Mr. Lawrence V. Jacques
Senior Vice President
Sargent & Lundy
55 East Monroe Street
Chicago, IL 60603-5780

October 6, 2000

SUBJECT: NRC INSPECTION REPORT NO. 99900507/2000-201

Dear Mr. Jacques:

This refers to the inspection conducted by Richard McIntyre and Robert Pettis of the Quality Assurance, Vendor Inspection, Maintenance, and Allegations Branch (IQMB), Kamal Manoly and John Ma of the Mechanical and Civil Engineering Branch (EMEB), and James Gavula of the NRC Region III Office on September 6-7, 2000, at the Sargent & Lundy (S&L) offices in Chicago, Illinois. The purpose of the inspection was to review S&L pipe support design practices as it relates to the generic design assumptions for modeling of pipe support structural connections to base plates, the technical justification for the use of certain concrete expansion anchor bolt stiffness values and to verify that the above S&L pipe support design activities did not result in operability concerns at any nuclear power plant where S&L had pipe support design responsibility.

S&L provided these engineering services as safety related in accordance with their 10 CFR Part 50, Appendix B, quality assurance (QA) program to Commonwealth Edison Company (ComEd) nuclear plants and to other NRC licensees. At the conclusion of the inspection, an exit meeting was performed with you and members of your staff identified in the enclosed report.

The inspection determined that S&L was adequately implementing their 10 CFR Part 50, Appendix B, QA program for the areas reviewed. Overall, the analysis results performed by S&L for LaSalle Generating Station (LaSalle) pipe supports provide adequate assurance that the assumptions used for modeling of pipe support anchorages is generally reasonable, though not overly conservative. Reevaluation of the most governing pipe support anchorages indicated that they possess a minimum factor of safety about three, which is well in excess of the operability criteria of two.

The NRC staff agrees with S&L's conclusion that the structural adequacy of pipe support installations at LaSalle and other S&L designed plants are acceptable. S&L's conclusions were based on comparisons of pipe support configurations and design philosophies, design standards that contained similar methodologies and general consistency in supervisory guidance. The NRC staff also finds that the revision to the anchorage design standards in S&L's Technical Alert TA2000-0013 provides clear guidance to increase the conservatism of future anchorage design.

In accordance with 10 CFR Part 2.790 of the NRC's "Rules of Practice," a copy of this letter, its enclosures, and your response will be placed in the NRC's Public Document Room. Should you have any questions concerning this inspection, we will be pleased to discuss them with you.

Sincerely,

/RA/

Theodore R. Quay, Chief, IQMB
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Enclosure: Inspection Report No. 99900507/2000-201

cc: Mr. Oliver D. Kingsley, President
Nuclear Generation Group
Commonwealth Edison Company
Executive Towers West III
1400 Opus Place, Suite 500
Downers Grove, IL 60515

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OFFICE OF NUCLEAR REACTOR REGULATION

Report no:	99900507/2000-201
Organization:	Sargent & Lundy (S&L) 55 East Monroe Street Chicago, IL 60603-5780
Contact:	Randy Kurtz, Quality Assurance Manager (408) 925-6587
Nuclear Activity:	Sargent & Lundy provides a wide range of design engineering and services to the nuclear industry.
Date:	September 6-7, 2000
Inspectors:	Richard P. McIntyre, IQMB, Team Leader Robert L. Pettis, IQMB John Ma, EMEB Kamal Manoly, EMEB James Gavula, Region III
Approved by:	Daniel H. Dorman, Chief Quality Assurance and Safety Assessment Section IQMB Division of Inspection Program Management

1 INSPECTION SUMMARY

The purpose of the inspection was to review Sargent & Lundy (S&L) pipe support design practices as it relates to the generic design assumptions for modeling of pipe support structural connections to base plates, the technical justification for the use of certain concrete expansion anchor bolt stiffness values and to verify that the above S&L pipe support design activities did not result in operability concerns at any nuclear power plant where S&L had pipe support design responsibility. S&L provides these design engineering activities to nuclear licensees as safety related under their 10 CFR Part 50, Appendix B, quality assurance (QA) program .

2 STATUS OF PREVIOUS INSPECTION FINDINGS

No previous inspection findings were examined during this inspection.

3 INSPECTION FINDINGS AND OTHER COMMENTS

3.1 Background

During inspection activities that were conducted by Region III at the Commonwealth Edison Company (ComEd) LaSalle Nuclear Generating Station, Units 1 and 2 (LaSalle) from May through October 1999 and documented in Region III Inspection Report 50-373/99020(DRS) & 50-374/99020 (DRS), certain potential generic issues pertaining to pipe support end connection modeling and anchor bolt stiffness values were identified. The Region III inspection report identified a non-cited violation (NCV) for failure to adequately demonstrate the technical basis for anchor bolt stiffness values used in certain pipe support calculations at LaSalle. S&L was identified as the architect engineer who had design responsibility for the pipe supports with the identified concerns at LaSalle.

Prior to the Region III inspection activities at LaSalle, ComEd had already initiated actions to review and evaluate pipe support concerns identified at LaSalle that dealt with the modeling of several pipe support end connections as pinned versus the generally practiced conservative assumption of fixed end connections for supports with base plates and concrete expansion anchors (CEAs). ComEd contracted S&L to review the specific calculations of concern and also analyze additional supports from 64 randomly sampled piping subsystems. The sample population of pipe support calculations re-analyzed consisted of 79 supports.

On March 23, 1999, S&L issued report SL-5275, Revision 0, “LaSalle County Station Unit 1 & 2, Closure Report on Modeling of Anchorage Assemblies of Pipe Supports,” to ComEd. This report documented the results of S&L’s evaluation of previously identified LaSalle pipe support calculations and their further evaluation for extent of condition of an additional 79 pipe supports that had designs utilizing pinned end connections at the CEA or embedment plate. The report also included a technical discussion (including input from outside consultants) on the merits of modeling pipe support end connections as pinned or fixed. The report concluded that modeling the supports in question as pinned versus fixed in the original design basis calculations for LaSalle was reasonable, though not overly conservative and the design basis methodology used in the LaSalle design leads to generally acceptable design margins.

After NRC Region III issued the above referenced LaSalle inspection report on November 2, 1999, S&L initiated further actions to review and address the NRC concerns identified in the NCV. This included initiating Performance Improvement Process (PIP) No. 1999-0511, "Anchor Bolt Stiffness Value," dated November 9, 1999, to determine and review the generic aspects of pinned versus fixed modeling and the S&L development of anchor bolt stiffness values. S&L initiated another PIP on March 2, 2000, (PIP 2000-0200) to address new aspects of the LaSalle issue as documented in a February 8, 2000, Region III letter to ComEd. Ultimately, the S&L corrective actions included clarifying and revising internal Engineering Design Standards and on July 11, 2000, issuing Technical Alert TA2000-0013 on Concrete Expansion Anchor bolt Stiffness and Pipe Support Boundary Conditions. Finally, S&L contacted all their users of the APLAN computer program in July 2000 (including ComEd) by means of a Software Technical Alert Notification. This is further discussed in Section 3.2 b.3 of this report.

3.2 Sargent & Lundy Design Practices

a. Inspection Scope

The inspection team from NRR and Region III performed an inspection of S&L pipe support design practices. The inspection focused on modeling techniques of pipe supports anchored to concrete structures using concrete expansion anchors. As described above, the inspection was initiated as a result of a Region III inspection finding (NCV) that S&L might not have used proper bolt stiffness in the analyses of anchorages at the LaSalle Plant. The inspectors examined design records in support of the S&L's determination that its pipe support design approach at LaSalle is technically justified and did not result in installations with operability concerns.

b. Observations and Findings

During the inspection, S&L made presentations to the NRC inspectors regarding the acceptability of the methodology employed in the design of piping support anchorages at LaSalle. The inspectors examined design records made available by S&L and held discussions with S&L engineers and their consultant (Robert Kennedy) regarding several design related issues that are discussed below. S&L's design practices at issue and their justification for acceptance of existing anchorages are discussed below and in Sections 3.2 b.1 and 3.2 b.2 and the inspection team's evaluation of S&L's design approach and justification is discussed in Section 3.2 b.4 of this report. Section 3.2 also includes the team's conclusions regarding the design issue of concern.

S&L stated that its design standard for anchorages did not specify guidance on how a pipe support structural connection to the concrete should be modeled (i.e., a "pinned" or "fixed") for computer analysis. Therefore, the mathematical model for anchorages was left to the individual design engineer to decide. Boundary conditions are typically modeled as fixed or pinned connections. Semi-rigid boundary model is only used when a pin condition is not justified and a fixed condition is overly conservative for determining anchor bolt loads.

b.1 Sargent & Lundy's Justifications for the Assumption of Pin-connected Conditions

S&L cited some design sources that permit the application of pin 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 pin 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 text book's comments on certain types of steel connection that can be designed as pin conditions.

S&L presented analysis results of postulated design bolt displacements in five highly stressed anchorages that undergo significant postulated rotations of the anchorage locations that are equivalent to the assumption of pin conditions. The calculated values of bolt displacements are less than 0.05 inches when the anchorages were modeled as pin-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 pin condition with sufficient margin to failure, and used this justification for its use of a pin condition in the design phase of these anchorages.

b.2 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. The 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 governing cases at LaSalle, by increasing the value of the secant modulus ten fold. The analysis results indicate that factors of safety of 4 existed for bolts in two cases and factors of safety about 3 for the other two cases.

b.3 S&L Design Practices/Process Improvements

Sargent and Lundy 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 this basis, 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".

As part of the corrective actions identified in Technical Alert TA20000-0013, S&L Design Standards SDS E-11, "Structural Design Standard for Drilled-in Concrete Anchors" and SDS E-37, "Mechanical Component Auxiliary Support Steel Framing," and the APLAN

(Anchor Plate Analysis Program), Users Manual will be revised by May 30, 2001, to incorporate the recommendations and requirements of the Technical Alert on anchor bolt stiffness, fixed versus pinned boundary conditions, and use of the APLAN computer analysis program.

The inspectors also noted that S&L contacted all their users of the APLAN program in July 2000 (including ComEd) by means of a Software Technical Alert Notification. This letter included a copy of the Technical Alert TA20000-0013 and explained that the TA provides guidance for the use of the APLAN program in certain situations.

During the inspection, S&L committed to update Report SL-5275, Revision 2, "LaSalle County Station Unit 1 & 2, Closure Report on Modeling of Anchorage Assemblies of Pipe Supports," to include additional information on concrete expansion anchor stiffness and pipe support design process improvements. Revision 3 to SL-5275, re-titled "Modeling of Anchorage Assemblies of Pipe Supports," was issued with a date of September 2000. This update included a new Section 6 on Pipe Support Design Process Improvements and a revised Section 7, Conclusions, that included more detail on technical information derived from the various evaluations performed to address the fixed versus hinged modeling of anchorage assemblies for S&L designed pipe supports.

b.4 NRC Inspection Team Evaluation

In general, the inspectors did not identify any significant concerns with S&L's justification of the design adequacy of pipe support anchorages at LaSalle. The team also agrees with the Technical Alert as stated above except that the stiffness value of 250 k/in. needs to be justified based on anchorage test results. The major weakness in the S&L's semi-rigid analysis methodology is that the mathematical model does not include 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 S&L'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 bolt installation.

In its document for "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 requires 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 a long time of service. 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 inconsequential increase of bolt loads and reduction of estimated design factors of safety.

The analysis results provided by the S&L, which indicate that the five highly stressed anchorages for pipe supports will not fail before the anchorages rotate into pin 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 involve multi-bolts and is expected to function in cracked concrete during earthquakes. The spacing effect of multi-bolts and the effect of concrete cracking 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 three 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 well in excess of two, 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.”

c. Conclusion

The analysis results performed by S&L for the LaSalle pipe supports provide adequate assurance that the assumptions used for modeling of pipe support anchorages are generally reasonable, though not overly conservative. Reevaluation of the most governing pipe support anchorages indicated that they possess a minimum factor of safety about three, which is well in excess of the operability criteria of two.

The team concludes that the revision to the anchorage design process standards identified in S&L’s Technical Alert TA2000-0013 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”.

3.3 Potential Generic Implications

a. Inspection Scope

The inspectors reviewed the S&L actions taken to evaluate and address the extent of the technical pipe support concerns that were first identified by LaSalle and further expanded upon by the NRC during the NRC Region III inspection, as documented in the November 2, 1999, NRC Inspection Report 50-373 &374/99020. These review actions were taken to evaluate the extent of the condition for potential reportability to the NRC and other customers under 10 CFR Part 21. The inspectors reviewed S&L Standard Operating Procedure (SOP) 1401, "Performance Improvement Process," Revision 3, dated November 19, 1999, and SOP-1405, "10 CFR 21 Defects, Noncompliances, and Reportable Conditions," Revision 1B, dated September 1, 2000. These procedures identify the requirements for identifying, addressing and evaluating, among other things, quality problems and errors or deficiencies in S&L deliverables.

b. Observations and Findings

S&L stated that six different PIPs had been initiated to address the various pipe support concerns. The inspectors reviewed the two most recent PIPs and the identified corrective actions and process improvements to address the LaSalle/ComEd and NRC pipe support concerns.

As stated earlier in Section 3.1, S&L initiated PIP No. 1999-0511, "Anchor Bolt Stiffness Value," dated November 9, 1999, to determine and review the generic aspects of pinned versus fixed modeling and the S&L development of anchor bolt stiffness values. S&L initiated an additional PIP on March 2, 2000, (PIP 2000-0200) to address new aspects of the LaSalle issue as documented in a February 8, 2000, Region III letter to ComEd. Ultimately, the S&L actions included clarifying and revising internal Engineering Standards, and on July 11, 2000, issuing Technical Alert TA2000-0013 on Concrete Expansion Anchor Bolt Stiffness and Pipe Support Boundary Conditions.

The inspectors also reviewed documentation that showed that a S&L Discipline Engineering Manager had conducted several group meetings with staff in July 2000 to identify historical information on pipe support design philosophy for modeling end connections as pinned versus fixed and how to identify anchor bolt stiffness values.

Based on the above described extent of condition evaluations, S&L stated that the design approach was correct and design margins had not been reduced by this approach. S&L concluded that the types of anchorages designed for pipe supports at LaSalle are similar to those designed at other plants. This was concluded since the same design philosophy, similar support configuration, the same design standards, and similar supervisory guidance were used at all plants designed by the S&L. Therefore, the studies performed for LaSalle are also applicable to other S&L designed plants.

c. Conclusion

The team agrees with S&L's conclusion that the structural adequacy of pipe support installations at LaSalle and other S&L designed plants are acceptable. S&L's conclusion was based on comparisons of pipe support configurations at other plants that utilized the same design philosophy for pinned versus fixed, the use of the same design standards that contained similar methodologies and general consistency in supervisory guidance.

4.0 LIST OF PERSONS CONTACTED

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