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SCREENING CRITERIA FOR THE VERIFICATION OF SEISMIC ADEQUACY OF PIPING SYSTEMS (U)

by

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ABSTRACT

This paper describes practical screening criteria to be used by engineering walkdown teams, for the evaluation of seismic adequacy of piping systems. The application of the screening criteria to a nuclear facility are described and compared to the results achieved using conventional analytical techniques.

INTRODUCTION

The large body of knowledge accumulated in the 1980's on the behavior of piping systems subject to actual or simulated earthquakes is generating renewed interest in the improvement of seismic criteria for piping systems. Important criteria changes are being considered by the ASME Code Committee [1,2] and EPRI [3], aimed at improving the Code Seismic Qualification requirements for piping systems. A parallel effort has been suggested [4,5] to develop guidelines and rules, based on experience data, for the verification of seismic adequacy of piping systems.

This paper defines screening criteria for the evaluation of the seismic adequacy of existing piping systems. The screening guidelines described here have recently been applied to a nuclear facility. The screening effort was then followed by confirmatory analyses of the piping systems. The results of this application are discussed at the end of the paper.

BASIS FOR SCREENING CRITERIA

The screening criteria are based on a large body of analytical, experimental and field knowledge on the behavior of above ground steel piping systems subject to seismic loading. This knowledge can be grouped into four categories:

(1) The extensive application, throughout the 1970's and 1980's, of analytical requirements contained in the industry codes and standards (ASME III, ANSI B31, AISC)

(2) Industry practice with nuclear regulations for seismic evaluation of piping systems (Standard Review Plan, Regulatory Guides, IE Bulletins)

(3) Test data on piping fittings and piping systems subject to seismic excitation [3,6,7]

(4) Earthquake experience data on piping systems gathered from a number of facilities and sites following large earthquakes [5]

The screening guidelines are to be implemented in two phases:

(1) A visual walkdown of the piping system by a team of experienced piping engineers to identify features that could result in the "failure" of the piping system, and

(2) A quantitative assessment of the structural capacity of critical features of the piping system

PREREQUISITES AND LIMITATIONS

- The expertise of the engineering review team must include knowledge of: a) dynamic analysis of piping, b) pipe supports, c) equipment qualification, d) test, and e) earthquake experience data applicable to piping systems.
- The system performance requirements must be clearly understood so as to define "failure" modes. Failure is defined with respect to the system performance requirements (i.e., component operability, pressure boundary, spatial interaction, flooding, jet, pipe whip, etc.). For example, where component operability is a requirement (such as for active pumps,valves, instruments), a different level of review is needed than where concern is limited to pressure boundary integrity (no leaks, breaks, jets or flooding) or structural integrity (no spatial interactions on adjacent equipment or structures).
- The piping systems under consideration must be properly designed for thermal expansion and operating and abnormal loads other than seismic. The systems must have had a good operational record under fluid pressure and thermal transients.
- The engineering guidelines apply to facilities for which the expected seismic excitation is not very large, with peak floor spectral horizontal accelerations not expected to exceed approximately 1.5g at 5% damping.

- Features which cannot be visually inspected (limitation in access, insulation, anchorage details) must be evaluated on the basis of confirmed drawings and specifications.

- Our knowledge of the extent and type of piping erosion or corrosion which constitutes a seismic concern is still evolving [7,8] and should therefore be addressed thoroughly. While the walkdown covers external signs of corrosion, it is essential to separately investigate the condition of erosion and corrosion inside the pipe. This investigation should involve a combination of: (a) system evaluations (flow rates, cavitation , etc.) to identify the most probable locations for potential erosion/corrosion, (b) metallurgical evaluations (fluid and metal chemistry, temperature, etc.) to evaluate the susceptibility to corrosion, and (c) performance records from inservice inspections.

- An important aspect of seismic adequacy is the seismic performance of piping components and equipment (valves, pumps, tanks, etc). Screening criteria for the components have been developed for the Seismic Qualification Utilities Group [13], and should be considered in the piping evaluation process.

ENGINEERING EVALUATION WALKDOWN

The engineering review team evaluates the following attributes during the walkdown. The attributes are not all-inclusive and the review team members should use experience and judgement to report additional questionable conditions. The evaluation is divided into piping system and pipe supports, for simplicity.

Piping System Review

- Visible damage such as signs of wear, dents or permanent deformation. Missing, broken or loose bolts on flanges or components, etc.

- Signs of excessive rust or corrosion

- Brittle connections, such as threaded or friction joints and cast iron fittings, particularly where large reaction forces are expected to occur

- Nonstandard fittings that could have large stress indices, and therefore locally intensify the stresses resulting from an earthquake

- Deadweight supports unevenly or overly spaced, and not able to accommodate the eventual seismic lateral swing of the pipe, with some yielding but without rupture

- Insufficient lateral supports or guides (lateral stops allowing a few inches of lateral movement) to limit the lateral swing of the pipe, particularly close to equipment sensitive to nozzle loads [9]

- Overly stiff piping, which may be unable to accommodate the differential motion of buildings, structures, equipment and header pipes

- Heavy unsupported valve operators [3]. Conversely, the eccentric masses from valves should not be supported independently from the valve body or the pipe

- Long, unsupported cantilevered vents or drains, particularly when socket welded to the header pipe

- Flexible joints that are sensitive to differential movements (such as expansion joints and bellows), must be analyzed quantitatively

- Equipment must be properly anchored to the floor to preclude large reaction loads on the pipe due to equipment rocking, tipping, or sliding.

- Spatial interactions from falling objects (including impact and spray)from adjacent structures and components that are not seismically fastened or anchored

- Spatial interactions resulting form the eventual sway of the piping, and the resulting impact of pipe components on adjacent structures. This concern applies to piping components that are sensitive to impact (such as certain valves and instrument taps)

Pipe Supports Review

- General condition of the support: no damaged, loose, or improperly installed components (bolt/nut minimum thread engagement, slotted holes without washer, base plate/concrete configurations with excessive gap, etc.)

- Sufficient width of the support surface to prevent the pipe from falling off the support, should sliding occur.

- Adequate anchorage capacity for ceiling or wall mounted supports, to avoid pull out of anchors under seismic inertia loads. This same capacity may not be required for seismic anchor motion loads when it is preferable for the support to fail instead of imparting excessive reaction loads on the pipe or equipment.

- The evaluation of anchorage capacity includes the assessment of edge distances, type of anchor, capacity and condition (no cracks) of the concrete. Where in doubt, a quantitative evaluation will be required

- Sound quality and sufficient area for welds and welded attachments between the pipe and the pipe support

- Where supporting rods are threaded to walls, the swing angle of the rod should be limited, to avoid fatigue failure at the wall connection

QUANTITATIVE ASSESSMENT OF SEISMIC CAPACITY

Having used the screening guidelines above, the engineering review team may identify conditions that require further evaluation. This is particularly true for anchorage on certain critical pipe supports.

To this end, the engineering review team should first resort to simple estimates of the seismic loading using standard span charts or static load coefficients [10, 11]. In the quantitative assessment process, it is important to focus the engineering resources to real failure modes potentials. In most practical cases, yielding of steel supports under large seismic loads will not result in "failure" of the piping system, and therefore does not warrant exhaustive analysis. The quantitative assessment should therefore be mostly limited to potentially nonductile components that have proven, in test or earthquake experience, to be prone to rupture.

APPLICATION OF THE SCREENING CRITERIA

The screening criteria described above were recently applied to the seismic evaluation of 87 safety related piping systems in an older nuclear plant located in the eastern part of the United States. These screening criteria were implemented by teams of experienced seismic engineers, who had also been trained on the utilization of experience data (both actual earthquake data and test data). This more realistic approach proved to be most efficient when compared with the standard analytical review of all piping systems. The results of this study are summarized in Figure 1.

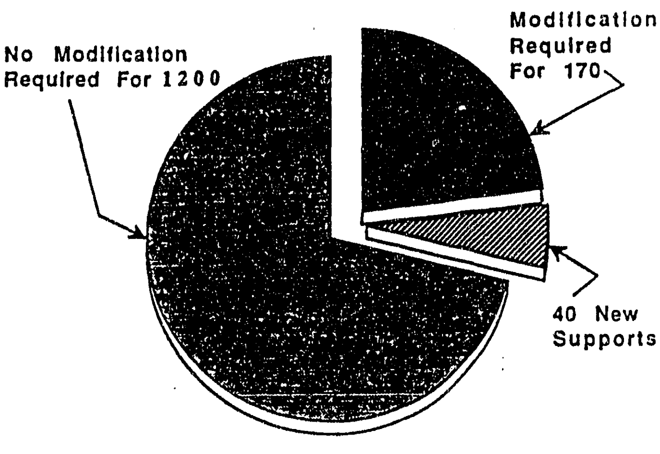

Figure 1. Summary of Support Modifications Resulting from the Application of the Screening Criteria to Piping Systems in a Nuclear Facility Designed in the 1950's.

Of 1200 pipe supports evaluated using the screening criteria, 170 required design upgrades and 40 new supports were installed.

The same piping systems were then analyzed (using a combination of static and response spectra modal analysis methods [12]). The acceptance criteria for this confirmatory analysis were similar to current ASME and AISC code criteria for faulted loading. The analysis identified only 20 additional support fixes out of a total of 1200 supports. No attempt was made at eliminating some of the original 170 modifications or 40 new supports introduced to satisfy the walkdown screening criteria. The fixes identified by analysis were mostly due to: (a) predictions of overstress (exceedance of code allowable) in unreinforced branch connections, and (b) exceedance of safety margins on expansion anchors. These analytical limitations could have been resolved by a better estimate of stress intensification factors and actual anchorage capacity. For the purpose of expediency it was decided however to implement the 20 pipe support fixes.

The results of this application indicate the significant value and potential of the experience-based screening criteria methodology.

CONCLUSION

The extensive knowledge on the behavior of above-ground, welded steel piping systems points to the possibility of verifying their seismic adequacy by experience-based screening criteria, supplemented by a limited quantitative assessment of critical features.

This paper introduces the type of screening criteria that can be used, particularly for facilities in regions of low seismicity.

The application of the method to an older nuclear facility, and its comparison to the stress analysis results, indicates the significant potential of the screening criteria approach.

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REFERENCES

1. ASME Section III Code Case N-451. "Alternative rules for Analysis of Piping Under Seismic Loading, Class 1".
2. ASME Section III Code Case N-462. "Alternative rules for Analysis of Piping Products Under Seismic Loading, Class 2 and 3 Piping Systems".
3. D.J. Guzy. "Piping and Fitting Dynamic Reliability Program", Proceedings of the 14th Water Reactor Safety Information Meeting, Washington D. C., December 1986.
4. J.D. Stevenson et. al. "Report of the U.S. Nuclear Regulatory Commission Piping Review Committee, Summary and Evaluation of Historical Strong-Motion Earthquake Seismic Response and Damage to Above Ground Industrial Piping" NUREG-1061 Volume 2, Addendum, U.S. Nuclear Regulatory Commission, April 1985.
5. P.I. Yanev et.al. "Piping Seismic Adequacy Criteria Recommendations Bases on Performance During and After Earthquakes" EPRI Research Project RP-2635-1, 1987.
6. L.K. Severud et.al. "High-Level Seismic Response and Failure Prediction Methods for Piping" NUREG/CR-5023, 1988.
7. K.L. Merz and Y.K. Tang "Dynamic Testing of Eroded/Corroded Piping Components" ASME PVP Conference, Nashville, TN, 1990.
8. ASME Section XI Code Case N-480 "Examination Requirements for Pipe Wall Thinning Due to Single Phase Erosion and Corrosion", 1990.
9. J.D. Stevenson and Associates, EQE Engineering "Procedure for Seismic Evaluation and Design of Small Bore Piping (NCIG-14)" EPRI-NP-6628, Electric Power Research Institute, April 1990.
10. ASME Section III Code Case N-468 "Alternate Method of Earthquake Description for Class 2 and 3 Piping at Low Seismicity Sites", 1989.
11. Uniform Building Code (CA), Part V "Engineering Regulations-Quality and Design of Materials of Construction" Chapter 23, 1988 Edition.
12. G. Antaki, "Application of the Load Coefficient Method of ASME Code Case N-468" ASME Pressure Vessel and Piping Conference, June 1991.
13. Seismic Qualification Utilities Group, Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment, September 1990, Revision 2.

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