settling of buildings and equipment foundations (gas turbine foundations and the like) Exposed fuel tank foundation piles (fuel tank does not appear to be leaning) Cracked, leaning tide embankments
Amagasaki Higashi	● Land subsidence and fissures (areas surrounding the main building, on-site roads, and the like) Distilled water tank leaning, purified water tank has settled, drainage gutter damage, and partial cracking of oil retention embankment) ● Steel frame damage to turbine building (braced portions and the like) ● Piping support damage (main steam pipes, high temperature reheating steam pipes, and the like)
Amagasaki No.3	● Land subsidence and fissures (areas surrounding the main building, on-site roads, and the like) Partial buckling of water intake reservoir crane foundation and similar damage ● Boiler frame bent (boiler seismic tie mounting portion, braced portions, and the like) ● Piping support damage (main steam pipes, high temperature reheating steam pipes, and the like)
Osaka	● Boiler tube damage (cooling spacer tubes bent and fractured; wall tubes partially deformed from impacts)
Sakaiko	● Boiler tubes bent (bending of cooling spacer tubes) ● Economizer header drain tube nozzle fractured
Sanpo	● Economizer element damage (cracks developed on welded portions of attached metal fixture)
Nanko	● Boiler tubes bent (cooling spacer tubes bent)
Kasugade	● Superheater and reheater spacers became detached from boiler
Himeji No.2 Takasago Himeji LNG Terminal, etc.	● Thermal insulation dropped off (high temperature reheating steam pipes and the like) ● Building structure damage (cracks developed on main building and service building) ○ Partial cave-in of soil bank

Legend ●: Repaired
○: To be repaired



Earthquake Research Institute, University of Tokyo

Figure A3.1 Maximum Accelerations and Velocities of the 1995 Hyogoken-Nanbu Earthquake

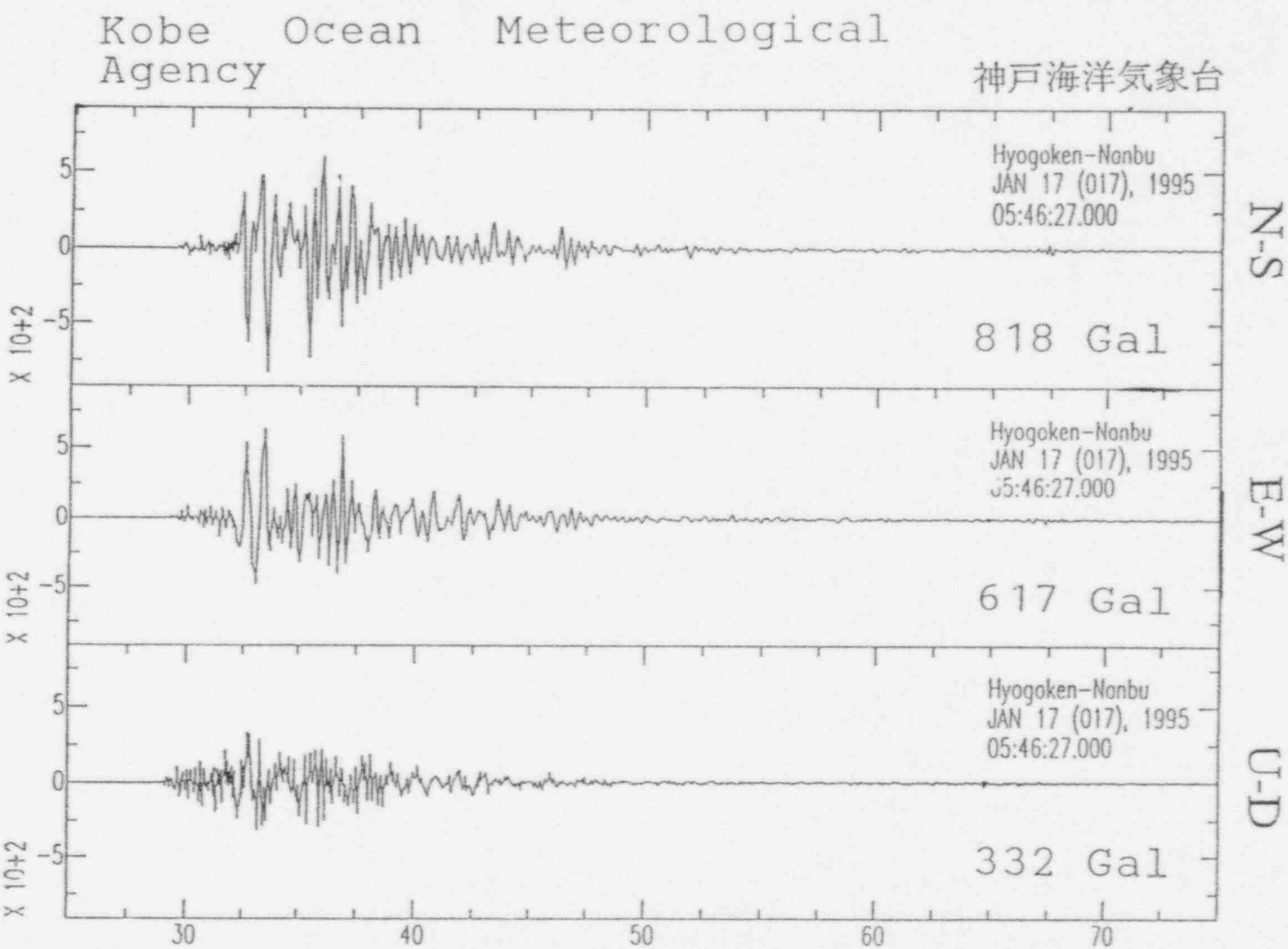


Figure A3.2 Recorded Time History Motions at the Station Shown in Figure A3.1

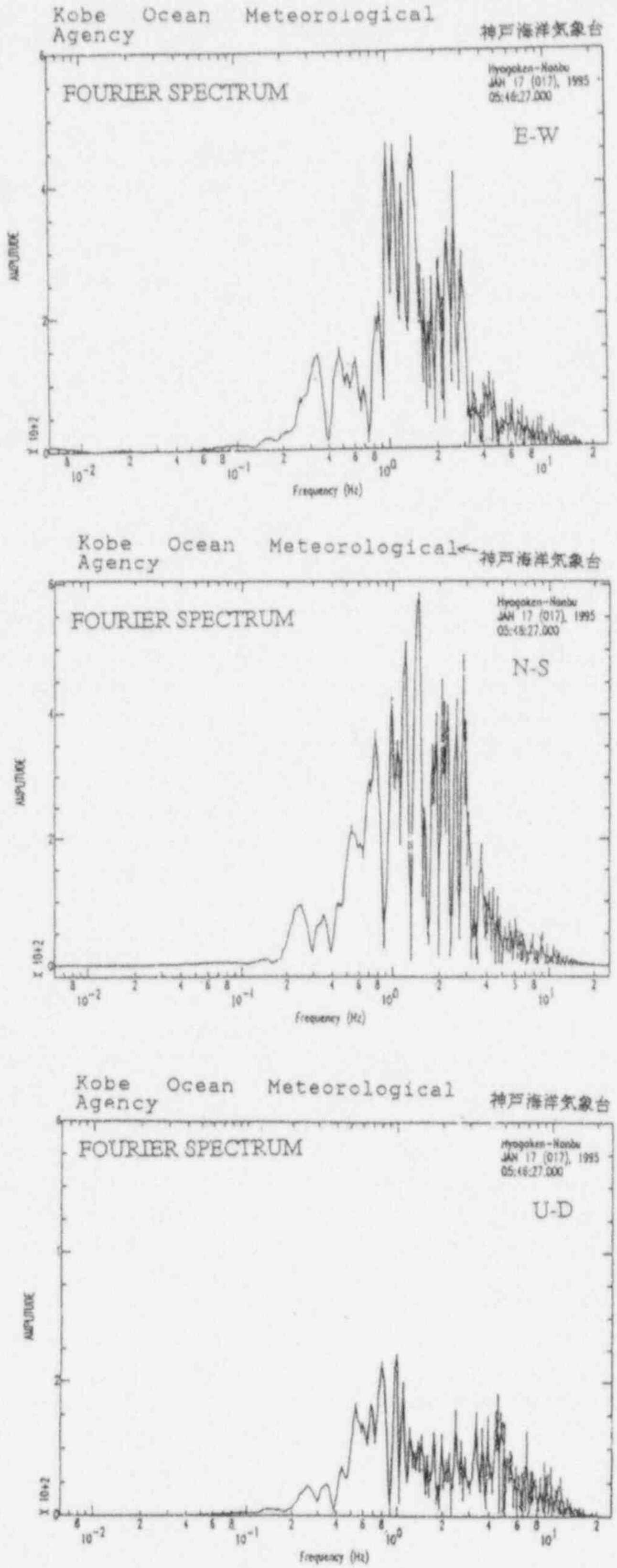


Figure A3.3 Fourier Spectrum of the Kobe Earthquake Motion Station Shown in Figure A3.1

Appendix A4: Summary of Observations from Earthquake Experience

A4.1 Introduction

This Appendix discusses suggested changes to US Industry Codes and Standards resulting from investigation of the response and performance of industrial and power plant facilities subjected to strong motion earthquakes. These suggestions are also discussed in Section 3.6 of the report.

A4.2 Distribution Systems

The design codes and practice for electric cable systems and HVAC ducting systems appear to be adequate to insure these systems can withstand strong motion earthquakes. This could be further assured if their support systems are capable of carrying three times the deadweight load of the ducting. It is, however, imperative that adequate attention is provided to the anchorage of equipment to which these systems are attached, so as to limit seismic anchor motions. For seismic Category I systems there are several sets of standards which could be applied to the design of supports for these distribution systems including:

- AISI-CFSDM
- AISC-N690
- IEEE-628
- SMACNA Standards
- ASME AG-1

To avoid confusion and promote standardization for Advanced Reactors, it is suggested that the USNRC should establish via a Regulatory Guidance document the preferred application of these standards to the design of HVAC and raceway systems. Further it is suggested that the standards and overall distribution system design should consider the provision of a design by rule criterion which is supported by actual earthquake experience and which promotes the use of flexible and ductile design concepts to reduce the size and costs associated with HVAC and raceway system supports. The raceway system evaluation criteria developed by the SQUG Program [A20] provides a good basis for the development of such an experienced based "design by rule" criterion.

The relatively poor performance of fire protection piping and sprinkler systems would indicate that changes in design codes and industry practice are warranted for application to Seismic Category I fire protection piping and sprinkler systems. It is suggested that an appendix to NFPA-13 or a new NFPA standard be developed for Seismic Category I fire protection systems. Items which should be considered in the standard include:

- Elimination of the use of cast iron, malleable iron, and friction fittings and connections

- Lateral and vertical span limitation for systems containing threaded fittings.

- Expanded guidance on spatial interaction issues

- More design guidance for seismic anchor motion

- Provision of support, support anchorage details and support welding details which insure that the support system has a ductile failure mode.

These considerations plus the application of an experienced based "design by rule" approach could significantly enhance the seismic capacity of these piping systems.

For piping system supports the experience data suggests the design rules of ASME BPVC Section III, Division 1, Subsection NF and AISC N690 if appropriately applied should provide adequate margin for piping system supports. The major issues with piping system and piping system supports would appear to be with the design practice and analytical methods currently applied to these systems. The current practice which results in high frequency stiff piping systems would appear to be overly conservative from a seismic inertial loading point of view and may not be safety neutral when considering son eismic anchor motions or thermal expansion and displacement effects. Consideration should be given to modify this design practice to promote low frequency, flexible piping systems.

A4.3 Buildings/Structures

The recent near field earthquake experience supports the need for consideration of displacement and story drift limits as well as stress limits in structural members responding to earthquake ground motions. This is particularly true for facilities near (within 10 km) of the epicenter or fault rupture lines of thrust type faults from a damaging earthquake. Changes to ACI-349 and AISC

N690 should be considered to address this issue.

A second concern resulting from the earthquake experience investigations is the potential of brittle fracture of carbon steel members. Current material specification or selection and past weld heat treatment requirements contained in AISC Specification N690 and AWS D1.1 should be reviewed for possible modification to address this issue.

Appendix A5: References for Appendix A

A1 Wiseman, R., "Reconnaissance Report on the 1964 Alaskan Earthquake," Prepared for Westinghouse Electric Co., 1965.

A2 Stevenson, J.D. and Leeds, D., "Reconnaissance Report on the Union S.C. - 1900 and El Centro - 1940 Earthquakes," Prepared for Westinghouse Electric Co., 1966.

A3 Pacific Gas and Electric Co , "Report on the June 7, 1975 Ferndale Earthquake," August, 1975.

A4 Cloud, R.L., "Seismic Performance of Piping in Past Earthquakes," Presented at ASCE Specialty Conference, Knoxville, TN, September, 1980.

A5 Murray, R.C., et. al., "Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake," NUREG/CR-1665, Lawrence Livermore National Laboratory for Nuclear Regulatory Commission, October, 1980.

A6 Herring, K.S., et. al., "Reconnaissance Report: Effects of November 8, 1989 Earthquake on Humboldt Bay Power Plant and Eureka, California Area," NUREG-0766, June, 1981.

A7 Yanev, P.I., Swan, S.W., "Volumes I and II: Pilot Program Report; Program for the Development of an Alternative Approach to Seismic Equipment Qualification," Prepared for Seismic Qualification Utilities Group by EQE Inc., San Francisco, California, 1982.

A8 USNRC, Report of the U.S. Nuclear Regulatory Commission Piping Review Committee, "Summary and Addendum to Volume 2 of NUREG 1061," April, 1985.

A9 EQE Inc., "An Overview of the Performance of Aboveground Piping Systems at Selected Facilities During Strong-Motion Earthquakes," Prepared for Stevenson and Associates, Cleveland, Ohio, April, 1984.

A10 Shibata, H., "Damage to Piping Systems by Earthquakes," Prepared for Stevenson and Associates, Cleveland, Ohio, by Prof. H. Shibata, University of Tokyo, May, 1984.

A11 EPRI, "Recommended Piping Seismic-Adequacy Criteria Based on Performance During and After Earthquakes: Volume: Summary Document, Volume 2: Reference Document," Report NP-5617, Prepared by EQE Inc. for Electric Power Research Institute, Palo Alto, California, January, 1988.

A12 Stevenson and Associates, "Survey of Strong Motion Effects on Thermal Power Plants in California with Emphasis on Piping Systems," Draft Prepared for Oak Ridge National Laboratory, July, 1992.

A13 Stevenson and Associates, "Trip Report Intransit Storage and Part Office Building (Old Railroad Building), Whittier, Alaska," September, 1992.

A14 U.S. Nuclear Regulatory Commission, "Regulatory Analysis for Resolution of Unresolved Safety Issue A-46, Seismic Qualification of Equipment in Operating Plants," NUREG-1211, Washington, D.C., February, 1987.

A15 Stevenson and Associates, "An Evaluation of the 1983 Hawaiian Earthquake with Particular Attention to Mechanical and Electrical Systems and Equipment," Prepared for USNRC, December, 1983.

A16 EQE Engineering, "The Performance of Raceway Systems in Strong-Motion Earthquakes," EPRI-NP-7150-D, Prepared for the Electric Power Research Institute, Palo Alto, California, March 1991.

A17 Iwan, W.D., "Near-Field Considerations in Specification of Seismic Design Motions for Structures," Proceedings of the 19th European Conference on Earthquake Engineering, Vienna, Austria, 1994.

A18 United States Nuclear Regulatory Commission, Regulatory Guideline 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Revision 1, December 1973.

A19 Newmark, N.M. and Hall, W.J., "Development of Criteria for Seismic Review of Selected Nuclear Power Plants", NUREG/CR-0098

A20 EQE Engineering, "Cable Tray and Conduit System Seismic Evaluation Guidelines," Report EPRI NP-7151-D, Prepared for the Electric Power Research Institute, Palo Alto, California, March 1991.

A21 Letter from Mr. C.T. Brazell, Riley Stoker Corporation, to Mr. R. Hawley, City of Burbank, transmitting a Post Earthquake Evaluation Report following the Northridge Earthquake, February, 25, 1994. Proprietary information. Not publicly available.

Appendix B: Comparison of SRP Cited Editions Versus Current Editions of Selected Civil Structural Industry Codes and Standards

In conducting this program, a large amount of data was reviewed and tabulated for a significant number of industry consensus codes and standards. At the request of the USNRC some of this data is extracted and formatted for use in other ongoing programs and studies at the USNRC. In this appendix comparative information is extracted for several Civil-Structural Codes, Standards, and Specifications to support the ongoing Standard Review Plan (SRP) Update Program.

The codes which are the subject of this comparison effort are:

- AISC N690
- ACI - 349
- ACI - 359 (ASME BPVC, Sec. III, Div. 2)
- ASME BPVC, Section III, Division 1, Subsection NE

In this appendix the revision of the code referenced in the current revision of the Standard Review Plan (NUREG-0800) or related documents was compared to the current revision or edition of the code. The purpose of the review was to (1) identify changes or differences between the SRP cited version of the code and the current version of the code; (2) determine and categorize the significance of the changes; (3) provide a description of the changes; and (4) make a preliminary assessment as to the regulatory significance of the changes. Table B.1 shows the revisions of the codes used in this comparison effort.

Table B.1 - Standard Revisions (Editions) Used in the Comparison

Code	Cited Version (Revision)	Current Version (Revision)
AISC N690	1984 Edition	Draft 1995 Edition[1]
ACI-349	1976 Version including the 1979 Supplement with 1985 version of Appendix B	1990 Edition
ACI-359 (ASME BPVC, Section III, Division 2)	1980 Edition	1992 Edition up to and including the 1994 Addenda
ASME BPVC Section III, Division 1, Subsection NE	1980 Edition up to and including the winter Addenda	1992 Edition up to and including the 1994 Addenda

[1]See discussion in Section B1.2 of Appendix B1.

Appendix B1: AISC N690 Comparison

B1.1 Overview of the Code

The N690 Specification applies to the design, fabrication, and erection of steel safety-related structures and structural elements for nuclear facilities. This Specification shall also apply to composite structures consisting of structural steel and concrete.

Structures and structural elements which are the subject of the N690 Specification are those steel structures which are parts of the nuclear safety-related system or which support, house, or protect nuclear safety-related systems or components, the failure of these systems or components.

B1.2 Versions Compared

The 1984 version of AISC N690 was chosen as the cited version because the USNRC staff endorsed that version, with exceptions, in the GE/ABWR and ABB/System 80+ Final Safety Evaluation Reports. It was compared to the Final Draft of the 1995 version. Per discussions with AISC headquarters the Draft version used in the review is the final version and is as it will be published. Publication has been delayed due to logistical reasons.

B1.3 Summary of Significant Changes

There are no major changes in the overall philosophy, methodology and criteria used by this specification. There are changes in specific criteria and design equations which reflect changes to industry practice since the 1984 version was issued. In some cases the modifications are more conservative than the 1984 and in some cases they are less conservative. It should also be noted that the USNRC concerns as expressed in Section 3.4.1.7 of the main report do not appear to have been addressed in this latest revision.

B1.4 Regulatory Impact

No major impact on the current regulations is apparent. Some issues which will need further review are:

(a) Flexible - Torsional, Torsional buckling checking for asymmetric thin wall columns (Q.1.5.3.6)

(b) Shear and Tension bolts (Q.1.6.3)

(c) Web yielding, crippling and buckling (Q.1.10.10)

It is difficult to make an assessment of the impact these changes will have because very few, if any, of the existing operating nuclear power plants were designed using AISC N690. Most were designed to commercial structural steel codes with additional restrictions and criteria as put forth in the respective plant specific FSAR's. Lacking the benefit of an indepth comparative review to existing plant practice, it is the author's belief the direct citation of N690 in the updated SRP would not have significant impact on new plant construction.

B1.5 Detailed Comparison

Table B1.1 presents a detailed comparison of the changes between the two editions of the Specification.

Table B1.1 - Detailed Comparison for AISC N690		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Table of Contents	E	The subsection titles defined with three numbers are not included in the Table of Contents.
Table of Contents	E	The section titles for the commentaries are introduced in the Table of Contents.
Q1.0.3	TI	The referenced documents are updated and a few new references are included.
Q.1.4.1	TI	Explanatory text including new requirements is introduced after Table Q.1.4.1.1. The requirements are specific for materials such as: ASTM A6 rolled shapes to be used as members subjected to primary tensile stresses; plates exceeding 2 in. thick used for built-up members with bolted splices and subject to primary tensile stresses due to tension or flexure. New code requirements are stated for welded full-penetration joints in heavy rolled and built-up members subject to primary tensile stresses.
Q.1.5.1.2.2	TS	A new expression for the tension force beam end connections is introduced.
	TI	A new requirement to check the minimum net failure path on the periphery of welded connections is introduced.
Q.1.5.1.3.1	E	The expression Q.1.5-1 is corrected and parameter C_c is corrected for axial force evaluation.
Q.1.5.3.6	TS	The subsection Q.1.5.1.3.6 is introduced. This refers to new requirements for checking to flexural torsional and torsional buckling. This is a significant additional requirement however in most cases in the past, this item has been checked, in some manner.
Q.1.5.1.3.4	TS	The expression of the axial force is changed. The words "crippling" is changed to "yielding".
Q.1.5.1.4.2	TS	A new expression for the allowable bending stress for built-up members is introduced. In this expression a new coefficient K_c is defined (equation Q.1.5-4b). <u>Editorial mistake:</u> equation Q.1.5-4b is defined also in Section Q.1.5.4.3.
Q.1.5.1.3.2	TI	Some words in the first paragraph are changed. Some words in the second paragraph are also changed. They refer to members with yielding point greater than 65 Ksi instead of members of A514 steel.
Q.1.4.1.4.4	E	Includes a new expression for allowable bending stress for rectangular tubular sections from Section Q.1.5.1.4.3.
Q.1.5.1.5.3	TS	Equation for evaluation of allowable bearing stress is split into four expressions Q.1.5-7 through Q.1.5-10 depending on the type of slotted holes. Explanatory text is introduced.

Table B1.1 - Detailed Comparison for AISC N690 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Table Q.1.5.2.1	TS	The content of the table is changed. The values for allowable stresses on fasteners in shear and tension are changed. The references in the table text are also slightly changed. Table footnotes are changed.
Q.1.5.1.5.3	TS	The text after Table Q.1.5.2.1 is deleted. Apparently, some text (footnote K in old standard) is missed.
Table Q.1.5.3	TS	The text in column two of the table is shortened. The restriction due to shear stress in the base metal is not to exceed 0.40 yield stress is relaxed.
Table Q.1.5.7.1	TS	A new footnote (i) was introduced for category of "severe" load combinations however, in general these loads are considered in NPP design. The Code now references ASCE 7 for definition of snow and other loads.
Table Q.1.5.8.1	E	Redefine parameter E_o.
Table Q.1.5.8.1	TS	The point D referring to elements in uniform compression due to bending is deleted.
Q.1.5.9.1	TI	The equation Q.1.5-12 (in the old standard Q.15-8) is incomplete, i.e. the factor F_y is missed.
Q.1.6.2	TS	The interaction curve for members subject to both axial tension and bending stresses was modified. The new expression Q.1.6-3 is different from the old one Q.1.6-1.b, i.e. the notation F_t is used instead of 0.60 Fy. F_t is now defined differently in section 1.5.1.1.
Q.1.6.3	TS	The equations to compute the tensile stress in both are changed.
Q.1.6.3	E	In paragraph b) the words "friction type" are changed by "slip critical". The division in a) and b) is new. This change is repeated later.
Q.1.6.3	E	The notations "PART A", "PART B", "PART C" for paragraph headers are changed with "1", "2", "3".
Q.1.6.3	E	For paragraphs 2 and 3 the header a) has no sense as header b) does not exist.
Q.1.6.3	E	In paragraph 3 the words "slip critical" instead of "friction type" is introduced. Same for footnote**.
Table Q.1.6.3	TS	The table content is reorganized and changed. The values for slip coefficient are slightly modified. There are only three classes of surface conditions A through C instead of nine in the old document A through I.
Q.1.6.4	TS	The subsection Q.1.6.4 on torsion effects consideration is not in the old standard. This could be of significance but in general it is considered in NPP design.

Table B1.1 - Detailed Comparison for AISC N690 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Q.1.8.6	TS	The slenderness l/r for tension members was relaxed at 300 instead of 240 for main members. An additional paragraph is added at the end of the section.
Q.1.9.1.2	TS	The limits for ratio of width to thickness are changed for struts comprising double angles in contact. A coefficient K_c is introduced and defined in the footnote.*
Q.1.10.1	TS	The criterion of considering the gross moment of inertia is defined by new expressions. The effective flange area is defined. Some old text is cut.
Q.1.10.4	E	The words "friction type" are changed with "critical slip".
Q.1.10.52	TS	The application of equation Q.1.10-1 for allowable shear based on stiffener is conditioned on ratio h/t_N. Two new rows are introduced one before equation Q.1.10-1 and one after it.
Q.1.10.6	E	This section is reorganized using some new notations for flange stress allowable. The parameter α is numerically defined.
Q.1.10.7	E	In the last paragraph instead of "A514 Steel" the terminology "steel with yield point greater than 65 Ksi" is used.
Q.1.10.10.1	TS	Some wording of this subsection is changed. The allowable stress at web toe of the fillets without bearing stiffness is 0.66 Fy instead of 0.75 Fy. This value, 0.66 Fy, is used also in equation Q.1.10-7 and Q.1.10-8, instead of 0.75 Fy. Formulas Q.1.10-7 and Q.1.10.8 are changed.
Q.1.10.10.2	TS	This section is completely changed. New text, new equation for limits of compression force in web, equations Q.1.10-9 and Q.1.10-10.
Q.1.10.10.3	TS	A new subsection is introduced for side way web buckling.
Q.1.11.1	TS	The first paragraph is changed. The requirements for selecting the effective width of the concrete flange are changed.
Q.1.11.2.2	TS	The first two paragraphs after equation Q.1.11-1 are compressed (changed) in one paragraph and the old equation Q.1.11-2 is deleted.
Q.1.11.4	E	The footnote related to the total horizontal shear to be resisted, (defined by equation Q.1.11-2) refers to the term $A'_s F_{yr}$ instead of $1/2\ A'_s F_{yr}$. This should be corrected.
Q.1.11.5.1	E	Point 5) in the old document was deleted. The old paragraph 6) becomes in the new document paragraph 5).
Q.1.11.5.2	TI	The limit spacing of stud shear connectors at point 2) is relaxed to 36 in from 32 in.

Table B1.1 - Detailed Comparison for AISC N690 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
Q.1.14.2.2	TS	This subsection is rewritten. The reduction coefficient to calculate the effective net area has been changed as notation from "C_t" to "U". A clear distinction is made between bolt and welds connection and two separate equations are applied, Q1.14-1 and Q.1.14-2.
Q.1.14.2.3	TS	After the last paragraph in the old standard, three new paragraphs are introduced. These paragraphs make a difference if the load is transmitted by transverse welds to some but not all of the cross-sectional elements or is transmitted to a plate longitudinal welds along edges. The new modification in text allows also the use of a larger coefficient justified by tests or other criteria (last paragraph).
Q.1.15.5.4	TS	The paragraph 3) in the old standard was deleted. The new paragraph 3) is the paragraph 4) in the old standard. Paragraph 3) in the old document referred to the required stiffener length when the force delivered was only on one column flange.
Q.1.15.12	TS	New section on splices in heavy sections. It applied to ASTM A6 Group 4 & 5 rolled shapes or built-up spheres.
Q.1.15.13	TS	New section on beam copes and weld access holes.
Q.1.16.4.2	TS	A new paragraph is in the beginning of the subsection, introducing new requirements for the distance between holes.
Q.1.16.5.3	TS	This section was cancelled from the old standard. The new Section Q.1.16.5.3 is the old Section Q.1.16.5.4.
Q.1.18.2.7	TS	Two sentences are added at the end of the old subsection including new requirements for separated element connections. These refer to the Table Q.12.8.
Q.1.21.3	E	Paragraph 1) and 2) reference paragraphs 3) and 4), instead of only 3).
Q.1.21	TS	Paragraph 4) is a new requirement about finishing.
Q.1.22.2.1.1	E	This subsection is new. It refers to Appendix B, ACI 349 for minimum requirement for anchorage of anchor bolt.
Q.1.22.2.1.2	TS	This subsection is new. It states that design limits less conservative than those specified may be used by the engineer if substantiated by experiment or detailed investigation.
Q.1.22.2.2	TI	Subsection is reduced to only one new paragraph which cites ACI 349, Appendix B for design of anchor bolts and steel embedments. The old Sections Q.1.22.2.1.1 through Q.1.22.2.3 are deleted
Q.1.22.2.2	TS	The old Sections Q1.22.2.2 and Q.1.22.2.3 are deleted. Subsection is reduced to only one paragraph which cites ACI-349, Appendix B for design of anchor bolts and steel embedments.

Table B1.1 - Detailed Comparison for AISC N690 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
Q.1.23.2	TS	New paragraph is added. This paragraph introduces new requirements for beam copes and weld access holes.
Q.1.23.7.6	TS	New subsection for bolts of type A490 greater than 1 inch diameter.
Q.1.23.8	TS	A new sentence in the beginning of the first paragraph was introduced.
Q.1.23.8	E	A new sentence was introduced in the middle of the second paragraph. It refers to the orientation of fully inserted finger shims.
Q.1.23.8	E	The fourth paragraph includes some new text. Does not refer to Table Q.1.23.8.
Q.1.23.8.	TS	The fourth paragraph is new and gives requirements for high strength bolts.
Q.1.23.8	E	The Table Q.1.23.8 is deleted.
Q.1.23.8	TS	A new sentence was introduced in the middle of the second paragraph. It refers to the orientation of the fully inserted finger shims.
Q.1.23.8	E	The fourth paragraph includes some new text. Does not refer to Table Q.1.23.8.
Q.1.2.3.8	TS	The fourth paragraph is new and gives requirements for high strength bolts.
Q.1.23.8	E	The Table Q1.23.8 is cancelled.
Q.1.26.1.5	E	The paragraphs after the first one are changed or deleted. The last paragraph refers to the EPRI NP-5380 report. The last five paragraphs of the old document are deleted.
App. QA List of Tables	E	The references for the first row and last row are changed. The description text is changed for the last row, Table Q.12.
Table Q2	TS	The allowable bearing stress in the connected part is limited to 1.5 F_u instead of 1.2 F_u, thus the 6th column is changed.
Table Q6	E	In the second row the expressions of slenderness ratio as a function of F_y are different than in the old document; instead of multiplication by $[C_b]^{1/2}$ it defines division by $[C_b]^{1/2}$.
Table Q8	TI	The values of C_m in the third column are given also for values of the ratio M_1/M_2 greater than 0.50.
Table Q12	TS	The table is changed. The content refers to "Limiting Width-Thickness Ratios for Compression Elements" instead of coefficient Ch for allowable bending stress.
QB3.1	TS	Subsection is rewritten.

Table B1.1 - Detailed Comparison for AISC N690 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
Table QB2	TI	The content of the table slightly changed.
Table QB3	TS	The allowable range of stress is modified in the table.
QC2	TS	Equations QC2-3, QC2-4 are modified. New footnotes, also.
QC5	E	In equation QC5 the parenthesis is missing.
QC6	E	An additional explanatory sentence is added to the last paragraph.
QE1	E	This subsection is split in two, QE1 and QE2 in the new document. The text is reorganized and changed.
Table QE1	TS	The values of allowable shear stresses are changed and then are only three classes A, B and C related to the surface condition of bolted parts instead of A through I.
QE2	TS	The old section is deleted. The new section is different.

Appendix B2: ACI-349 Comparison

B2.1 Overview of the Code

The ACI-349 Code provides the minimum requirements for the design and construction of nuclear safety related concrete structures and structural elements for nuclear power generating stations. Safety related structures and structural elements subject to this standard are those concrete structures which support, house, or protect nuclear safety class systems or components or which are component parts of nuclear safety class systems.

Specifically excluded from this Code are those structures covered by "Code for Concrete Reactor Vessels and Containments," ASME Boiler and Pressure Vessel Code Section III, Division 2 and pertinent General Requirements (ACI-359).

B2.2 Versions Compared

The cited version (as endorsed in Regulatory Guide 1.142) is the 1976 version including the 1979 supplement except for Appendix B. For Appendix B, the cited version in the 1985 version which was endorsed, with exceptions, in the GE/ABWR and ABB/System 80+ Final Safety Evaluation Reports. It is compared to the latest version of ACI-349 which is ACI-349-90.

B2.3 Summary of Significant Changes

There are various changes between the two revisions of the Code. These changes include new requirements, new analytical expressions, new subsections. These changes impact design, analysis and construction methods for nuclear power plant reinforced concrete structures.

B2.4 Regulatory Impact

It is anticipated that evoking the new revision of ACI-349 in the SRP will have significant impact (both cost and technical) on the design of new safety related nuclear power plant reinforced concrete structures. Items of significance include new design and construction requirements and new analytical requirements. Prior to such implementation it is suggested a detailed impact evaluation study (both cost and technical) should be conducted.

B2.5 Detailed Comparison

Table B4.1 presents a detailed comparison of the changes between the versions of ACI-349.

Table B2.1 - Detailed comparison of ACI-349		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Front Page	E	Same names, key words, text is slightly changed.
Content	E	Only slight changes made. The appendices A,B,C,D, and E contents are new.
1.3.1	E	Some changes in the text about responsibilities for inspection.
1.3.2	TI	The text is changed. The restriction for temperatures below 40°F is no longer stated.
2.1	E	Some general definitions have been deleted.
3.6.1 through 3.6.7.2	E	Slight change in the text and arrangement of paragraphs on admixtures.
3.71 through 3.7.4	E	Numbering of paragraphs changed, including new paragraphs on storage and identification of materials.
3.8.1 through 3.8.3	TI	Changes in the referenced standards are made. The impact of potential changes in the referenced standards are not reviewed as part of this effort, but should be reviewed prior to invoking the latest code editions in the SRP.
4.1 through 4.6	TS	Significant changes in the text on concrete quality namely, on field experience, trial mixture water-cement ratio, average strength reduction.
4.7.1 through 4.7.4.4	E	The text is rearranged, including new paragraphs on evaluation and acceptance of concrete.
5.1.1	E	Rearrangement of the paragraphs on equipment preparation.
5.2	TI	Some new paragraphs added. No significant technical changes.
5.3	E	A few wording changes.
5.4	E	A few wording changes.
5.5, 5.6, and 5.7	E	A few wording changes.
6.1	E	A few paragraphs are reordered.
6.2	E	Some paragraphs were reworded.
6.3	E	Some paragraphs were reworded.

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
6.4	TI	The text is rewritten.
7.2	E	Slight changes in the text. No significance
7.5	TI	Additional text on placing reinforcement is added.
7.6	E	The text and paragraphs are rearranged. Primarily editorial.
7.7	TI	This is at 7.14 in the old standard. A few minor changes were made.
7.7.3 through 7.7.6	TI	Some rewording of these paragraphs.
7.8	TI	Old section is 7.10. Paragraphs are rearranged. Some text is changed. Old Sections 7.10.3, F.10.7, F.10.5 are reduced editorial and reduced in content.
7.8.2	E	Section rearranged.
7.10	E	The text is rearranged.
	E	Sections 7.5, 7.6, 7.7 and 7.8 in the old standard are not in the same location and have been folded into other sections.
7.12	TS	New Section on minimum reinforcement.
8.1	TI	Last two paragraphs in the old standard are deleted.
	E	Old Section 8.3 was moved (on evaluation of elasticity modulus for concrete) to Section 8.5.
8.3	E	Title changed.
8.4	E	It is the old Section 8.6.
8.6 through 8.9	E	These Sections are obtained from the rearrangement of old Section 8.5.
9.0	TI	Few new notations are defined. None of significant impact.
9.1	TI	It is rearranged. New notations are provided for liquid pressures, F, and lateral earth pressure, H.
9.2	TI	New notations are introduced, ie., H and F. (See 9.1).
9.3	TS	This section was not included in Section 9 of the old standard. It refers to Design Strength, (including the reduction factors).

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Table 9.5(a)	TS	This is a new table. It compares deflections based on unfactored load combinations, which were obtained by defining a new factor γ. The values of the displacement limits are different than those given in the old standard.
9.5.1.1	TS	First paragraph has a new addition at the end. The 2nd and 3rd paragraphs are new and refer to table 9.5(a).
9.5 .1.4	TS	New text with some new requirements for deflections is introduced.
Table 9.5(b)	TS	The minimum thickness required for beams is changed. The values in the table are larger.
9.5.2.5	TS	The long-time deflection resulting from creep and shrinkage is determined using a factor defined differently than that given in old standard. The text is also changed.
9.5.3.1 through 9.5.3.3	TS	Text is changed. Minimum thickness is different and is given by Table 9.5(c) rather than by the evaluations of Sections 9-6 to 9-8 from the old document.
9.5.3.4	TS	There are changes to text references for displacement calculations.
9.5.3.5	E	Text editorial changes.
9.5.4.1	TS	A new sentence is added referring to cracked sections.
9.5.5.3 ad 9.5.6	TS	These are new Sections. Section 9.5.6 refers to Walls subjected to lateral loads which has to satisfy the same requirements.
10.1	E	The last sentence in the old standard deleted.
10.2.1	E	An addition to the first paragraph is provided.
10.3.3	TS	There are some wording changes (referring to magnitude of the design load strength). New requirements are included for flexural and compressive design strength.
10.3.5	TS	Includes new requirements for the design axial load strength.
10.6.4 through 10.6.6	TS	New requirements on flexible reinforcement distribution are provided.
10.9.3	TS	The yield strength of spiral reinforcement is limited to 60,000 psi.
10.11.4.1	E	The moment relation is written in small letters, 1b .
10.11.5.1	TS	The expression for magnified factored moment M_c is changed.

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
10.11.5.2	TI	The Euler's formula for critical axial compression force is deleted from the section.
10.11.5.4 and 10.11.5.5	TS	New subsection referring to the braced compression member has been added.
10.11.7	TS	New paragraph for bi-axial bending is added.
10.14.7.3	TI	New paragraph included but with no significant impact.
	E	The last subsection in the old document on walls is moved to another subsection.
11.0	E	Small changes in notations are made, none of which are of significance.
	TI	The old Section 11.1 on Design Loads is removed.
11.1.1.1 through 1.1.3	TS	The shear strength is expressed in force rather than stress. New text is provided including new requirements on shear strength.
11.2	TI	New subsection which is not technically significant is added.
11.3.1 through 11.3.2.3	TI	The text is rewritten in terms of the shear force rather than shear stress.
11.4.1 through 11.4.3	TI	The text is rearranged in terms of shear force rather than shear stresses, as in the old document.
11.5.1	E	This section has been moved. It provides acceptable types of shear reinforcement. In the old standard, it was 11.2.7.
11.5.2	TS	This is a new section on spacing limits for shear re-enforcement.
11.5.4	TI	These are new paragraphs.
11.5.6	TS	This section is rewritten. The shear force rather than the reinforcement area is evaluated in the new version.
11.6.1	TS	New requirements for torsional effects with shear for flanged sections are introduced.
11.6.1 through 11.6.4	TS	It includes several new paragraphs related to evaluation of torsional effects.
11.6.6.1	TS	A new expression for torsional moment strength is introduced. The new expression is significantly different than criteria in the old standard.
	TS	Some subsections of the old standard are deleted, (11.7.4 and 11.7.5). Expression (11-17) from the old standard corresponds to the equation (11-22) in the new one.

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
11.6.7.3 through 11.6.7.5	TS	These are changes in criteria for non-prestressed rectangular members.
11.6.8	E	These paragraphs are moved earlier in the standard (in the old version they are 11.8.6).
11.6.9.1	TS	This section is the old section 11.8.2, and is slightly different. A new expression for torsional moment strength is given.
11.6.9.2	TI	New Addition.
11.6.9.3	TS	Some changes in the expressions of longitudinal bar required area, (equation (11-25)).
11.6.9.4	TS	New requirement on the magnitude of the allowable torsional moment strength.
11.7.1 and 11.7.2	TI	New text paragraphs are included in these subsections.
11.7.4	TS	New test and requirements on shear/friction design are introduced. New expression (11-27).
11.7.6	TI	New requirements are introduced on shear/friction reinforcement.
11.7.8 through 11.7.10	TS	New text including new requirements are introduced on shear/friction.
11.8.2 through 11.8.10	TI	The text is rearranged, the order of paragraphs is modified.
11.9	TS	All this section has significant changes which include new analytical formulas and new requirements. These are significantly different than the old ones.
11.10.1 through 11.10.8	E	The text is rearranged, the text paragraphs have been reordered. However, the requirements are unchanged.
10.9.1 through 11.10.9.5	TS	The text is slightly changed. In paragraph 11.10.9.5 the ratio $l_w/3$ has been changed from $l_w/5$ in the old document. Some old paragraphs, as inspection, (11.15.7) are deleted in the new edition.
11.11.1.2	E	Small text changes.
11.11.2	TS	All this section on design of slab/footing is drastically changed. New text, new analytical formulas, new requirements are introduced for shear force evaluation.

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
11.11.3 and 11.11.4	TS	New paragraphs and requirements on shear reinforcement are introduced. Significant differences in comparison with the old edition are noted.
11.11.5	TS	A new section on Openings in Slabs introduced.
11.12	TS	This section is around three times larger in the new document. It includes new requirements on moment transfer to columns from slabs. The analytical formulas for shear forces in nonprestressed slabs and at columns of two-way prestressed slabs are new.
12.1	TI	New subsection without significant impact.
12.2 and 12.3	TI	These paragraphs are rearranged but similar to the old 12.5 and 12.6 sections.
12.5	TS	This subsection on standard hooks in tension is significantly changed.
12.7 through 12.8	TS	This section contains several new requirements on welded deformed wire fabric.
12.15.1 through 12.15.6	TS	These paragraphs contain new inclusions, new paragraphs, in comparison with the old sections 7.6.1 and 7.6.2.
12.16.1 through 12.16.4	TS	This section corresponds to the section 7.7.1 in the old Standard. These are changes of significance.
12.16.5	E	It is similar to 7.7.2 old section
12.17	E	It is similar to old section 7.10.3 through 7.10.5.
12.9.3	E	Only few words changed in the text, compared with the old paragraph 2.11.2.
12.11.3	E	New text is included in subsection 12.11.3. This section is placed earlier, (being 12.2.3).
12.13.2.3	TS	New subsection on #5 Bar and D31 wire with web reinforcement.
12.14	E	This section is placed much earlier in the older version of the standard.
12.14.3	TS	The text on Welded Splices has some changes in the first paragraph of 12.14.3.2
12.14.3.4	TS	New criteria on Mechanical Connections is included.
12.14.3.5 through 12.14.3.6	TS	New subsections on welding splice design criteria.
12.15	E	This section was placed earlier in the old standard (7.6).

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
12.18 and 12.19	TS	Significant changes in the text and new additions on Splices of Welded Deformed Wires and Welded Smooth Wire Fabric in tension are included.
13.1.2	TI	New subsection for slabs supported on columns on walls (obtained by changing the old subsection 13.1.6).
13.3.1.2 through 13.3.3.3	TS	New paragraphs and content changes are made. The subsection 13.3.3.2 is similar to the old section 11.12.2 which is placed earlier in the text. Changes are of significance.
13.4.1	TI	New subsection with no significant technical content.
13.4.8.3 and 13.4.8.4	TI	New paragraphs with no significant technical content.
13.6.1.7	TS	New subsection including a limitation for Direct Design Method.
13.6.3.3	TI	It is a modified version of the old subsection 13.3.3.3; Static moment distribution is now given in a table not through an analytical expression.
13.6.3.5 and 13.6.3.6	TI	New subsections, introducing new requirements for edge beams are introduced.
13.6.5.3 and 13.6.6.1	E	These correspond to the old subsections 13.3.4.4 and 13.3.4.5. Some text changes are made, but no significant technical changes.
13.7.2.1 through 13.7.2.5	E	Small changes in comparison to the old standard.
13.7.4	TS	New subsections are provided in place of old section 13.4.7.5 (equation 13-5 in the old standard is deleted).
13.7.7.5	TI	New Subsection not technically significant.
14.1 and 14.2	TI	New text paragraphs are introduced on wall design.
14.3	TS	New subsection on minimum reinforcement in walls.
14.4 through 14.3	TS	This section includes new requirements for Walls. Equation 14.1 is changed for evaluation of design axial load.
15.1 through 15.3	E	Includes new text modifications to existing text but none of significance.
15.4	E	Only small editorial changes.
15.5 and 15.6	E	Only few small editorial changes.

Table B2.1 - Detailed comparison of ACI-349 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
15.7 and 15.8	TS	This section is significantly changed. New requirements on force transfer are introduced.
15.9 and 15.10	TS	The text is significantly changed and includes the new requirements for sloped steeled fittings.
	TI	The old subsection 16.2.2 is deleted.
16.4.2	TI	New paragraph and requirements are provided for the design details for precast concrete cement.
17.5	E	Slight editorial changes in the text.
17.6.3	E	Text modifications and additions are editorial.
18.4.1	TS	The last paragraph is changed. This paragraph is close to the last paragraph of the old subsection 18.4.1. The other paragraphs have changes referring to permissible stress in concrete.
18.4.2	E	Similar requirements as in the old section 18.4.2. Some changes in the text are noted.
18.5.1	TS	Requirements on stresses in tendons are changed.
18.7	TS	Significant changes in this section, including new requirements and new analytical expressions on flexible strength.
18.9	TS	It includes significant additional text on Minimum Bonded Reinforcement.
18.10	TS	New text and new requirements are introduced. The expression for negative moment distribution is new.
18.11	E	The text is editorially changed.
18.12 and 18.13	TS	New text including several additions are made for design slab systems and tendon anchorage zones.
18.18.2 and 18.18.3	TS	New text is introduced on pretensioning measurement and force application in bulkheads and for long exposed pretensioning members.
18.19.4	TI	The paragraph is rewritten providing more direction on fatigue.
19.2 and 19.4	TS	The subsections are rewritten.
Appendix B B.6.1	E	A new sentence is added at the end. This sentence is from old B.6.2.2.2.

Appendix B3: ACI-359 Comparison

B3.1 Overview of the Code

ACI-359 was jointly developed by the American Concrete Institute (ACI) and the American Society of Mechanical Engineers (ASME). Therefore it is also known as the ASME Boiler and Pressure Vessel Code, Section III, Division 2. It follows the format of Section III of the Boiler Code and is revised on the Boiler Codes Revision Schedule. The Code provides design and construction criteria for Prestressed Concrete Reactor Pressure Vessels and Containment Structures.

B3.2 Versions Compared

The 1980 version of ACI-359 was chosen as the cited version because it is endorsed , with exceptions, in Regulatory Guide 1.136. It is compared to the 1992 version up to and including the 1994 Addenda.

B3.3 Summary of Significant Changes

Significant changes have been made throughout the Code. A summary of the significant changes is as follows:

- Concrete quality based on field experience/trial mixture, water-cement ratio
- Concrete examination
- Welding of steel, welding repair
- Acceptance, installation, certification of pressure relief process
- Concrete Constituents
- Grouting, Grouted Tendons
- Liner design
- Shear reinforcement including prestressed concrete
- Embedment anchors

The last Section CC-6000 on Structural Integrity of Concrete Containments has been completely rewritten.

B3.4 Regulatory Impact

The items listed in Section B3.3 will have significant impact on the construction and performance of prestressed concrete vessels and concrete containments. Evoking these new revisions in the SRP will have significant impact (both cost and technical) on the design of nuclear power plant prestressed concrete containments and Reactor Vessels. They will probably increase design and construction costs but should result in more robust concrete reactor vessel and concrete containment designs. However, it is not clear that such an increase in robustness is necessary and warranted by increased costs. It would be hoped that these increased design and construction costs would be off set to some extent by decreased operations and maintenance costs. Prior to such implementation it is suggested that a detailed impact evaluation study (both cost and technical) should be conducted.

B3.5 Detailed Comparison

Table B3.1 presents a detailed comparison of the changes between the versions of ACI-359.

Table B3.1 - Comparison of ACI-359		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
Content	E	SI Units Appendix is new.
Organization of Section III	E	Some references are updated and changed. New paragraphs are included.
Introduction	E	This section contains some editorial updates.
Article CB-2000 Material	TE	Some text changes are made.
CB-2111 Terms	TS	Significant changes in the text on concrete quality namely on field experience and trial mixture water/cement ratio, average strength reduction.
CB-2112.	TI	This section is shorter than in the old document; some referenced documents were removed.
CB-2121	E	The paragraph (c) is more indepth than in the old document.
CB-2122	TS	Changes are made in this section including new subsections (see comment on content). CB-2122.2 and CB-2122.3 are new subsections on Special Material Requirements.
CB-2131.1	TS	Paragraph (d) and CMTR's for plastic concrete is new.
CB-2131.3 and CB-2131.4	TS	These subsections on concrete constituents and personnel qualifications are new.
CB-2140	E	Paragraph (a) has some editorial changes.
CB-2152	TS	This section on procedures for heat treatment has been modified.
Table CB-2160-1	TI	The Dimensional Standard Table is significantly larger in the new edition (including also standards on bolting, threads and valves listed separately).
CB-2200	E	Slight editorial changes in the table.
CB-2210	TI	Paragraphs (a) and (b) are now intermixed.
CB-2211	TS	Paragraph (c) is new and it refers to a water/cement ratio.
CB-2221	TI	New reference documents are included.
CB-2222	TS	Changes are made in this section on aggregates. A new paragraph (g) is added in CB-2222.1.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CB-2223	TI	This section on mixing water is reduced.
CB-2224	TS	Each subsection on Admixtures have modifications.
CB-2231	TS	Subsection CB-2231.2 is modified. Subsection CB-2231.4.1 has the title changes. Subsection CB-2231.6 on durability is new.
CB-2232	TS	Several changes in the section on Proportion and in the content of various subsections.
CB-2233	TS	New section on proportioning of concrete.
CB-2241	E	Subsection 2241.2 has some editorial modifications.
CB-2242	TS	Subsection CB-2242.5 and CB-2242.6 on grout design are new.
CB-2251	E	Small editorial modifications.
CB-2300	TS	Several changes on reinforcing material requirements are made; new subsections were added and some subsections were deleted.
CB-2400	TS	Several changes on Materials for prestressing systems are made; new subsections were added and some subsections were deleted.
CB-2500	TS	Several changes were made in this section on material for liners; new paragraphs, new tables, and paragraphs are deleted. CB-2521: Paragraphs (e) through (h) new. CB-2623: Significant changes. CB-2524: Subsection CB-2524.3 is considerably larger in the new document. CB-2625 through CB-2527: General editorial changes.
CB-2530	TS	Some changes in the subsection numbers cited in text. Subsection CB-2536 has added paragraphs and changes.
CB-2540	TS	CB-2540 is considerably shorter and has a new title. Some subsections were deleted.
CB-2600	TS	Several changes in subsection CB-2611, CB-2612.11. Subsection CB-2612.\4 through CB-2612.5 deleted. CB-2613: Few changes and deletion in the text. Figure slightly changed.
CB-2630	E	Editorial changes.
CB-4123	TI	New subsection on Examinations.
CB-4224.2	E	Small editorial additions.
CB-4240	TS	Changes in the text on concrete curing.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CB-4260	TS	Changes in the temperature conditions.
CB-4320	TS	Subsections CB-4321.1 and CB-4321.2 have some changes.
CB-4222	E	Paragraph (a) is changed.
CB-4323.2	TS	Paragraph (b) is changed.
CB-4333.8	TS	New subsection on impact requirements.
CB-4334	TI	All the subsection is deleted. It refers only to Appendix XI for qualification requirements.
CB-4341 CB-4342 CB-4343	TI	Changes in titles and subject. Table CB-4341-1 is new.
CB-4351	E	Editorial changes.
CB-4432.6	E	Editorial changes.
CB-45211.3.2	TI	Equation for percent strains for spherical or dished surfaces is changed. The old coefficient 65 now has a value of 75.
CB-4522.1.4	TS	New subsection on localized thin areas was added.
CB-4532.2.1	TS	The text of this section is greatly enlarged including requirements on identification of joints by welder or welding operator.
CB-4533 and CB-4534	TS	Technical modifications are made and Subsection CB-4534 has a new last paragraph.
CB-4533.4 and CB-4533.5	TS	This section is significantly expanded in the current version. The subsection CB-4533.5.3, CB-4533.5.4, and CB-4533.6 of the old standard are deleted. The subsection CB-4533.6.1 through CB-4533.6.4 of the old standard are deleted.
CB-4552	TS	CB-4552.2.1, CB-4552.2.3, CB-4552.2.4 have modifications. CB-4552.2.5 is a new subsection number, having the contents of the CB-4552.2.6 subsection. Subsection CB-4552.2.6 corresponds to the old CB-4552.2.7.
CB-4556	E	Editorial changes.
CB-4555	TS	Section is totally rewritten. This includes several new sections on Welding Repairs.
CB-5122	TS	Significant modifications in this section on Personnel Qualification, Certification, and Verification.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
CB-5220	TS	Changes in each subsection including Tabie CB-5234.2. New subsections are also introduced.
CB-5230	TS	Significant text changes. However, the subsection CB-5234.2 on Evaluation and Acceptance of Concrete remains unmodified.
CB-5233	E	This subsection was numbered CB-5235 in the old standard revision. Only minor text changes.
		Subsection CB-5234 is moved in other place becoming CB-5232.3.
CB-5300	TS	Subsection is significantly changed. New titles, new text. Subsection CB-5340 remained unchanged.
		Subsection CB-5527 on Electroslag Welds is deleted (moved as CB-5536)
CB-5535	E	Some editorial changes on leak testing.
CB-5536	E	New subsection on Electroslag Welds (Old section CB-5527).
CB-5545	E	Paragraph (b) has some new text minor modifications.
CB-5546	E	New subsection on Ultrasonic Acceptance Standards. (The old section CB-5546 becomes CB-5547).
CB-5547	E	It is the old subsection CB-5546.
CB-7111	TI	A new section on definitions is introduced.
CB-7120	TS	Changes are made in this section on Integrated Overpressure Protection.
CB-7130	TS	New subsection on provisions for Checking Operation of Pressure Relief Devices. Partially this subsection corresponds to the old subsection CB-7140.
CB-7140	TS	This subsection corresponds to the old subsection CB-7150 on the installation provisions for Pressure Relief Devices. Significant changes.
CB-7150 through CB-7170	TS	New subsections on acceptable and unacceptable Pressure Relief Devices.
CB-7200	TS	This subsection corresponds to the old subsection CB-7300 on the Overpressure Protection Report. All subsections have significant changes. CB-7240 is new.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
CB-7300	TS	Corresponds to the old subsection CB-7400 on Relieving Capacity Requirements. Old sections CB-7421 through 7430 are deleted. Significant changes in all the other subsections.
CB-7400	TS	It corresponds to the old subsection CB-7500 on set pressures of Pressure Relief Devices. This section is significantly reduced.
CB-7500	TS	It corresponds to the old subsection CB-7600 on operating design requirements for pressure relief valves. Significant changes were made. Subsections CB-7510 through CB-7515 are drastically modified. Subsection CB-7520 which corresponds to the old CB-7620 is split into several new subsections. New, large amounts of text is included in the new edition. Subsection CB-7530 has significant changes. Subsection CB-7540 has also significant changes.
CB-7600	TS	It corresponds to the old subsection CB-7700 on requirements for Nonreclosing Pressure Relieving Devices. Significant changes are made in all subsections.
CB-7700	TS	It corresponds to the old subsection CB-7800 on Certification requirements. All subsections have significant changes. A large number of new requirements are introduced.
CB-7800	TS	It corresponds to the old subsection CB-7900. Some slight changes in the text. New subsection CB-7830 on Pressure Relief Valve in combination with rupture disk device.
Article CC-1000 Introduction	E	Small editorial changes.
CC-2100	TS	This subsection on Material Requirements has some text modifications. Subsection CC-2111 on terms has significant changes. Subsection CC-2122 on special requirements for materials is considerably enlarged, including new subsections.
CC-2100	TS	This subsection on Certification of Material has been modified. In subsection CC-2131.1, paragraph (d) is deleted. Subsection CC-2131.3 on concrete constituents is completely new. Table CC-2160-1 is also modified. Subsections CC-2140 through CC-2753 also has modifications. Subsection CC-2150 is the old section CC-2152.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
CC-2200	TS	This subsection is also modified. Subsection CC-2210 the Introduction has only few words changed. Subsection CC-2211 on General Requirements has an additional paragraph, (c). Subsection CC-2212 on Substitution is new. Subsection CC-2221.1 on Material Requirements for cement is reduced. Subsection CC-2222 on Aggregates has also several changes, practically in all paragraphs and new subsections are also added. Subsection CC-2230 on concrete mix design is also changed. New subsections on chloride alkali content are included. Subsections on durability CC-2231.7 are placed earlier than in the old document, CC-2232.3. There are modifications, including a new subsection on Corrosive Protection. Subsection CC-2232 on selection of concrete proportions is significantly changed and rearranged. The Strength Tests Subsection CC-2232.2 in the old document is deleted. New Subsection CC-2233 includes these requirements. Subsection CC-2240 on Cement (Grout has significant modifications) CC-2241 has a few changes. The other Subsections from CC-2242 to CC-2243 have large amounts of new text. Subsection CC-2250 on Marking and Identification of Concrete Material adds a new paragraph in Subsection CC-2253 on Admixtures.
CC-2300	TS	Subsection CC-231 on Material for Reinforcing Systems has a new added paragraph (c); Subsection CC-2330 in Material Testing has significant modifications. Subsection CC-2331.2 is slightly modified and Table CC-2332-1 is deleted. Subsection CC-2332 on Bend Tests is deleted. Subsection CC-2333 on Chemical Analysis is also expanded in the new version.
CC-2400	TS	Subsection CC-2400 on Material for Prestressing Systems has few significant changes. Subsection CC-2433 for Anchor Head Assemblies and Wedge Blocks has a supplementary paragraph. Section CC-2433.2 on Mechanical Properties is new. Subsection CC-2440 on Non-load-carrying and Accessory Materials has changes. In Subsection CC-2441 some sentences are reworded. In Subsection CC-2442.3 only few slight changes are made, but they include new requirements. Subsection CC-2450 on Performance Requirements has changes in CC-2452.2 and CC-2452.3 is new.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CC-2500	TS	Subsection CC-2500 is on material for Liners. Subsection CC-2514 is new. Subsection CC-2521 on Fracture Toughness has some modifications. Subsections CC-2522 through CC-2524 have numerous changes and addition of requirements. Subsections CC-2525.3 through CC-2525.5 are essentially new. A new Subsection CC-2527 is developed. CC-2533 is new. CC-2535 through CC-2535 are new. CC-2540 is significantly changed.
CC-2600	TS	In Subsection CC-2600 on Welding Material significant changes are made. Subsection CC-2611 on Required Testing has some changes and new paragraphs. Subsection CC-2612 on Weld Metal Testing has new inspections and new tests. The old Subsections CC-2612.7.3 through CC-2612.2.3 are deleted. Subsection CC-2613 on Chemical Analysis Test has modifications. In Subsection CC-2613.1 on Test Methods, paragraph (c) has additional requirements and Subsection CC-2613.3 on Delta Ferrite Determination is larger including new requirements. Subsection CC-2630 on Identification of Welding Material is shorter in the new standard.
CC-2700	TS	Subsection CC-2700 is on Material for Embedment Anchors. Subsections CC-2710 through CC-2713 are different from the old Subsections. Subsection - CC-2720 on Fracture Toughness Requirements is new.
CC-3100	TI	CC-3123 on Liner Anchors is deleted. CC-3132 on Factored load Category is new. CC-3136.3 on Shear Stress definition is new. CC-3140 on Tolerances is new.
CC-3200	TS	CC-3242 on Impulse Loads has a new paragraph (c) referring to diagnostic effects of valve actuation.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CC-3300	TS	CC-3320 on Shells has new sentence referring to the stiffness degradation due to concrete cracking. CC-3421.4 on Radial Shear has some modifications. The application of equation (f) has a more restrictive application. CC-3421.5 on Tangential Shear also refers to tornado and wind loading as lateral loads. CC-3427.5.1 on Reinforced Concrete is reduced to only one paragraph. CC-3421.5.2 on Prestressed Concrete is new giving an analytical expression for shear stress in the concrete. CC-3421.6 on Peripheral Shear is drastically changed, including the analytical expressions for shear stress. CC-3424.7 on Torsion is now very large compared with one paragraph in the old version. The analytical expression for shear stress is slightly changed (could be a typographical error). CC-3421 on Brackets and Corbels is larger and includes new requirements and a new analytical expressions for shear stress. CC-3424 is a new Subsection of shear friction including new requirements. CC-3431.3 in Allowable Stresses for Service Loads has significant changes for concrete elements under torsion and bearing. New requirements are introduced in CC-3432.2 for Reinforcing Steel for Bar Tension. The last paragraph is expanded giving additional information on secondary effects combination. CC-3433 on Function System Stresses has some slight changes in the text and allowable values.
CC-3500	TS	CC-3521.1 on Design of Shear Reinforcement for tangential and shear forces has changes. In CC-3521.1.1 on reinforced concrete the required steel area is determined by a new set of equations (12) through (14) which include a quadratic summation instead of an algebraic one. Also, other requirements are introduced. CC-3521.1.2 on Prestressed Concrete is new. CC-3521.3 and CC-3521.4 on Peripheral and Torsional Shear are new Subsections with new requirements. The old small Subsection on shear reinforcement CC-3521.2.4 is deleted. CC-3522 on Service Load Design includes many new paragraphs on evaluation of stresses. CC-3530 on reinforcing Steel requirements is changed. Paragraph (d) in CC-3532 is new. CC-3532.1.2 on Development Length has new clarifications in some paragraphs and new paragraphs. CC-3532.2.3 includes a new paragraph (c) referring to Hooks. CC-3532.3 on Standard Hooks is considerably expanded in the new document. The old CC-3533.2 on Development of Reinforcement for service loads is deleted. CC-3536.1 on concrete cover for steel rebars has a new paragraph (b). CC-3534.2 on spacing between rebars is almost totally new. In CC-3535 on Concrete Crack Control the minimum area of reinforcement required is changed to 0.2% (times the concrete gross area) instead of 0.12%. CC-3545 on Radial Tension Reinforcement is significantly larger in the new standard.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CC-3700	TS	CC-3700 on Liner Design has modifications. At the end of CC-3720 a new paragraph is added on Strain Evaluation in the Liner. CC-3730 is provided with a new paragraph (c). CC-3740 on penetration assemblies has two new paragraphs at the end, (e) and (f). CC-3750 on Attachments has a new paragraph (c).
CC-3800	TS	CC-3800 on Liner Design Details has some modifications. CC-3831.1 has only one paragraph at (b), obtained by compressing the requirements in the old version. New CC-3841 on Welded Joints includes F and H categories. (CC-3842.8 and CC-3842.9 are also new). CC-3842.10 on Minimum Dimension is also new. Old CC-3843 on Structural Attachments is deleted. Figures CC-3840 are deleted. New CC-3844 is the old CC-3843 on Unequal Thickness Transitions.
CC-4100	TI	CC-4123 on Visual Examination is new.
CC-4200	TI	CC-4210 includes some modifications. A few minor changes are made in CC-4224 and CC-4225 on conveying and Depositing of Concrete. In CC-4231 the last paragraph is deleted. CC-4240 on Curing has an expanded paragraph (c) defining the cold weather conditions. Paragraph (d) is changed. In CC-7260 the last sentence is changed. All text of Subsections CC-4280 through CC-4282 is new.
CC-4300	TS	CC-4300 has some changes. CC-4321 on Standard Hooks has new requirements added, paragraphs (1), (2) and (3). CC-4321.2 on bar diameter is slightly changed. Same is true for CC-4322. CC-4323.2 has a new paragraph (c). CC-4332 on Lap Splices is reduced. CC-4332.2 on Splice System Qualification Requirements is significantly larger than is the old version. Several new Subsections are inserted in the text. In CC-4333.5 on testing frequency a paragraph has been inserted in the beginning and significant changes were made at the end of the paragraph. CC-4333.8 on impact requirements is new. CC-4334 is deleted almost entirely. It refers to Appendix XI. CC-4331 is new. CC-4351 is shorter.
CC-4400	TS	CC-4432.5 on Twisting and Coiling is changed. CC-4432.6 has an addition of a new sentence at the end. CC-4470 on Permanent Corrosion Protection has a second new Subsection on Cement Grout, CC-4472.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CC-4500	TS	In CC-4521.3.2 the analytical expression for percent strain for spherical or disked surfaces is changed (coefficients are now 65 instead of 75 as in the old standard). CC-4523 has some changes. CC-4531.1.1 and CC-4531.1.2 on Welding Qualifications are new. CC-4532.2.1 on Identification of Joints by welder or welding operator was significantly enlarged. CC-4533.4 (with CC-4533.4.1 and CC-4533.4.2) on Preparation of Test Coupons is changed with text additions. CC-4533.5 on impact test requirements has been expanded with more explanations. CC-4533.5.1 and CC-4533.5.2 are considerably larger in the new standard. CC-4542.2 includes also the category joints H and Y which are not defined in the old standard. CC-4543.2 and CC-4543.4 on Welding of Permanent Attachments are changed. CC-4522.2.1 on PWHT time and temperature requirements has some new explanatory text. CC-4552.2.4 on holding temperature includes a new requirement at the end of the text. CC-4555.4.2 is deleted.
CC-4600	TS	This is a new subsection on Protection of Attachments.
CC-5100	TS	CC-5122.1 and CC-5122.2 on Personnel Qualification have new requirements. CC-5122.3 is also changed.
CC-5200	TS	CC-5210 has an insertion of some explanatory discussions. CC-5211 on Laboratory Qualifications is new. Old CC-5222 on Fly Ash and Pozzolan is placed after Admixtures subsection, (in the old document it is CC-5222). CC-5222.2.3 on uniformity is new. CC-5222.3 on Chemical Admixtures is new. CC-5223.1 on requirements for Aggregates has text changes introducing new requirements. CC-5231 on mixer uniformity is new. CC-5231.1 and CC-5231.2 are also new. CC-5232 on Concrete Properties is new. CC-5232.1 on Slump corresponds to CC-5232 in the old standard. It is slightly changed. CC-5232.3 on physical properties has some changes. CC-5232.3.1 is shorter without referring to other provisions. CC-5234 on general purpose grout is new. Also Section CC-5240 on cement grout for Grouted Tendons systems is new, including new Subsections CC-5320, including Subsections CC-5321, CC-5322, CC-5323 and CC-5324, is new.

Table B3.1 - Comparison of ACI-359 (continued)		
Section/ Subsection/ Article/ Subarticle/	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
CC-5400	-----	No significant change.
CC-5500	TS	In CC-5521 on Weldings categories paragraphs (d), (f) and (g) are different from the old standard. CC-5523 on Splice Sleeve Welds is new. Old CC-5523 on attachment welds is deleted. CC-5526 on Electo Slag Welds is new. CC-5331.5 on repair and reexamination has the first paragraph changed. All Section CC-5536 on Leak Testing has been expanded with new requirements. CC-5547 on leak testing acceptance standards is different from the old CC-5547 on visual acceptance standards.
CC-6100	TS	The whole CC-6000 on Structural Integrity of Concrete Containments is drastically changed. New write-ups, new subsections and requirements. Because of large amount of qualitative and quantitative changes a comparison between the new and old standards is very difficult to quantify. Pretest, test and posttest conditions are now separately stated. Acceptance criteria, instrumentation, evaluation of tests are described in more detail. This is completely changed from the older version.
CC-7000	E	New paragraph included.

Appendix B4: ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NE Comparison

B4.1 Overview of the Code

Subsection NE of ASME Boiler and Pressure Vessel Code (BPVC), Section III, Division 1 establishes rules for material, design, fabrication, examination, inspection, testing, and preparation of reports for metal, Class MC, containment vessels. Subsection NE does not contain rules to cover all details of construction of Class MC containment vessels. The ASME N Certificate Holder shall provide details of construction which will be consistent with those provided by the rules of Subsection NE.

B4.2 Versions Compared

The version of Subsection NE currently cited in the SRP (NUREG-0800) is that contained in the 1980 ASME BPVC up to and including the Winter 1981 Addenda. This version was in effect as of July 1981 when SRP Sections 3.8.2 and 3.8.3 were published. These sections of the SRP cited Subsection NE without an explicit designation of version dates. It is compared to the current version of Subsection NE which is contained in the 1992 ASME BPVC up to and including the 1994 Addenda.

B4.3 Summary of Significant Changes

Significant changes were made in test (heat treatment, weld, nondestructive examination, pressure, impact, overpressure, pressure relief, coefficient of discharge of pressure relief valves, etc.) methodologies, calibration, evaluation, and acceptance criteria.

B4.4 Regulatory Impact

The changes made in the current version are based on over 15 years of research and operating experience. The changes have impact on the SRP because a number of sections cited by the SRP have been modified, deleted and significantly changed. Some of the general areas in which these changes occur are:

(a) Ductility considerations of both the base and weld materials, and the related impact testing.

(b) Weld quality that is dependent on NDE and NDE personnel.

(c) Overpressure protection that is related to overpressure test.

(d) Quality of pressure relief valves that affects the overpressure protection of the Class MC containment vessel.

These changes would most likely increase design and construction costs but should result in a more robust containment vessel design. However, it is not clear such an increase in robustness is necessary and warranted by increased costs. Hopefully these higher initial costs would be off set by lower metal containment operating and maintenance costs. Prior to their implementation it is suggested that a detailed impact evaluation study (both cost and technical) should be conducted.

B4.5 Detail Change Summary

Table B4.1 presents a detailed comparison of the changes between the two versions of subsection NE.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-1132.1	TS	New in the current version. The definitions of various kinds of attachments are provided.
NE-1132.2	TS	New in the current version. The definitions of various kinds of jurisdictional boundary are provided. In NE-1132 of the SRP cited version only general limitations are given for boundaries of the containment vessel.
NE-2110 (a)	E	The term Material Manufacturer is defined in NCA-9000 for the current version and in NCA-3810 for the SRP cited version.
NE-2110 (c)(3)	E	The casting thickness is defined directly in the current version and indirectly in the SRP cited version (cited to SA-613).
E-2121 (e)	TS	New in the current version. Excludes the hard surfacing or corrosion resistant weld metal overlay which is 10% or less of the thickness of the base material (NE-3122).
NE-2121 Table NE-2121(a)-1	TS	New in the current version. Gives material specifications and grades permitted for Class MC construction. Most previously used engineering materials are included in the table.
NE-2123	TI	Deleted from the current version the requirements of design stress intensity and allowable stress values above the design temperature.
NE-2180	TS	In the current version added "the heat treating shall be performed in temperature-surveyed and -calibrated furnaces or the heat treating shall be controlled by measurement of material temperature by thermocouples in contact with the material or attached to blocks in contact with the material or by calibrated pyrometric instruments." This change covers more detailed application of heat treating temperature measurement.
NE-2190 (a)	TI	Delete "....with the exception that the requirements of NE-2500..." from the SRP cited version.
NE-2190 (b)	TS	Added in the current version that deals with material not performing a pressure retaining function and not in the containment vessel support load path, (nondistructural attachments) welded at or within 2t of the pressure retaining portion.
NE-2212.2	TI	Footnote of using SA-654 in the SRP cited version is deleted in the current version for the requirements of quenched and tempered forgings.
NE-2226	TI	In the current version the title is "Tensile Test Specimen Location for Quenched and Tempered Ferritic Steel Castings". While in the SRP cited version the title was generally written as "Castings".

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-2226	TS	The current version applies only to quenched and tempered Ferritic steel castings with a thickness t exceeding 2 in., and exclude the castings with 2 in. maximum thickness required in NE-2226.1 of the SRP cited version. The titles of Sections NE-2226.2 through NE-2226.4 in the SRP cited version are deleted in the current version. However, the contents of these sections are kept in the current version that provides more detailed and accurate requirements for sampling of test coupons.
NE-2311	E	For the definition of T_{NDT} the current version uses ASTM E208-91 while the SRP cited version uses ASTM E208-69.
NE-2321.1	TI	For drop weight tests the current version requires use of ASTM E208-91 rather than ASTM E208-69 by the SRP cited version. The test temperature is requested to be reported in the current version.
NE-2321.2	TI	In the current version test temperature, orientation and location of all tests performed shall be reported.
NE-2322.1	TS	The current version specifies detailed location of test specimens for impact test using the results of advanced fracture mechanics.
NE-2331	TS	The current version deletes the titles of Section NE-2331.1 through NE-2331.3 and extends the pressure retaining material test methods and temperature in a more detailed manner.
NE-2332.1 (c)	TI	The current version uses ASTM-E208-91 rather than ASTM E208-69 by the SRP cited version, as the acceptance for drop weight testing of pressure retaining material other than bolting with 2 1/2 in. maximum thickness.
NE-2334	TI	Section NE-2334 of the SRP cited version has been deleted from the current version for test data to be reported.
NE-2342 (d)	TI	New in the current version to provide an alternative for test of forgings or castings of different sizes.
NE-2342 (f)	TI	New in the current version to provide an alternative for charpy V-notch and drop weight tests of static castings.
NE-2410 (b)	TS	New in the current version for general requirements to provide welding material information in detail.
NE-2431	TS	New in the current version for the requirements of welding material used for GTAW root deposits.
NE-2433.1 (a)	TI	The current version requires to calibrate magnetic instruments using AWS-A4.2-91, while the SRP cited version requires to calibrate magnetic instruments using AWS-A4.2-74.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-2538	TI	Section NE-2538(1) in SRP cited version is deleted in the current version for duplicated requirement of remaining thickness.
Figure NE-2433.1-1	TS	Significant changes are made in the current version for welding material with delta ferrite content.
NE-2546.2 (c)	TI	The current version uses "imperfections" to replace "unacceptable mechanical discontinuities" that are used by the SRP cited version.
NE-2546 3 (b)(3) and (4)	TI	The current version uses "relevant indications" to replace "indications" that are used by the SRP cited version.
NE-2551	TS	New in the current version to provide examination and repair of seamless and welded (without filler metal) tubular products and fitting in a detailed manner.
NE-2552	TS	New in the current version to provide detailed requirements for ultrasonic examination.
NE-2553	TS	New in the current version to provide detailed requirements for radiographic examination that is a general requirements using SA-652 in the SRP cited version.
NE-2554	TS	New in the current version for eddy current examination in a detailed manner.
NE-2557, NE-2558, NE-2559	TS	New in the current version for time of examination, elimination of surface defects, and repair by welding.
NE-2561 (b)	TS	The current version requires 100% radiographic exams using basic material specification or NE-2563. However, the SRP cited version requires using SA-655 and SA-652.
NE-2563 NE-2567 NE-2568 NE-2569	TS	New in the current version for the requirements of radiographic examinations, time of examination, elimination of surface defects, and repair by welding.
NE-2570 NE-2571 NE-2572 NE-2573 NE-2574 NE-2575 NE-2576 NE-2577	TS	New in the current version for examination and repair of statically and centrifugally cast products, and replaces the general requirements of SA-613 by the SRP cited version.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change** **E = Editorial** **TI = Technical, not significant** **TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-2581 NE-2582	TS	The current version uses visual examination to replace the requirements of SA-613 by the SRP cited version.
NE-3125	TI	New in the current version for configuration requirement.
Table NE-3132-1	TS	New versions of dimensional standard ANSI, SAE, MSS, API, and AWWA in the current version comparing with the SRP cited version.
NE-3221.5 (d)(2)(b)	TS	New in the current version for the definition of "S" from "S_a" value in the applicable design fatigue curve when the total specified member of service cycles exceeds 10^6 cycles.
NE-3221.5 (d)(4)(b)	TS	New in the current version for the definition of "S" from "S_a" value in the applicable design fatigue curve when the total specified member of service cycles exceeds 10^6 cycles.
NE-3221.5 (d)(5)(6)	TS	New in the current version for the definition of "S" from "S_a" value in the applicable design fatigue curve when the total specified member of service cycles exceeds 10^6 cycles.
NE-3221.5 (d)(6)	TS	"If the total specified number of significant load fluctuations exceeds the maximum number of cycles defined on the applicable design fatigue curve, the S_a value corresponding to the maximum number of cycles defined on the curve may be used." in the current version v.s. "...exceeds 10^6..., the S_a value at $N=10^6$ may be used." in the SRP cited version.
NE-3221.5 (d)(6)(b)	TS	New in the current version for the definition of "S" from Sa" value in the applicable design fatigue curve when the total specified number of service cycles exceeds 10^6 cycles.
Table NE-3335.1-1	TS	New in the current version for the arrangement of multiple openings.
NE-3335.1 (a)(2)	TS	In the current version adding "the openings shall be re-enforced as described in (b) below."
NE-3335.1 (b)	TS	In the current version adding "The diameter of the assumed opening shall not exceed the following: (1) For vessels 60 in. diameter and less, one half the vessel diameter, but not to exceed 20 in. (2) For vessels over 60 in. diameter, one-third the vessel diameter, but not to exceed 40 in."
NE-3338.1 (a)	TS	New in the current version for adding an Analytical Method as one of acceptable methods for determining peak stresses around the opening. In particular the analytical method covers finite element computer analyses.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-3338.1 (c)	TS	In the current version adding "Stress indices may also be determined by theoretical or experimental stress analysis." In combination with the Stress Index Method.
NE-3365.1 (g)	TS	"Convolutions or toroids of a bellows expansion joint shall be fabricated from material in the annealed condition" in the current version replaces "Bellows sections of an expansion joint shall be purchased in the annealed condition" in the SRP cited version.
NE-4122 (a)	TI	In the current version "...... Material supplied with a certificate of compliance and welding materials shall be identified and controlled..." while in the SRP cited version. ".... Welding materials shall be identified and controlled ..." for material identification in fabrication and installation.
NE-4122 (b)	TS	New in the current version for identification of material from which the identification marking is lost.
NE-4212	TS	In the current version adding "...., provided the required dimensions are attained (see NE-4214 and NE-4220), ...below the lower transformation temperature of the material." for forming and bending processes.
NE-4213	TI	In the current version the title is "Qualification of forming processes for impact property requirements." while in the SRP cited version, the title is "Qualification of forming processes and acceptance criteria for formed material." Both versions have the same text under the titles.
NE-4241	TS	In the current version "....Joints that have been welded from one side with backing that has been removed and those welded from one side without backing are acceptable..." while in the SRP cited version".... Joints made with consumable inserts or gas backing or with metal backing strips that are later removed are acceptable...." for Category A weld joints.
NE-4242	TS	For Category B weld joins in the current version adding "...., except that NPS 2 and smaller pipe sizes may be socket welded...."
NE-4311.2	TI	In the current version, Section NE-4311.2 covers sections NE-4311.2 and NE-4311.3 in the SRP cited version, in addition to the change of using the provisions of NE-4435 (b) to replace the requirements of NE-4231.
NE-4311.4	TS	New in the current version to exclude use of inertia and continuous drive friction welding methods.
NE-4334	E	In the current version the title is "Preparation of Test Coupons and Specimens", while in the SRP cited version the title is "Test Coupons and Specimens."

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-4334 (a) and (b)	TS	In the current version are provided the requirements of removal of impact coupons and the dimensions of impact test specimens, rather than the requirements in NE-4334.1 and NE-4334.2 by the SRP cited version.
NE-4335	TI	The current version points out that materials are required to be impact tested per NE-2300, while the SRP cited version does not.
NE-4335.1	TS	NE-4335.1 (c) in the SRP cited version is deleted from the current version to require impact tests for austenitic and nonferrous weld metal.
NE-4335.2 (a)	TS	The current version does not include the paragraph "Exemption of base materials by NE-2311(a)(8) does not apply to the welding procedure qualification heat affected zone or unaffected base material for such materials."
NE-4335.2 (a)(2)	TS	The current version requires "the qualification for weld deposit cladding or hardfacing on any base material." while the SRP cited version requires "the qualification for weld deposit cladding on any base material."
NE-4424(d)	TS	The current version requires "the resulting thickness of the weld meets the requirements of NE-3000." While the SRP cited version requires "the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined."
NE-4427	TS	The current version gives more detailed requirements of shape and size of fillet welds than the SRP cited version.
Figure NE-4427-1	TS	In the current version adding a sketch of (c--3) Socket Welding Fittings.
NE-4431	TS	The current version uses a title as "Materials for Attachments", while the SRP cited version uses a title as "Materials for Permanent Structural Attachments". The current version requires that non-pressure-retaining and pressure retaining attachments should meet NE-2190 and NE-2120, respectively. The SRP cited version requires the attachments meet NE-2190, NE-2300, NE-2311, and NE-2121(c), if applicable.
NE-4432	TS	The current version delete "permanent" from the title by the SRP cited version. The current version requires that the pressure retaining material shall meet NE-4321 while the SRP cited version requires that the pressure retaining material shall meet NE-4620.
NE-4435	TS	The current version adds "and their removal" in the title in contrast to the SRP cited version.
NE-4435(a)	TS	The current version uses NE-1132.1 to define non-structural attachments and states that NE-2000 should not be used herein. Tests are new relative to the SRP cited version.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-4435(b)	TS	New in the current version are requirements of removal of temporary attachments.
NE-4452(c)	TS	The current version adds "...Defects detected by the visual or volumetric and located on an interior surface need only be re-examined by the method which initially detected the defect when the interior surface is inaccessible for surface examination."
NE-4453.1	TS	The current version states "This examination is not required where defect elimination removes the full thickness of the weld and where the backside of the weld joint is not accessible for removal of examination materials." The SRP cited version states "this examination is not required where defect removal removes essentially the full thickness of the weld in partial penetration welds and fillet welds; the area need only be examined to determine suitability for rewelding."
NE-4460	TS	NE-4460 in the SRP cited version is removed from the current version for welded test plates.
NE-4622.3	E	"Time-at-Temperature" is the title of the SRP cited version is deleted in the title of the current version.
Table NE-4622.4 (c)-1	TS	Significant changes of alternative holding temperatures and times are made in the current version in contrast to the SRP cited version.
Table NE-4622.7 (b)-1	TS	For exemptions to mandatory PWHT, the current version adds a major group of exemption as 1 Gr. 1 by Gr. 2, and also adds four more notes to the table.
NE-5112	TS	In the current version adding "... method. The digitization of radiographic film and radioscopic images shall meet the requirements of Section V, Article 2, mandatory Appendix III, "Digital Image Acquisition, Display, and Storage for Radiography and Radioscopy." Written procedures..."
NE-5211.2	TS	NE-5211.2 in the SRP cited version is moved to NE-5250 in the current version for examination of inaccessible welds. However, some changes of conditions are made.
NE-5310	TS	NE-5310 in the SRP cited version is removed from the current version for the general requirements of acceptance standards.
NE-5351(c)	TI	The current version uses "imperfections" to replace "mechanical discontinuities" in the SRP cited version.
NE-5521(a)	TS	The current version introduces "employers" except NDE personnel for all persons involved in NDE.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-5521(a)(1)	TI	The current version deletes the explanation of the examination for qualification of NDE personnel that is in the SRP cited version.
NE-5521(a)(1)(a)	TS	The current version requires to meet 8.3.3(1) and 8.3.3(2) of SNT-TC-1A, but the SRP cited version requires to meet 8.5.3 (a) of SNT-TC-1A for the general examination of NDE personnel
NE-5521(a)(1)(b)	TS	The current version requires to meet 8.3.3(3) of SNT-TC-1A, but the SRP cited version requires to meet 8.5.3(b) of SNT-TC-1A for the specific examination of NDE personnel.
NE-5521(a)(1)(c)	TS	The requirement of NE-5521(a)(1)(c) in the SRP cited version for the practical examination of NDE personnel has been deleted from the current version.
NE-5521(a)(3)	TS	The SRP cited version requires to meet Table 6.2-1 A on SNT-TC-1A for training times, operation type and scope of NDE, while the current version requires to meet Table 6.3.1 on SNT-TC-1A and to describe training and experience times in the written practice.
NE-5521(a)(4)	TS	The SRP cited version uses 8.2(a)(1), but the current version uses 8.1.1(1), of SNT-TC-1A for the requirements of visual examination of NDE personnel.
NE-5521(a)(b)	E	Section NE-5521 (a)(6) in the SRP cited version is the same as Section NE-5521 (b) in the current version for examination methods for NDE personnel.
NE-5521(b)	E	Section NE-5521(b) in the SRP cited version is identical to Section NE-5521(c) in the current version.
NE-5521(c)	E	Section NE-5521(c) in the SRP cited version is identical to Section NE-5521(d) in the current version for allowing personnel qualified to perform one or more NDE operations.
NE-5522	E	Both versions have the same contents but use different number of paragraphs.
NE-5710(d)	TS	The contents of NE-5710(d) in the SRP cited version are included in NE-5710(d)(1) through NE-5710(d)(3) in the current version with the change of "five or more randomly distributed rounded indications in a weld length of 6 in. "from" up to five randomly distributed rounded indications, each not exceeding 1/32 in. diameter are permitted in any 6 in. length of weld." in the SRP cited version. In addition, one more requirement is added in the current version as NE-5710 (d)(4) "any rounded indication exceeding the lesser of one-half the bellows thickness or 1/16 in. in diameter."

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant	Description of the Change (Including Regulatory Significance)
NE-6412	TS	For the range of individual pressure gages, the current version extended the SRP cited version to describe in detail the requirements for the analog-type and digital-type pressure gages.
NE-6711	TS	For the pressure tests of electrical and mechanical penetration assemblies, the current version provides more detailed requirements than the SRP cited version.
Ne-6712	TS	New in the current version for the pressure tests of piping penetrations.
NE-7110(b)	TS	The current version deletes the description of the overpressure protection valves permanently installed on the containment vessel in the SRP cited version.
NE-7110 (c)	TS	The current version does not give the number of vacuum relief devices as the SRP cited versions . However, the current version provides the essential requirements of vacuum relief valves for overpressure protection purposes.
NE-7111(b)	TS	For the definitions of pressure relief devices the SRP cited version uses those given in ANSI B95.1-1977, but the current version uses those given in ASME/ANSI PTC-25.3-1988.
NE-7152	TS	Section NE-7152(c)(2) in the SRP cited version for the failure of the external power operated valves has been deleted from the current version.
NE-7152	TS	The requirement of "at least one self-actuating vacuum relief of a type specified in (b) above is of equivalent relieving capacity" in section NE-7152 (c)(3) of the SRP cited version is deleted from the corresponding Section NE-7152 (c) (2) in the current version.
NE-7200 through NE-7250	TS	New in the current version for the requirements of overpressure protection report.
NE-7311	TS	Section NE-7311 in the current version covers all the requirements of relieving capacity of vacuum relief devices in Section NE-7320 of the SRP cited version. However, the current version provides one more requirements in NE-7311(c) for the redundant requirements of at least two independent vacuum relief devices.
NE-7410	TS	In addition to the requirements in NE-7110 for set pressure for testing conditions, the current version requires to meet NE-6000 for the set pressure limitations rather than the descriptions in the SRP cited version.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-7512	TS	The current version eliminates the condition "except that for set pressures up to 25 psi" as used by the SRP cited version. The current version requires that the rated lift pressure of relief valves should not exceed the set pressure by more than 10% or 3 psi, whichever is greater. However, the SRP cited version requires that the lift pressure should not be greater than 10% above set pressure except that for set pressure up to 25 psi overpressure shall not be greater than 2.5 psi.
NE-7721.3	TS	The current venison requires that the lift pressure capacity of relief valves shall be tested at a pressure which does not exceed the set pressure by more than 10% or 3 psi, whichever is greater. The SRP cited version requires that the test pressure should not exceed 110% of the set pressure.
NE-7723	TI	In the current version the title is "Slope Method". while in the SRP cited version the title is "Capacity Curve Method". The current version covers the requirements in the SRP cited version and reorganizes these requirements.
NE-7724.2	TS	For the establishment of coefficient of discharge, the current version provides much more detailed requirements than the SRP cited version, such as definition, calculation, and evaluation of the coefficient
NE-7727	TI	For the laboratory acceptance of pressure relieving capacity tests, the current version requires to meet ASME/ANSI PTC 25.3-1988 instead of ASME/ANSI PTC 25.3-1976 by the SRP cited version.
NE-7731.5	TS	The current version requires that the Authorized Observer shall submit the drawings and test results to the ASME designer for review and acceptance. But the SRP cited venison does not.
NE-7733	TS	The current version uses the title as "Slope Method", while the SRP cited version uses the title as "Capacity Curve Method. The current venison, based on the SRP cited version, provides detailed requirements of definition, calculation, and evaluation.
NE-7734.2 (b)	TS	The current version eliminates the second test option of the three test options by the SRP cited version, i.e., if the coefficient of discharge K_D from the first test is unsatisfactory, the code permits the second test option, in which another valve of the same size and pressure setting or a modification of the original valve shall be tested.
NE-7734.3 (b)	TS	New in the current version for further evaluation of the calculated coefficient of discharge K_d.
NE-7735	TI	For the laboratory acceptance of relieving capacity tests, the current version requires to meet ASME/ANSI PTC 25.3-1988 rather than ASME/ANSI PTC 25.3-1976 that is required by the SRP cited version.

Table B4.1 - Comparison of ASME BPVC, Section III, Div. 1, Subsection NE (continued)		
Section/ Subsection/Article/ Subarticle	**Type of Change E = Editorial TI = Technical, not significant TS = Technical, significant**	**Description of the Change (Including Regulatory Significance)**
NE-7811	TS	The current version eliminates the marking and stamping requirements for vacuum relief valves that are required by the SRP cited version. In addition, the current version provides more detailed marking and stamping requirements for pressure relief valves, and only requires to use Table NCA-8100-1 for vacuum relief valves
NE-7820	TS	NE-7820 in the SRP cited version is eliminated in the current version for the requirement of certificate of authorization to use the code symbol stamp.
NE-8100	E	The current version cites the definition of the lowest service metal temperature in NE-2331 footnote 7, while the SRP cited version uses that in NE-2331 footnote 4.

Appendix C: Comparative Review of Seismic, Tornado, and Strong Wind Design Criteria for ALWR and Advanced Reactors

This Appendix provides summaries and comparisons of the seismic, tornado and strong wind design basis criteria being used in both the ALWR and advanced reactor designs. This information was assembled as a part of this review effort and is provided (1) as general background for reference (2) for use in compiling several of the suggested code textual modifications. The following summaries are provided:

Table C1 Seismic Design Criteria
Table C2 Wind and Tornado Design Criteria

Table C1 Summary of Seismic Design Criteria for Advanced Reactors

Advanced Reactor System	Seismic ZPGA	Ground Spectra Shape	Foundation Conditions Considered	Damping	In-Structure Response Spectra	Comments and References
ABWR	Single earthquake: At free field ground surface defined as 0.3g ZPGA	R.G. 1.60 for Category I Turbine building will be designed for UBC Zone 3 with restrictions on the lateral load carrying element assumptions.	Structures were evaluated for a large number of foundation conditions varying from soft soil to hard rock and an envelope of response developed. Categorization or grouping of foundation conditions in the future may be used to reduce the conservatism.	RG. 1.61 for Category I Structures Effective soil damping based on use of the finite element Soil Structure Interaction (SSI) program SASSI.	Envelop spectra were generated as a function of different foundation conditions.	Reference NUREG-1503, July 1994 Specific site requirements are as follows: 1) The peak ground acceleration is less than 0.30g SSE. 2) The site design response spectra are less than or equal to those given in R.G. 1.60 normalized to the peak ground accelerations in Condition 1. 3) There is no potential for liquefaction at the plant site as a result of an SSE as reviewed and concurred with by the NRC staff (the liquefaction potential of the foundation and site soils will be investigated and reported for a long duration, New Madrid-type earthquake.) 4) There is no potential for fault movement at the plant site as reviewed and concurred with by the USNRC staff. 5) The embedment depth of the reactor building is 25.9 m (85 ft). The excavation tolerance is ±15 cm (±0.5ft). 6) The average shear wave velocity for the top 9 m (30 ft) of soil is 305m/sec (1000ft/sec) minimum. The upper bound shear wave velocity is 3048m/sec (10000 ft/sec). 7) For layered soil sites with parameters that have very abrupt variations with depth, an analysis with site-unique properties will be performed to confirm the applicability of the generic analysis.

Table C1 Summary of Seismic Design Criteria for Advanced Reactors (continued)						
Advanced Reactor System	**Seismic ZPGA**	**Ground Spectra Shape**	**Foundation Conditions Considered**	**Damping**	**In-Structure Response Spectra**	**Comments and References**
SBWR	Anticipated same as ABWR.					
System 80+	Single earthquake design normalized to 0.3g at 40 Hz with 3 control motions specified.	Earthquake is defined with 3 control motions as follows: 1) R.G. 1.60 shape at ground surface free field CMS-1 2) CMS-2 for rock out cropping 3) CMS-3 for rock out cropping based on NUREG/CR 0098 median shaped spectra.	13 different soil column conditions were evaluated. A site specific SSI was committed which would demonstrate the 13 generic cases led to a envelope of the site specific response.	R.G. 1.61 for Category I structures and equipment and ASME CC N-411 for piping. Effective soil damping based on use of finite element program SASSI.	Envelope spectra were generated as a function of different foundation conditions.	Ref. NUREG-1462, August 1994
AP600	-The free field surface peak ground acceleration is less than or equal to a 0.30g safe shutdown earthquake.	R.G.1.60	Seven different foundation conditions were considered ranging from soft soil $v_s \geq 1000$ft/sec to hard rock=8000ft/sec. SSI performed using SASSI and 3D models.	R.G. 1.61 + ASME CCN-411 (piping) and ASCE 4-86. Higher damping used for conduits and cable trays. SSI soil damping limited to 15 percent.	Based on R.G. 1.122 committed to use envelop of spectra generated for range of foundation conditions.	1) Ref. Vols. 1 and 2 of AP600 Standard Safety Analysis Report, June 1992. 2) The site can support the foundation mat of the AP600 under all specified site conditions. There is no potential for liquefaction at the plant site due to a safe shutdown earthquake. 3) There is no potential for fault displacement at the plant site. 4) The shear wave velocity (based on low strain best estimate soil properties) is greater than or equal to 1000 feet per second.

Table C1 Summary of Seismic Design Criteria for Advanced Reactors (continued)						
Advanced Reactor System	**Seismic ZPGA**	**Ground Spectra Shape**	**Foundation Conditions Considered**	**Damping**	**In-Structure Response Spectra**	**Comments and References**
MHTGR	A site PGA would be selected which would permit citing at 85 percent of current reactor sites.	R.G. 1.60	SSI was considered using SASSI code. Assumption used in SSI not stated.	R.G. 1.61	R.G. 1.122 with ± 15 percent peak broadening.	Ref. NUREG-1338 March 1989
CANDU-3	DBE (SSE)=0.3g at free field ground surface ZPGA. Site Design Earthquake, SDE=0.15g Non-safety related structures designed to 0.15g Canadian Building Code.	Shape of ground spectra not specified.	Designed for a range of soil conditions. Shear Mod. 5 to 150 x 10^3 kg/cm^2. Poison Ratio .3 to .4. Unit weight 2.0 to 3.0g/cm^3 ground water level assumed at ground surface.	Damping not specified.	Means to generate in-structure response spectra not specified.	Ref. CANDU-3 Conceptual Safety Report, Vol. III, 1989.
PIUS	Single earthquake defined as 0.3g PGA location as to free field or surface not defined. Seismic Margin E.Q. has been established at 0.5g for a limited number of structures.	R.G. 1.60	Design will be evaluated for both "soft" and hard foundations. These terms not defined numerically. Unit weight of reactor heavier than PWR.	Damping values to be used are not defined.	In-structure response spectra to be generated over full range of foundation conditions.	Ref. PIUS, Preliminary Safety Information Document, Vol. 1, Dec. 1989.

Table C1 Summary of Seismic Design Criteria for Advanced Reactors (continued)

Advanced Reactor System	Seismic ZPGA	Ground Spectra Shape	Foundation Conditions Considered	Damping	In-Structure Response Spectra	Comments and References
PRISM	A site PGA would be selected so that it could be cited at least 90 percent of current sites i.e. 0.3g PGA. Requirements are as specified for Standard BWR in 1980.	R.G. 1.60	Not discussed.	R.G. 1.61	R.G. 1.122	Seismic Isolators would be used. Ref. NUREG-1368, Sept. 1989.

Table C2 Summary of Wind and Tornado Design Criteria for Advanced Reactors

Advanced Reactor System	Straight Wind Velocity	Tornado Wind Maximum Velocity	Tornado Differential Pressure	Tornado Missile	Barrier Design	References
ABWR	130 mph 33 ft. above grade 100 yr. Reoccurrence Interval	Tangential=240 mph Translational=60 mph Total=300 mph Radius to Max. Vel.=150 ft	2.0 psi at the rate of 1.2 psi per second	Spectrum I from SRP Section 3.5.1.4	Concrete - Use Modified Petri Formula; Steel - Stanford Formula	Bechtel Topical Report B-TOP-3A
SBWR	110 mph 50 yr. Reoccurrence Interval	Tangential=240 mph Translational=60 mph Total=300 mph Radius to Max. Vel.=150 ft	2.0 psi at the rate of 1.2 psi per second	Spectrum I from SRP Section 3.5.1.4	Concrete - Use Modified Petri Formula; Steel - Stanford Formula	Bechtel Topical Report B-TOP-3A
System 80+	110 mph 50 yr. Reoccurrence Interval with Importance Factor of 1.1	Tangential=260 mph Translational=70 mph Total=330 mph Radius to Max. Vel.=150 ft	2.4 psi at the rate of 1.7 psi per second	Spectrum II from SRP Section 3.5.1.4	Concrete - Use Modified Petri or NDRC Formulas; Steel - Stanford Formula	Williamson, R.A. and Aloy, R.R., "Impact Effects of fragments Sticking Structural Elements, 1973.
AP-600	110 mph 50 yr. Reoccurrence Interval with Importance Factor of 1.1	Tangential=240 mph Translational=60 mph Total=300 mph Radius to Max. Vel.=150 ft	2.0 psi at the rate of 1.2 psi per second	Spectrum I from SRP Section 3.5.1.4	Concrete - Use NDRC Formula; Steel - Stanford or BRL Formulas	
MHTGR	110 mph at 10 meters	Tangential=290 mph Translational=70 mph Total=360 mph Radius to Max. Vel.=150 ft	3.0 psi at the rate of 2.0 psi per second	Spectrum II from SRP Section 3.5.1.4	Concrete - Use Modified Petri or NDRC Formulas; Steel - Stanford Formula	Bechtel Topical Report B-TOP-3A
CANDU-3	Not defined	Tangential=260 mph Translational=57 mph Total=317 mph Radius to Max. Vel.=453 ft	1.46 psi; rate not defined	Spectrum II Modified for Max. Wind Vel.	Not defined	

Table C2 Summary of Wind and Tornado Design Criteria for Advanced Reactors (continued)						
Advanced Reactor System	Straight Wind Velocity	Tornado Wind Maximum Velocity	Tornado Differential Pressure	Tornado Missile	Barrier Design	References
PIUS	To be defined on a site specific basis	To be defined on a site specific basis	To be defined on a site specific basis	Not defined	Not defined	
PRISM	130 mph 30 ft above grade	Tangential=290 mph Translational=70 mph Total=360 mph Radius to Max. Vel.=150 ft	3.0 psi at the rate of 2.0 psi per second	Spectrum II from SRP Section 3.5.1.4	Concrete - Use NDRC Formula; Steel - Stanford Formula	Bechtel Topical Report B-TOP-3A

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11. ABSTRACT (200 words or less)

Through out its history, the USNRC has been committed to the use of US industry consensus standards for the design, construction, and licensing of commercial nuclear power facilities. The existing industry standards are based on the current class of light water reactors and as such may not adequately address design and construction features of the next generation of Advanced Light Water Reactors and other types of Advanced Reactors. As part of their on-going commitment to industry standards, the USNRC commissioned this study to evaluate U.S. industry structural standards for application to Advanced Reactors. The initial review effort included: (1) the review and study of the relevant reactor design basis documentation for eight Advanced Reactor Designs, (2) the review of the USNRC's design requirements for advanced reactors, (3) the review of the latest revisions of the relevant industry structural standards, and (4) the identification of the need for changes to these standards. The results of these studies were used to develop recommended changes to industry consensus structural standards which will be used in the construction of Advanced Reactors. Over seventy sets of proposed standard changes were recommended and the need for the development of four new standards was identified. In addition to the recommended standard changes, several other sets of information were extracted for use by USNRC in other programs. This information included: (1) detailed observations on the response of structures and distribution system supports to the recent Northridge, CA (1994) and Kobe, Japan (1995) earthquakes, (2) comparison of versions of certain standards cited in the standard review plan to the most current versions, and (3) comparison of the seismic and wind design basis for the subject reactor designs. Finally provided is a suggested plan of action for implementation of the recommended industry standard changes.

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