December 29, 2000

MEMORANDUM TO: John A. Grobe, Director
Division of Reactor Safety, Region III

FROM: Suzanne C. Black, Deputy Director ***/RA/***
Division of Licensing Project Management, NRR

SUBJECT: REQUEST FOR TECHNICAL ASSISTANCE - RESOLUTION OF PIPE SUPPORT DESIGN ISSUES AT LASALLE COUNTY STATION - TIA 2000-03 (TACS MA8972 AND MA8973)

By memorandum dated May 9, 2000, Region III requested Nuclear Reactor Regulation (NRR) technical assistance regarding pipe support design assumptions at Commonwealth Edison's (ComEd's) LaSalle County Station. Some pipe support structures, with structural members that were fully welded to baseplates, were designed with the assumption that these attachment points would behave like pinned connections as opposed to fixed connections. The region issued a letter to ComEd on February 8, 2000, documenting several questions associated with ComEd's assessment of the pinned vs. fixed issue. Region III requested that NRR evaluate the licensee's responses to these questions which were provided in letters dated March 10 and March 20, 2000. Specifically, the region requested that NRR answer the following questions: (1) is it appropriate to use a secant modulus based on the behavior of the anchor bolt at ultimate capacity for design or analysis, and (2) has the Nuclear Regulatory Commission (NRC) approved such a design approach. Because Sargent and Lundy (S&L) performed the pipe support analyses for LaSalle, the region indicated that these issues are potentially generic to any plant where S&L had performed pipe support analyses.

The staff conducted an inspection on September 6 and 7, 2000, at S&L offices to examine design records relating to the methodology used by S&L for the design of pipe support anchorages at LaSalle. As a result of the inspection, we did not identify significant programmatic deficiencies in the methodology used by S&L at LaSalle. In addition, we agree with S&L's determination that the concerns about the adequacy of pipe support anchorages at other facilities designed by S&L do not present any significant safety issues that require NRC's action. Our safety evaluation is enclosed.

Docket Nos. 50-373 and 50-374

Enclosure: As stated

cc w/encl: J. Wiggins, RI
B. Mallett, RII
A. Howell, RIV

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SAFETY EVALUATION BY THE

OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO SARGENT & LUNDY PIPE SUPPORT

DESIGN ISSUE AT LASALLE STATION

1.0 INTRODUCTION

In a letter dated May 9, 2000, Region III requested NRR's assistance to assess the safety significance of a design issue concerning the adequacy of modeling of pipe support anchorages designed by Sargent & Lundy (S&L). This review was initiated as a result of a Region III inspection finding that S&L may not have used proper bolt stiffness in the analyses of anchorages at LaSalle County Station. The NRR staff examined several design records, held a meeting with ComEd regarding this subject on June 8, 2000, and performed an inspection on September 6 and 7, 2000, at S&L's office to examine records relating to its pipe support design practices. The inspection focused on modeling techniques of pipe supports anchored to concrete structures using concrete expansion anchors. The purpose of the inspection was to examine design records in support of S&L's determination that its pipe support design approach at LaSalle is technically justified and did not result in installations that are not structurally adequate. The inspection findings are documented in Inspection Report 99900507/2000-201 dated October 6, 2000. The findings from the inspection and NRR's conclusions are discussed below.

2.0. SARGENT & LUNDY'S DESIGN PRACTICES AND JUSTIFICATIONS

2.1 Sargent & Lundy Design Practices

S&L stated that its design standard for anchorages did not specify how a pipe support structural connection to the concrete should be modeled (i.e., a "pinned" or "fixed"). Therefore, the mathematical model for anchorages was left to the individual design engineer to decide. Boundary conditions are typically modeled as fixed or pinned connected. A semi-rigid boundary model was only used when a pinned condition was not justified or a fixed condition yielded unrealistically conservative results.

2.2 Sargent & Lundy's Justifications for the Assumption of Pinned-connected Conditions

S&L cited some design sources that permit the application of pinned conditions as a justification of its use of this approach in certain anchorage configurations. S&L cited: (1) AISC type 2 construction (simple framing) which allows connections to be designed as pinned conditions due to adequate inelastic rotational capacity of the connections, (2) AISC tension splices that are allowed to be designed on average bolt loads instead of the peak load of an individual bolt due to adequate ductility in the splice, (3) ASME B&PV Code, Article NF-3121.3 that allows the stress created by the constraining effect to be neglected due to local yielding or minor

distortions, and (4) a textbook's comments on certain types of steel connection that can be designed as pinned conditions.

S&L presented analysis results of postulated design bolt displacements in five highly stressed LaSalle anchorages. These anchorages are postulated to undergo significant rotations of the anchorage locations that are equivalent to the assumed rotations for pinned conditions. The calculated values of bolt displacements are less than 0.05 inches when the anchorages were modeled as pinned-connected joints. S&L also presented test data of single expansion bolts embedded in concrete which indicate that the bolt displacements at the ultimate load condition are greater than 0.5 inches. S&L rationalized that the anchorages at issue can rotate into a pinned condition before they fail, and used this justification for its use of a pinned condition in the design phase of these anchorages.

2.3 Sargent & Lundy's Bases for Using Secant Modulus

S&L stated that the loss of pre-tension load from anchor bolts is significant and rapid with time, and the secant modulus (stiffness) it had used represented the anchor bolt stiffness without pre-tension load. S&L also stated that the secant modulus used in the semi-rigid boundary model is consistent with the July 5, 1979 IEB 79-02 submittal to the NRC. S&L's analyses indicate that the increase in bolt tensile force is not overly sensitive to the increase of bolt stiffness because a ten fold increase in bolt stiffness would only result in an increase of the bolt tensile force by about 25%. S&L stated that it had re-analyzed four anchorages, which it believed to be the worst cases at LaSalle, by increasing the value of the secant modulus ten fold. The analyses results indicate that factors of safety of 4 existed for bolts in two cases and factors of safety of about 3 were calculated for the other two cases.

2.4 Generic Implications

S&L stated that the types of anchorages for pipe supports at LaSalle are similar to those at other plants, and the same design philosophy, standard, and supervisory guidance were used at all plants designed by their engineers. Therefore, the studies performed for LaSalle are also applicable to other plants.

2.5 Improvement of Design Practices

S&L issued a Technical Alert TA2000-0013 titled "Concrete Expansion Anchor Bolt Stiffness and Pipe Support Base Plate Boundary conditions" on July 11, 2000. The Technical Alert states that the anchor bolt stiffness used in the analyses shall be consistent with the licensing basis and, in the absence of specific values, the anchor bolt stiffness shall be based on project-specific tests and, if these tests are not available, a stiffness value of 250 k/in. shall be used. The Technical Alert also states that the boundary condition at the anchor bolt shall be considered fixed unless the connection of the member to the anchor bolt plate is a "simple connection".

3.0 STAFF EVALUATION

The staff did not identify any significant concerns with S&L's justification of the design adequacy of pipe support anchorages at LaSalle. The staff agrees with the Technical Alert as

stated above, however, the staff believes that the stiffness value of 250 k/in. should be justified based on anchorage test results. The major weakness in S&L's semi-rigid analysis methodology is that the mathematical model does not include the pre-tension loads from anchor bolts on anchorages. As a result of this omission, the calculated stiffness of an anchorage at the design load may be different from the actual value. The assumption of lower than actual anchorage stiffness will result in the reduction of the magnitude of bending moment at the joint which in turn leads to lower estimation of tension forces for anchor bolt design. However, the omission of pre-tension loads in the vendor's semi-rigid design methodology is most likely not significant for anchor bolt design because of the significant relaxation that takes place over time after the anchor installation. In its report titled "Evaluation of Analysis Procedures for the Design of Expansion Anchored Plates in Concrete", dated May 31, 1979, S&L indicated that the initial expansion anchor pre-load will ultimately relax to approximately 60% of its initial value and its installation procedures require a torque test be applied to bolts after installation to achieve a minimum of 60% of the installation torque. Based on its experience with expansion anchor behavior over time, the staff believes that about one half of the original pre-tension load from anchor bolts will remain in properly installed anchorages even after an extensive service time. Therefore, the omission of pre-tension loads on anchorages in a semi-rigid analysis may result in some reduction to the anchorage stiffness. However, the magnitude of stiffness reduction will result in an inconsequential increase of bolt loads and reduction of estimated design factors of safety.

The analysis results provided by S&L, which indicate that the five most highly stressed anchorages at LaSalle will not fail before the anchorages rotate into pinned conditions, offer adequate assurance regarding the structural integrity of these anchorages. The test data cited by S&L represent tests conducted on a single bolt embedded in uncracked concrete, while the actual anchorage involves multi-bolts and is expected to function in cracked concrete during earthquakes. The spacing effect of multi-bolts and concrete cracking effects contribute to some reduction in the ultimate load and the corresponding displacement of bolts in anchorages as compared to that of test data of single bolts. The analysis results performed by S&L indicate that there is a factor of safety of about 3 for the two governing support installations when the secant modulus was increased by ten fold. These results provide adequate assurance that the factor of safety for anchorages in these supports is in excess of 2, which is the minimum requirement to ensure support operability in accordance with Generic Letter 91-18. The staff also agrees that these anchorages could undergo sufficient rotations under design load conditions consistent with the analysis assumption. However, the guidance for future analysis assumptions, relating to bolt ductility and ultimate displacement of single or closely spaced anchor bolts, should be consistent with the guidance provided by ACI 349 Code, Appendix B, "Anchoring to Concrete".

4.0 CONCLUSION

The analysis performed by S&L provides adequate assurance that the anchorages designed as pinned conditions are likely to undergo sufficient rotations under design load conditions, consistent with the modeling assumptions, and that the anchorages possess a factor of safety of 2 or greater, which meets the operability criteria.

The staff finds S&L's conclusion regarding the structural adequacy of pipe support installation acceptable for all plants at which S&L performed pipe support analyses. The staff also finds

that the revision to the anchorage design procedure in S&L's Technical Alert provides clear guidance to increase the conservatism of future anchorage design. However, the guidance for future analysis assumptions, relating to bolt ductility and ultimate displacement of single or closely spaced anchor bolts, should be consistent with the guidance provided by ACI 349 Code, Appendix B, "Anchoring to Concrete".

Principal Contributor: John Ma

Date: December 29, 2000