April 10, 2001

Mr. William T. Cottle
President and Chief Executive Officer
STP Nuclear Operating Company
South Texas Project Electric
Generating Station
P. O. Box 289
Wadsworth, TX 77483

SUBJECT: SOUTH TEXAS PROJECT, UNITS 1 AND 2 - CLOSEOUT OF GENERIC LETTER 96-06, "ASSURANCE OF EQUIPMENT OPERABILITY AND CONTAINMENT INTEGRITY DURING DESIGN-BASIS ACCIDENT CONDITIONS" (TAC NOS. M96868 AND M96869)

Dear Mr. Cottle:

On September 30, 1996, the U. S. Nuclear Regulatory Commission (NRC) staff issued Generic Letter (GL) 96-06. The NRC staff has reviewed STP Nuclear Operating Company's (the licensee's) responses to GL 96-06 dated October 29, 1996, and January 28, 1997; and the supplemental letters dated November 11, 1997, November 18, 1998, and February 21 and April 10, 2000, for South Texas Project (STP), Units 1 and 2. The following reviews, by the NRC staff, address the issues of waterhammer and two-phase flow associated with containment coolers, and thermally-induced pressurization of piping runs penetrating the containments for STP, Units 1 and 2.

GL 96-06 included a request for licensees to evaluate cooling water systems that serve containment air coolers to assure that they are not vulnerable to waterhammer and two-phase flow conditions. Enclosure 1 is the NRC staff’s Safety Evaluation (SE) including an attached letter report regarding these issues. The staff concludes that they have been acceptably addressed by the licensee. Regarding the thermally-induced pressurization concern of GL 96-06, Enclosure 2 is the NRC staff’s SE regarding that issue. The staff, again, concludes that it has been acceptably addressed by the licensee.

Therefore, the NRC staff concludes that the licensee's proposed corrective actions provide an acceptable resolution for the issues of waterhammer and two-phase flow associated with containment coolers, and thermally-induced pressurization of piping runs penetrating the containment at STP, Units 1 and 2.

This completes the NRC staff's review of the licensee's response, as supplemented, to GL 96-06 for STP, Units 1 and 2, and closes TAC Nos. M96868 and M96869.

Sincerely,

/RA/

Mohan C. Thadani, Senior Project Manager, Section 1
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-498 and 50-499

Enclosures: As stated (2)

cc w/encls: See next page

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DTatum
BJain

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OFFICE	PM:PDIV-1	LA:PDIV-1	SC:PDIV-1
NAME	MThadani	MMcAllister	RGramm
DATE	04/10/2001	04/10/2001	04/10/2001

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO GENERIC LETTER 96-06

ASSURANCE OF EQUIPMENT OPERABILITY AND CONTAINMENT INTEGRITY

COOLING WATER SYTEMS INSIDE CONTAINMENT

WATERHAMMER AND TWO-PHASE FLOW

STP NUCLEAR OPERATING COMPANY, ET AL.

SOUTH TEXAS PROJECT, UNITS 1 AND 2

DOCKET NOS. 50-498 AND 50-499

1.0 INTRODUCTION

Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," dated September 30, 1996, included a request for licensees to evaluate cooling water systems (CWSs) that serve containment air coolers to assure that they are not vulnerable to adverse hydrodynamic effects of waterhammer and inadequate heat removal as a result of previously unanalyzed two-phase flow conditions induced by loss-of-coolant accidents or main steamline break accidents.

2.0 DISCUSSION AND EVALUATION

STP Nuclear Operating Company (the licensee) provided its assessment for South Texas Project (STP) Units 1 and 2 in a letter dated January 28, 1997, and additional information was submitted in a supplemental letter dated November 18, 1998. The information that was submitted by the licensee was reviewed by Information Systems Laboratories, Inc. (ISL) under contract to the U. S. Nuclear Regulatory Commission (NRC) (NRC-03-95-026, Task 240). ISL has completed its review and the results are documented in the attached Letter Report No. 240-5 dated December 2000. Based on its evaluation, ISL found that the licensee's conclusion that waterhammer and two-phase flow will not pose a problem for the event scenarios discussed in GL 96-06.

3.0 CONCLUSION

Based on the NRC staff's review of Letter Report No. 240-5, the NRC staff concludes that the licensee response to issues associated with the evaluation of CWSs that serve containment air coolers, to assure that they are not vulnerable to waterhammer and two-phase flow conditions, with regard to GL 96-06, is acceptable for STP, Units 1 and 2.

Principal Contributors: J. Tatum
D. Jaffe

Date: April 10, 2001

Attachment: Letter Report No. 240-5 Enclosure 1

Letter Report No. 240-5

Review Of South Texas Project, Units 1 &2, Waterhammer And Two-Phase Flow Analysis

Hossein P. Nourbakhsh
25 East Loop Road
Stony Brook, NY 11790

December, 2000

Prepared for:
U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

Under Consultant Agreement No. 5401-240
From Information Systems Laboratories, INC.
11140 Rockville Pike
Suite 500
Rockville, MD 20852
Contract N0. NRC-03-95-026, Task 240,
TAC Nos. M96868 & M96869

Attachment

1. INTRODUCTION

NRC Generic Letter 96-06 (GL 96-06) " Assurance of Equipment Operability and Containment Integrity During Design Basis Accident Conditions"[1] included a request for licensees to evaluate cooling water systems that serve containment air coolers to assure that they are not vulnerable to Water hammer and two-phase flow conditions. More specifically, the issues of concern are :[1]

> "(1) Cooling water systems serving the containment air coolers may be exposed to the hydrodynamic effects of waterhammer during either a loss-of-coolant accident (LOCA) or a main steam line break (MSLB). These cooling water systems were not designed to withstand the hydrodynamic effects of waterhammer and corrective actions may be needed to satisfy system design and operability requirements.
>
> (2) Cooling water systems serving the containment air coolers may experience two-phase flow conditions during postulated LOCA and MSLB scenarios. The heat removal assumptions for design-basis accident scenarios were based on single-phase flow conditions. Corrective actions may be needed to satisfy design and operability requirements."

Houston Lighting & Power Company provided its assessment for the South Texas Project (STP), Units 1 and 2, in a letter dated January 28, 1997. [2] Parts of the licensee's submittal addresses waterhammer and two-phase flow conditions. The licensee was requested to provide additional information in a letter dated July 14, 1998.[3] The licensee's response was provided in a letter dated November 18, 1998.[4]

Information Systems Laboratories (ISL), Inc. was requested (NRC-03-95-026, Task Order No. 240) to assist the NRC staff in reviewing the waterhammer and two-phase flow analyses that has been completed by the licensee for the South Texas Project, Units 1 and 2, in response to GL 96-06. The objective of the review was to determine whether or not the analyses are adequate and conservative in all respects.

This letter report summarizes the results of the review that was performed and conclusions that were reached. Section 2 provides background information regarding the design characteristics of the containment fan cooler cooling water system in South Texas Project. The event considered for this evaluation is discussed in section 3. Section 4 provide the review results of the waterhammer and two-phase flow analyses. Section 5 provides a brief summary together with conclusions.

2. DESCRIPTION OF THE SOUTH TEXAS PROJECT REACTOR CONTAINMENT FAN COOLER SYSTEM

The South Texas Project Containment Fan Cooler (RCFC) system is a part of the safety -related Containment Heat Removal System (CHRS). The function of the CHRS is to remove heat from the containment atmosphere to limit, reduce, and maintain the pressure and temperature at acceptable levels following a Design Basis Accident. The RCFC system consists of three trains, with two RCFC units per train.[4]

During normal operation, the RCFC system maintains a suitable atmosphere for equipment located within containment. Non-safety class Chilled Water (CHW) is the cooling medium. Following initiation of an accident, the safety-related cooling medium, Component Cooling Water (CCW), supplies cooling for the RCFC system.[4] It should be noted that, due to the installed static head in the CCW system, the minimum saturation temperature of the water in the fan coolers is 262.9°F.

3. SEQUENCES OF EVENTS CONSIDERED FOR EVALUATION

The licensee separated the waterhammer /two-phase flow analyses of the accident into three time phases. The first time phase is from initiation of the accident (t=0.0 second) up to and including the initiation of component cooling water flow (t≈41 seconds). This is the time period in which the heat transfer from containment atmosphere could potentially lead to void formation within the RCFC cooling coils.

The second time phase is from time t≈41 seconds through t≈140 seconds. This is the time period for the initial hot water from the RCFC coils to travel through the CCW system and enter the RCFC. Peak RCFC discharge temperature occurs during this time frame.

The third time phase is from approximately time t ≥140 seconds to beyond t »hours and/or days. This is the time period in which the maximum CCW supply temperature occurs and when the CCW system will reach steady state temperature conditions.

The licensee considered both the LOCA and MSLB with simultaneous initiation of a Loss Of Offsite Power (LOOP) for heat-up evaluation of coolant within the RCFC cooling coils (for time phase 1). A design basis LOCA with the Model E steam generator double- ended hot leg guillotine break (LOCA-3) was determined to be the " worst case" scenario for RCFC coolant heat-up.

A double-ended pump suction break with minimum Safety Injection with the Delta 94 steam generators was considered to be the "worst case" scenario for time phases 2 and 3. This determination was based on the results of hydraulic network analysis performed by the licensee.

The licensee has previously performed a failure modes and effects analysis (FEMA) for all components (including electrical and pneumatic failures) that could impact the CCW system. The licensee performed a design review of CCW FEMA for GL 96-06. The review re-verified the capability of the affected components to perform safety-related functions based on the results of the two-phase flow and waterhammer analyses. Based on this review, the licensee concluded that the CCW system can tolerate a single failure and still perform its safety functions, and therefore, the original FEMA is still valid and applicable.

4. WATERHAMMER AND TWO-PHASE FLOW ANALYSIS

The licensee has evaluated the waterhammer and two-phase flow issues for the South Texas Project, Units 1 and 2, in response to GL 96-06.

A LOCA concurrent with a LOOP causes interruption of cooling water flow to the RCFC cooling coils soon after initiation of the event, while the associated fans would coast down for a much longer time. Continuation of high temperature containment air flow over the coils could potentially lead to void formation within the RCFC cooling coils prior to the re-establishment of coolant flow by means of the Standby Diesel Generators. The GOTHIC 5.0e computer code was used to evaluate the RCFC coolant heat-up based on the containment Design Basis Accident response profiles generated in the LOCA-3 and MSLB transient analyses. The peak coolant temperature for LOCA-3 (the "worst case" scenario) was reported to be 258.9°F. The internal pressure for the top tube in the highest cooling coil is 37.2 psia (due to surge tank elevation). Therefore, the peak coolant temperature is 4°F below the minimum coolant saturation temperature of 262.9°F and thus no void could form within the RCFC cooling coils.

The methodology, including the assumptions and input parameters used in GOTHIC 5.0e code, was found to be adequate and conservative for the evaluation of the RCFC coolant heat-up. The GOTHIC 5.0e computer code was validated by the STP in accordance with the STP software quality assurance program. The code validation was based on benchmark studies presented in an EPRI Interim Report[5].

After the CCW pumps start, the hot water "trapped" in the RCFC coil is forced out into the return piping manifold and header. The cold chilled water in the return piping quickly passes through the downstream throttling valve followed by the hotter water from the coils. The lower pressure at the outlet of the throttling valve is sufficient to reduce the local pressure below the vapor pressure of the hot water, and the flow becomes choked.[4] The cold chilled water velocity quickly reduces resulting in a sudden pressure rise hydraulic transient due to a change in mass flux between the cold and hot water flow.

The licensee performed a hydraulic network analysis for the RCFC to calculate flow rates, choked flow condition and the cavitation condition at the throttle valve. The hydraulic network analysis consisted of developing a network model using PIPEFLO software and an algorithm to find supply/return temperatures and heat loads for post accident conditions. This model conservatively used a zero fouling factor for the RCFC coils and the maximum design fouling factor for the CCW heat exchanger. After the start of CCW flow and replacement of the

initial "trapped" volume of water, the maximum RCFC outlet water temperature was determined to be approximately 229°F. Conservatively, this outlet temperature was analytically transported to the minimum static pressure location at the RCFC/RHR return line intersection tee for evaluation of the margin to boiling. This evaluation determined that approximately 4°F of subcooling is maintained in Train C. Trains A and B maintains approximately 17°F of subcooling.

The results of the hydraulic network analysis indicated a temperature step increase from 65°F to 127°F at the RCFC throttle valve. The water temperature at the throttle valve continues to increase from 127°F to 160°F until t=60 seconds when the hot water from the other RCFC reaches the valve resulting in a second temperature step increase from 160°F to 200°F at the throttle valve. The water temperature at the throttle valve continues to increase to a maximum temperature of 229°F.[4]

At each range of increasing water temperatures, the severity of predicted choked flow and the effect of the hydraulic performance of the throttle valve were evaluated by the licensee. Two methodologies were used for this evaluation: (1) NUREG/CR-6031, "Cavitation Guide for Control Valves", and (2) "Flow Manual for Quarter-Turn Valves", by Rockwell International Corporation. Both methods provided similar results concerning the temperature of the water at which the throttle valve becomes choked. It was found that choked flow conditions may exist duringthe step increases in fluid temperature, and the mass flow rates and upstream and downstream system pressures were analyzed for choked flow. The results of the analysis showed that Trains A and B become choked at the second temperature step increase (200°F) and Train C is choked at the initial CHW system temperature (65°F).

The severity of predicted cavitation across the RCFC throttle valve was also evaluated by the licensee. Two methodologies were used for this evaluation: (1) NUREG/CR-6031, "Cavitation Guide for control Valves", and (2)ISA-RP75.23 -1995, "Consideration for Evaluating Control Valves". The following results of the cavitation severity across the throttling valve during the time intervals following the accident is from Reference 4.

Time	**Cavitation Severity**	
	Method 1 (NUREG/CR-6031) Cavitation Damage Rate (Times incipient damage Level)	**Method 2 (ISA-RP75.23-1995) Cavitation Damage Intensity Index**
40-140 Seconds	4.	~ 9
1200 Seconds	3.3	~ 5
8500 Seconds	3.1	~ 1

The licensee concluded that the cavitation resonance and fatigue effect is bounded by the existing piping stress analysis since the cavitation duration was found to be relatively short. No information about the available margins was originally provided. However, during a conference call[6] , the licensee provided further clarification and indicated that based on the evaluation that was done and accordance with the ISA-RP75.23-1995, it was determined that the wear that would result to the RCFC throttle valve during the 30 days period following accident initiation would be equivalent to the wear that would result during one year of normal operation. This is not excessive for a valve which is designed to last for many years, and the licensee's conclusion that cavitation is not a concern for the event scenarios of interest is considered to be justified and acceptable.

The licensee also performed an analysis to assess the impact of the reduced component cooling water flow through the RCFC on the containment pressure and temperature response. The results of the analysis show that the resulting containment pressure and temperature do not exceed the equipment qualification requirements, and therefor is considered to be acceptable.

The column closure and condensation induced waterhammer scenarios were found not to be applicable to the South Texas Project system configuration because no void formations were predicted to occur. However, the results of the hydraulic network analysis indicated that the potential for a sudden pressure rise hydraulic transient (waterhammer) exists at the RCFC throttle valve located in the CCW return line, near the containment wall penetration. This waterhammer is due to the change in mass flux between the cold water flow and hot water flow resulting from the choked flow condition. The magnitude of the pressure pulse was determined by the licensee, using the Joukowsky Equation, based on the fluid velocity change and pressure wave speed in water. The maximum initial pressure pulse was reported to be approximately 9.2 lb_f/in^2 which results in an applied force of approximately 1270 lb_f to the piping and supports. The licensee's conclusion that this magnitude of waterhammer is insignificant is considered to be acceptable.

5. SUMMARY AND CONCLUSIONS

The waterhammer and two-phase flow evaluation that has been completed by the licensee for the South Texas Project, Units 1 and 2, in response to GL96-06, was reviewed. The selection of a LOCA concurrent with a LOOP as a bounding scenario for evaluating the responses of the containment cooling system is appropriate.

The containment fan cooler waterhammer and two-phase flow concerns raised in Generic Letter 96-06 were addressed by a combination of calculations. A thermal analysis established the initial margin to boiling conditions within the RCFC. A hydraulic network analysis established the cavitation effect and the margin to boiling for the duration of the accident. The hydraulic transient analysis established the magnitude of the pressure wave and the forces acting on the piping. The pipe stress and support analyses established the resulting stress

levels in the piping and support components. The methodology, including the assumptions and input parameters used in the analyses, is considered to be adequate for the waterhammer and two-phase flow evaluation.

The column closure and condensation induced waterhammer scenarios were found not to be applicable to the South Texas Project system configuration because no void formations were predicted to occur. However, the results of the hydraulic network analysis indicated that the potential for a sudden pressure rise hydraulic transient (waterhammer) exists at the RCFC throttle valve located in the CCW return line, near the containment wall penetration. The maximum initial pressure pulse was reported to be approximately 9.2 lb_f/in^2 which results in an applied force of approximately 1270 lb_f to the piping and supports. The licensee's conclusion that this magnitude of waterhammer is insignificant is considered to be acceptable.

The licensee concluded that the cavitation resonance and fatigue effects are bounded by the existing piping stress analysis since the cavitation duration was found to be relatively short. Through analysis, the licensee determined that the level of cavitation at the RCFC throttle valve for the period of one month after accident initiation is equivalent to a year of normal wear. The licensee's conclusion that cavitation is not a concern for the event scenarios of interest is considered to be justified and acceptable.

The licensee also performed an analysis to assess the impact of the reduced component cooling water flow through the RCFC on the containment pressure and temperature response. The results of the analysis show that the resulting containment pressure and temperature are bounded by the equipment qualification requirements and therefor is considered to be acceptable.

7. REFERENCES

1. Nuclear Regulatory Commission (NRC), " Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," NRC Generic Letter 96-06, 1996.

2. Houston Lighting & Power Company, " South Texas Project, Units 1 and 2, 120-Day Response to Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design- Basis Accident Conditions,"Letter from T. H. Cloninger to U.S. NRC, ST-HL-AE-5554, January 28, 1997.

3. Nuclear Regulatory Commission (NRC), " Request for Additional Information (RAI) Regarding Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions, South Texas Project, Units 1 and 2 (STP)", Letter from Thomas W. Alexion to William T. Cottle, July 14, 1998.

4. STP Nuclear Operating Company, " South Texas Project Units 1 and 2 Response to Request for Additional Information (July 14, 1998) Regarding Generic Letter 96-06, Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions," Letter from S. E. Thomas to U.S. NRC, NOC-AE-000289, November 18, 1998.

5. Numerical Applications , Inc. "Containment Air Cooler Heat Transfer During Loss of Coolant Accident With Loss of Offsite Power," Prepared for EPRI , November 1996.

6. Conference Call Between NRC Staff and The Licensee, December 12, 2000.

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO GENERIC LETTER 96-06

ASSURANCE OF EQUIPMENT OPERABILITY AND CONTAINMENT INTEGRITY

THERMALLY-INDUCED PRESSURIZATION OF PIPING SYSTEMS

STP NUCLEAR OPERATING COMPANY, ET AL.

SOUTH TEXAS PROJECT, UNITS 1 AND 2

DOCKET NOS. 50-498 AND 50-499

1.0 INTRODUCTION

The U. S. Nuclear Regulatory Commission (NRC) staff has reviewed the STP Operating Company's (the licensee's) January 28, 1997, response to a requirement included in Generic Letter (GL) 96-06, "Assurance of Equipment Operability and Containment Integrity During Design-Basis Accident Conditions" regarding potential thermally induced pressurization of water-filled piping sections in containment, that could jeopardize the ability of accident-mitigation systems to perform their intended safety function and could lead to a breach of containment integrity via bypass leakage for South Texas Project (STP), Units 1 and 2. The licensee subsequently submitted supplemental letters dated November 11, 1997, February 21, and April 10, 2000, to complete its response to GL 96-06.

2.0 DISCUSSION AND EVALUATION

The following evaluation addresses the issue of thermally-induced pressurization of piping runs penetrating the containment. The NRC staff has reviewed the heat transfer coefficients used by the licensee in calculating the maximum temperature and pressure for the piping runs penetrating the containment, and concludes that these heat transfer coefficients are commonly used in containment heat transfer calculations and its use for this application is acceptable.

In the licensee's submittal dated January 28, 1997, the licensee identified 10 penetrations in each STP unit as vulnerable to a water solid volume that may be subjected to an increase in pressure due to heating of trapped fluid. The licensee installed insulation on one of the lines and determined that the pipe stress is within the design basis of American Society of Mechanical Engineers (ASME) Section III, Subsection NC Code limits. The licensee also determined that the remaining nine lines are operable based on the potential leakage through packing, bonnet, gaskets, and/or valve seating surfaces. For its long-term corrective action, the licensee committed to continue its evaluation to determine whether to install modifications or provide other means to ensure that overpressurization will not occur.

In response to the NRC staff's September 12, 1997, request for additional information, the licensee submitted its response of November 11, 1997, which provided the design criteria for the piping and valves including the design load combinations, maximum calculated pipe stress pressure at which the valve was determined to lift off its seat, and methodology to estimate this pressure including any source of associated uncertainties. The licensee, in its evaluation of the remaining nine penetrations, concluded that the stresses in the penetrations are within the design basis of ASME Section III, Subsection NC Code limits for faulted condition. The licensee also identified the source of additional margin in its computation of maximum pipe stress. The licensee stated that the maximum pipe stress values were conservatively calculated by adding the stress values due to thermally-induced overpressurization to the existing highest and bounding stress value previously computed in the design calculation. The additional margins are available because the actual stress value at the data points located between the containment isolation valves is much lower than the bounding value used in the evaluation.

In its review of the licensee's methodology for calculating the thermally-induced overpressure, the NRC staff finds that the licensee did not consider the Poisson's effect in the formulation of its methodology. Failure to consider Poisson's effect can potentially lead to overestimating the change in pipe deformation and therefore in underestimating the change in magnitude of increased water pressure. The NRC staff estimated the increase in pipe pressure due to the Poisson's effect, to be in the order of 10 percent. In reviewing the licensee's computation of maximum pipe stress and the identified source of additional margin, the NRC staff considers the licensee's conclusion reasonable and acceptable. The licensee, in its submittal of November 11, 1997, had committed to (1) perform additional calculation to determine if there is a need to take credit for the air-operated valves for overpressure protection, and (2) verify a preliminary version of a computer code developed to perform the pipe pressurization analyses. The licensee, in its submittals of February 21, and April 10, 2000, confirmed that there is no need to take credit for the air-operated valves for overpressure protection, and the revised version of the computer code has been verified and there were changes in peak pressures calculated using the verified code; however, the resulting stresses remain within the design basis of ASME Section III, Subsection NC Code limits for faulted condition.

3.0 CONCLUSION

The NRC staff concludes that the licensee's evaluation provides an acceptable resolution for the issue of thermally-induced pressurization of piping runs penetrating the containment.

Principal Contributor: B. Jain
D. Jaffe

Date: April 10, 2001

South Texas, Units 1 & 2

cc:

Mr. Cornelius F. O'Keefe
Senior Resident Inspector
U.S. Nuclear Regulatory Commission
P. O. Box 910
Bay City, TX 77414

A. Ramirez/C. M. Canady
City of Austin
Electric Utility Department
721 Barton Springs Road
Austin, TX 78704

Mr. M. T. Hardt
Mr. W. C. Gunst
City Public Service Board
P. O. Box 1771
San Antonio, TX 78296

Mr. G. E. Vaughn/C. A. Johnson
Central Power and Light Company
P. O. Box 289
Mail Code: N5012
Wadsworth, TX 74483

INPO
Records Center
700 Galleria Parkway
Atlanta, GA 30339-3064

Regional Administrator, Region IV
U.S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011

D. G. Tees/R. L. Balcom
Houston Lighting & Power Co.
P. O. Box 1700
Houston, TX 77251

Judge, Matagorda County
Matagorda County Courthouse
1700 Seventh Street
Bay City, TX 77414

A. H. Gutterman, Esq.
Morgan, Lewis & Bockius
1800 M Street, N.W.
Washington, DC 20036-5869

Mr. J. J. Sheppard, Vice President
Engineering & Technical Services
STP Nuclear Operating Company
P. O. Box 289
Wadsworth, TX 77483

S. M. Head, Supervisor, Licensing
Quality & Licensing Department
STP Nuclear Operating Company
P. O. Box 289
Wadsworth, TX 77483

Office of the Governor
ATTN: John Howard, Director
Environmental and Natural
Resources Policy
P. O. Box 12428
Austin, TX 78711

Jon C. Wood
Matthews & Branscomb
112 East Pecan, Suite 1100
San Antonio, TX 78205

Arthur C. Tate, Director
Division of Compliance & Inspection
Bureau of Radiation Control
Texas Department of Health
1100 West 49th Street
Austin, TX 78756

Jim Calloway
Public Utility Commission of Texas
Electric Industry Analysis
P. O. Box 13326
Austin, TX 78711-3326