OCT 2 2 1985

Docket Nos. 50-373/374

Mr. Dennis L. Farrar
Director of Licensing
Commonwealth Edison Company
P.O. Box 765
Chicago, Illinois 60690

Dear Mr. Farrar:

SUBJECT: LA SALLE COUNTY STATION DESIGN OF SINGLE ANGLE MEMBERS

As a result of a meeting held on February 5, 1985, followed by a telecon on February 11, 1985, and a report you submitted, at our request, on your procedures used for calculating the combined stresses on single angle members, the staff has reviewed the available material. We have consulted with the AISC and other experts in this area. The staff's evaluation and preliminary conclusions are contained in Enclosure 1. As a result, the staff is requesting additional justification and will require this information for acceptance of your design methodology. In addition, Enclosure 2 contains some correspondence between ourselves and the other experts.

If there are any questions concerning this information, please contact Anthony Bournia, Project Manager, (301) 492-8535.

Sincerely,

Walter R. Butler, Chief
Licensing Branch No. 2
Division of Licensing

Enclosures:
As stated

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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Mr. Dennis L. Farrar
Commonwealth Edison Company

La Salle County Nuclear Power Station
Units 1 & 2

cc:
Philip P. Steptoe, Esquire
Suite 4200
One First National Plaza
Chicago, Illinois 60603

John W. McCaffrey
Chief, Public Utilities Division
160 North La Salle Street, Room 900
Chicago, Illinois 60601

Assistant Attorney General
188 West Randolph Street
Suite 2315
Chicago, Illinois 60601

Resident Inspector/LaSalle, NPS
U.S. Nuclear Regulatory Commission
Rural Route No. 1
Post Office Box 224
Marseilles, Illinois 61341

Chairman
La Salle County Board of Supervisors
La Salle County Courthouse
Ottawa, Illinois 61350

Attorney General
500 South 2nd Street
Springfield, Illinois 62701

Chairman
Illinois Commerce Commission
Leland Building
527 East Capitol Avenue
Springfield, Illinois 62706

Mr. Gary N. Wright, Manager
Nuclear Facility Safety
Illinois Department of Nuclear Safety
1035 Outer Park Drive, 5th Floor
Springfield, Illinois 62704

Regional Administrator, Region III
U. S. Nuclear Regulatory Commission
799 Rossevelt Road
Glen Ellyn, Illinois 60137

ENCLOSURE 1

STAFF EVALUATION REPORT
ON
LASALLE SINGLE ANGLE MEMBER DESIGN

Background

At the request of the licensee for LaSalle County Station and its architect/engineer firm, Sargeant and Lundy (S&L), the staff met with their representatives on February 5, 1985 to discuss a concern raised by the Region III staff with regard to S&L design practice on unbraced length and slenderness ratio at LaSalle. In order to perform a detailed review of these problems, the staff requested in a subsequent telecon that sample calculations be provided for review. Calculations No. 8.20.0-10 Rev. 0, 2-22-85 was provided to and reviewed by the staff. This report summarizes the results of the staff's review of these calculations.

The licensee in its presentation indicated that the issue of slenderness ratio and unbraced length was brought forth in the Byron review by an alleger who indicated that the computer code used to design structural hangers for the HVAC systems and cable trays by S&L was not meeting the AISC Code specification. The purpose of the meeting was to present the licensee's case in order to show that, in fact, the structure analyses for LaSalle was within the bounds of the code. With respect to unbraced length, S&L indicated that the AISC Specification was not applicable to the design of single angles in bending and that as a result some Australian research that was performed on single angles in bending was used to confirm its analysis to be conservative. S&L indicated that with a length to thickness ratio up to 900, the S&L methodology was conservative with respect to the Australian date. Because their designs did not exceed this maximum length to thickness ratio, S&L stated that the analyses was conservative.

With respect to the slenderness ratio (kl/r), S&L design used a ratio limit of 300 for members in tension and a 200 ratio limit in compression. In Section 1.8.4 of the AISC Specification, 1978 edition, states in part that:

> "The slenderness ratio, Kl/r, of compression member shall not exceed 200."

S&L stated that the 200 limitation specified by AISC was not for any structural safety nor theoretical consideration but only related to economy and practicality of handling and fabrication. A nonlinear dynamic analysis was performed by S&L using a slenderness ratio of 282. One of the conclusions from the analysis was that the dynamic behavior of a hanger was unaffected by the slenderness ratio.

DISCUSSION

On February 5, 1985, S&L presented, at a meeting held in Bethesda, the technical background for their request to exceed the staff maximum unbraced length criterion for single angles subject to bending, based on the Australian work on the subject. At this meeting the staff agreed that this length criterion may be extended from the current value, 270, to a limit of 900 with a corresponding reduction in stress allowable. This decision was based on our understanding of the S&L presentation of a method of combining stresses in their computer program used for designing these duct hangers, which they claimed to be "conservative" with respect to the Australian methodology. The staff also indicated at this meeting we did not agree with the Australian method for specifying allowable stresses for beams in bending.

On further review of the material presented by S&L at this meeting it became apparent that the procedure used by S&L for calculating the combined stresses and the allowable stresses for these angle members needed additional clarification. Therefore, in a telecon held on February 11, 1985 with S&L, the staff requested S&L to submit a report showing in detail the procedure used for calculating the stresses in these members, the method for combining axial loading with biaxial bending, and the corresponding allowable stresses. Other concerns which were raised in this telecon included the effects of member self weight and connection rigidity on the design of the long longitudinal braces. This report was submitted as a response to our request.

S&L analyzed a HVAC duct frame hanger, and stress checked the two highest loaded members by the S&L procedure and by a procedure based on the Australian Standard "Use of Steel in Structures" AS 1250-1981. This standard has stress combination rules similar to those in the AISC Manual, and a procedure for prescribing strong axis allowable bending stresses for arbitrary shaped beams. The objective of this analysis was to show that the S&L approach is conservative, as compared to the Australian approach, for angle members exceeding the length to thickness (L/T) criterion of 270. This value was accepted by the staff as the unbraced length criterion for angle members with a corresponding allowable major principal bending stress of .60 Fy. For values of L/T > 270, the staff believes that the allowable bending stress must be decreased, to prevent lateral/torsional buckling. The AISC Manual has no bending criteria for long angle members. For short unbraced members the bending allowable of .60 Fy is applicable, for bending about both principal axes, but the maximum unbraced length for which this is valid is undefined (AISC Section 1.5.1.4.5 (2)b) and not applicable to angle members (Ref. 8).

The S&L stress method has the following features:

a. Uses geometric axes.
b. Stresses are calculated based on minimum section modules.
c. Uses .60Fy as the basic bending allowable for both geometric axes, for all L/T ratios.
d. The stresses are combined according to interaction equations specified in the AISC Manual of Steel Construction, Ref. 1, Sections 1.6.1 and 1.6.2.

The Australian stress check method has the following features:

a. Uses principal axes.
b. Stresses are based on principal section modulus.
c. Uses .66Fy as the bending allowable for bending about the minor or weak principal axis.
d. Uses a certain procedure for calculating compressive bending stress allowables for bending about the major, or strong, principal axis for long unbraced members, Refs. 2 and 6. This procedure is not currently used in the U.S., is not contained in any American code, nor has it been accepted by the NRC or the AISC.
e. Stresses are combined according to interaction equations specified in Section 8 of the Australian Standard, Ref. 2. These equations are similar to those in the AISC Manual, Ref. 1, and in Refs. 3, 4, 6 and 7.

The members selected by S&L to show the stress comparison were:

(a) The vertical member between nodes 2 and 4, of size 2x2x1/4, L/T = 96, with rigid end connections.

(b) The brace member between nodes 4 and 10, of size 3x3x1/4, L/T = 594, with pinned end connections.

The loads acting on these members were obtained from the frame analysis described above. For both members the compressive loads were such that the ratio $fa/Fa \leq .15$, such that AISC equation 1.6-2 was applicable.

S&L calculated the interaction ratio for both members according to the S&L procedure and the Australian procedure. For the shorter member S&L specified the bending allowables .60Fy (for S&L) and .66Fy (for the Australian procedure). However, since the analysis was done for accident conditions, the allowables in both cases were increased by 60% per SRP, but not to exceed .95 Fy for the Australian allowable. Therefore, the bending allowables were almost the same in both cases, the only difference being whether the analysis was performed in the geometric axes or the principal axes.

The results of the S&L calculations show that the Australian interaction ratio exceeds the S&L interaction ratio by 3% in compression, and in tension. The staff has verified these calculations independently. However, it appears that S&L has misinterpreted the manner in which the interaction equations are to be applied and that under certain conditions the S&L procedure can under-estimate the actual interaction ratio by a considerable amount, in the order of 30%. (The application of these equations was also discussed with Prof. T. Galambos, Refs. 9 and 11, Prof. P. C. Wang, Ref. 10 and Dr. G. Haajer, Ref. 12). Based on this independent verification of the 2 x 2 x 1/4 member we conclude that the approach by S&L can be conservative, or highly unconservative, depending on the magnitude and direction of the applied moments.

Conclusion

Based on our review, the staff has reached the following conclusions:

1. The general approach used by S&L for combining stresses in a stress check may be conservative, or highly unconservative, depending on the condition as compared to the approach specified in the AISC Manual or the Australian Standard.

2. S&L appears to have misinterpreted the application of the AISC and Australian Standard combined stress interaction equations. S&L's calculations should be reviewed for conformance to the correct interpretation.

3. S&L specifies the maximum bending allowable stress regardless of member length, because of the claimed conservatism for the S&L approach. This conservatism is based on the calculation of a quantity called "effective major principal axis allowable." The basis of this quantity and its calculation needs additional justification.

4. In the application of the Australian stress check approach S&L specified .66Fy as the maximum bending allowable. The AISC Manual does not permit this; it specifies .60Fy as the maximum bending allowable. S&L should check their calculations using .60 Fy as the limiting stress.

5. For short and intermediate beam-columns the Australian approach for determining allowable strong-axis bending stresses will produce allowables which exceed the critical buckling stresses, when the factor 1.6 specified in the SRP is applied under accident conditions. The actual factor of safety cannot be determined since the Australian approach is not based on determining critical stresses. However, even for short members, the accident allowable 1.6 x .6 x Fy will exceed the critical stress (determined independently). S&L should check their calculations to determine if any members have loads that exceed the critical buckling load.

6. In the stress check of the short angle member attached to the duct, S&L claims credit for the restraint of the duct sheet metal. The amount of restraint is questionable and should not be considered. The calculations should be revised and field modification should be made if necessary.

7. In the stress check of the long angle member by the Australian approach a factor C = 1.1 was used. This member was considered with pinned boundary conditions in the analysis. The AISC manual specifies that C = 1.0 when the bending moment at any point within an unbraced length is larger than at both ends of this length. S&L will be required to conform with this specification.

The staff recommends that the program SEISHANG be reviewed in regard to the following concerns:

1. Verification that closely spaced modes are combined in accordance with R.G. 1.92.

2. Verfication that member global stiffness matrices include the transformation from local principal axes to global axes, including the eccentricity effects due to end shear and axial forces (C.G. to shear center torques).

3. Verification that shear stresses due to torsion, and warping effects in WF and channel beams are evaluated.

4. Verification of the program.

References

1. AISC Manual of Steel Construction, 8th Edition, Chicago, 1980.

2. Australian Standard Rules "Use of Steel in Structures" AS 1250-1975.

3. Salmon, C. G. and Johnson, J. E. "Steel Structures, Design and Behavior," 2nd Edition, Harper and Row, 1980.

4. Johnston, B. G., Lin, F. J., and Galambos T.V., "Basic Steel Design," 2nd Edition, Prentice Hall, 1980.

5. Leigh, J. M. and Lay, M.G., "The Design of Laterally Unsupported Angles," in "AISC Notes on Steel Design Current Practice." January 1984.

6. Chen, W. F., and Atsuta, T. "Theory of Beam-Columns," Vol. 2, McGraw-Hill, 1977.

7. Lambert, Tall, Ed., "Structural Steel Design," 2nd Ed., Ronald, 1974.

8. Letter from Prof. T.V. Galambos, University of Minnesota, February 27, 1985.

9. Telecommunication with Prof. T. V. Galambos, April 18, 1985.

10. Telecommunication with Prof. P.C. Wang, @ BNL, April 19, 1985.

11. Letter from Prof. T. V. Galambos, University of Minnesota, June 14, 1985.

12. Letter from Geerhard Haaijer, AISC, June 25, 1985.

ENCLOSURE 2