Proceedings of the American Power Conference, Chicago, IL, Apr. 13-15, 1992. Chicago, IL: Illinois Institute of Technology, 1992.

THE EVOLUTION OF THE SEISMIC QUALIFICATION UTILITY GROUP METHODOLOGY FOR ASSESSING SEISMIC ADEQUACY OF NUCLEAR PLANT EQUIPMENT

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BACKGROUND

In 1980, the NRC established Unresolved Safety Issue (USI) A-46, Seismic Qualification of Equipment in Operating Nuclear Power Plants(1), to evaluate the seismic adequacy of equipment in plants which were designed prior to the development of current seismic qualification criteria. In 1982 a group of about 15 utilities, recognizing that conventional seismic testing and analysis would not be practical for these existing plants, formed the Seismic Qualification Utility Group (SQUG). SQUG took the lead in developing a cost-effective method of resolution of USI A-46 based on the performance of equipment in actual earthquakes. SQUG sponsored an evaluation of earthquake experience data for eight classes of equipment in non-nuclear facilities. The evaluation(2), concurred with by the independent expert judgement of the Senior Seismic Review and Advisory Panel (SSRAP), showed that adequately anchored equipment in these classes are inherently rugged under seismic ground motions less than "bounding spectra" having peak ground accelerations of up to about 0.3g. It also demonstrated the feasibility of applying earthquake experience data to verify the seismic ruggedness of certain classes of equipment used in both conventional and nuclear power plants. The SQUG approach has since been extended to cover a total of twenty-one generic classes of equipment (including cable trays and conduit) needed to shut down a nuclear power plant.

The USNRC accepted the SQUG approach and defined implementation requirements in 1987.(3) SQUG, with EPRI support, has since developed additional data and evaluation criteria, implementation procedures and training programs to apply the SQUG methodology to resolve USI A-46. This paper describes the evolution of this work.

DEVELOPMENT OF APPLICATION GUIDELINES

The primary element of the SQUG methodology is the experience data base. The experience data base, developed by EQE, Inc. (4), covers 20 classes of equipment found in conventional and nuclear power plants. It describes the performance of equipment in past earthquakes and defines (1) the level of shaking under which the equipment has performed satisfactorily, (2) any specific seismic vulnerabilities observed, (3) limitations, or caveats, on the use of the experience data, and (4) guidance on what equipment types and parameters are covered by the data base.

It was recognized by SQUG that additional guidance would be needed to apply the experience data in nuclear plant equipment reviews. The additional guidance involves supplemental data needs and criteria for evaluation of technical areas not covered explicitly in the experience data, as well as documentation and personnel qualification requirements. Accordingly, SQUG and EPRI developed additional data and assessment criteria in the following areas:

Generic Equipment Ruggedness Spectra (GERS)

Early in the program development it was recognized that substantial information on the performance of equipment under earthquake conditions exists in the form of shake table test data accumulated since the early 1970s on many classes of nuclear plant equipment. Accordingly, this test experience data was assimilated in a form that could be used in a generic sense, similar to actual earthquake experience. This effort was undertaken by EPRI through ANCO Engineers. The products of the program are Generic Equipment Ruggedness Spectra, or GERS.(5) GERS have been developed for a wide variety of mechanical and electrical equipment such as pumps, valves, motor-control centers, switchgear, control panels, instrument racks, and relays. The GERS are used in the SQUG seismic review process in much the same manner as equipment-specific seismic qualification data.

Safe Shutdown Equipment List (SSEL)

Procedures have been developed to assist utilities in selecting appropriate safe shutdown systems in accordance with the requirements of NRC Generic Letter 87-02 and in identifying the specific components and support systems for which seismic verification is required under USI A-46. The procedures, developed by MPR Associates, provide a systematic method for selection of safe shutdown functions, systems and equipment, and for identifying those equipments which are required to function during the earthquake, as opposed to those components which are required to operate only after the earthquake.

Anchorage Criteria

An early finding of the surveys of earthquake damage in power plants and industrial facilities was that proper anchorage of equipment is the single most important feature in ensuring seismic functionality of equipment. To address this important finding, action was initiated to develop clear and practical criteria and guidelines for evaluating installed equipment anchorages likely to be found in operating nuclear plants. This project was undertaken by EPRI through URS/J. A. Blume & Associates and has resulted in agreed-upon methods and acceptance criteria for evaluation of a wide variety of anchorage types, including weldments, expansion anchors and cast-in-place bolts.(6)

Criteria for Tank and Heat Exchanger Evaluation

Guidelines and criteria for seismic evaluation of tanks and heat exchangers required for safe shutdown have been developed by EPRI and URS/Blume.(7) These guidelines provide simplified analytical methods and acceptance criteria for the evaluation of tank and heat exchanger anchorage and for the evaluation of the buckling resistance of cylindrical, floor-mounted storage tanks.

Cable Tray and Conduit Evaluation Criteria

During the development of the SQUG methodology, it was noted by SQUG investigators that: (i) the data base plants surveyed by SQUG contained literally miles of cable tray and conduit typical of (and generally less well-engineered than) those in operating nuclear plants, and (ii) there were virtually no earthquake-induced failures in the cable tray/conduit systems. Because seismic adequacy of cable trays and conduit was a subject under evaluation by the NRC and several utilities, SQUG and the NRC mutually agreed to add cable tray and conduit systems to the scope of USI A-46 as the most cost-effective approach to evaluate the seismic adequacy of these systems. As a result of this decision, SQUG, through its contractor, EQE, Inc., and the Senior Seismic Review and Advisory Panel, have developed criteria for applying the large amount of successful earthquake experience on cable tray and conduit systems to the seismic evaluation of nuclear plant systems.(8)(9)

Relay Screening and Evaluation Criteria

The systems required to shut down nuclear plants include numerous electrical relays, the chatter of which could conceivably cause equipment malfunction during an earthquake. One of the important findings of early surveys of power plants which had experienced strong motion earthquakes was the apparent absence of widespread electrical relay malfunctions leading to system unavailability, control room alarms and operator confusion. However, there were several instances in which relays chattered during the earthquakes, and some caused trips of isolated systems and/or equipment. Further, it was difficult, after the fact, to identify those relays which malfunctioned and those which did not.

Faced with these findings, it was concluded that a different approach was required for the evaluation of seismic functionality of important electrical relays and similar contactors and switches. A project was undertaken in 1986 by EPRI through MPR Associates to develop such an approach. The methodology which was developed(10) consists of a two-part screening process involving: (1) system and electrical circuit analyses which identify those relays (and other contactors) whose function is essential during and immediately after an earthquake, and (2) evaluation of the seismic ruggedness of only these essential relays using relay ruggedness data (e.g., GERS), together with guidelines to estimate the seismic demand at specific relay locations.

The benefit of these screening procedures is that only a small fraction of electrical relays in nuclear plants are required to be seismically verified.

THE GENERIC IMPLEMENTATION PROCEDURES (GIP)

The various elements of the SQUG approach have been consolidated in the primary implementation vehicle for the program, the Generic Implementation Procedure, or GIP.[11] The GIP provides the following:

- An overview of the SQUG program and its governing requirements
- The procedure for identification of safe shutdown equipment
- Qualification and training requirements for seismic review personnel
- Requirements for performing the seismic review and walkdown of all classes of equipment
- Requirements and options for resolution of outliers
- Documentation requirements

In addition, the GIP includes sections which provide summaries of important evaluation methodologies such as anchorage evaluation, cable tray and conduit evaluation, tank and heat exchanger evaluation, as well as non-mandatory appendices which cover useful information on the logistics of the seismic review and walkdown. The GIP was jointly developed by Winston & Strawn; EQE, Inc.; Stevenson and Associates; URS/J.A. Blume and Associates; and MPR Associates, Inc. under the guidance of the SQUG Steering Group.

The NRC staff has accepted the methodology embodied in the GIP in NRC generic safety evaluations.[12]

SEISMIC EXPERIENCE DATA BASE

As part of the codification of the SQUG methodology for use by nuclear utilities, EPRI and its contractor, EQE, Inc., are currently developing a searchable electronic data base which will embody the seismic experience data gathered by SQUG, EPRI and EQE. This data base will be available to SQUG utilities to assist in the future use of the SQUG methodology.

TRAINING PROGRAM DEVELOPMENT

Inasmuch as the SQUG program emphasizes the use of engineering judgment in the application of prior earthquake experience data, a comprehensive training program covering the SQUG background, experience data base and methodology is essential to proper application of the approach. To meet this need, SQUG and its contractors have developed a training program for experienced utility engineers which is intended to provide the necessary background and insights to properly apply the SQUG methodology and data for resolution of USI A-46. In addition, because much of the SQUG methodology is utilized in the Seismic Margin Assessment (SMA) approach developed by EPRI for the Individual Plant Examination of External Events (IPEEE)[13], EPRI and SQUG training contractors, in concert with the Nuclear Management and Resources Council (NUMARC), are developing additional training program segments to cover the seismic review scope and approach to be used for the IPEEE. These "add-on" training segments will be available to all domestic nuclear utilities. Conduct of this training started in 1989 and is expected to continue throughout and beyond SQUG utility implementation of USI A-46.

APPLICATION OF THE SQUG METHODOLOGY

USI A-46

The SQUG methodology is scheduled to be implemented in over sixty operating nuclear units in the United States, and in several SQUG member nuclear facilities in Belgium, Spain and Great Britain, to verify the capability of these plants to safely shut down during and after a design basis earthquake. The implementation of the review process is planned to take place for most of these plants over a three-year period starting in approximately mid-to-late 1992. The reviews and plant walkdowns will be followed by comprehensive reports to the USNRC, in the case of the domestic nuclear facilities, which will provide the results of the reviews and will identify any corrective actions found to be necessary. Completion of the review process will resolve USI A-46 for the affected plants.

IPEEE

During the development and review of the SQUG experience-based approach for assessing seismic ruggedness of equipment and certain structures, the USNRC's Division of Research and EPRI were evaluating approaches for determining structural margins in nuclear power plants for large, low probability earthquakes. This research effort led to the development of the Seismic Margin Assessment (SMA) methodology for evaluating seismic margins in important nuclear plant structures, components and systems. This approach is described in EPRI report NP-6041-SL, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1),"(14) and has since been accepted by the USNRC as a method for responding to the IPEEE.

A central part of this assessment is a plant walkdown, similar to the SQUG-developed walkdown for USI A-46. Because of the similarities, and to encourage integration of these seismic reviews, the SMA approach makes use of experience-based data and procedures developed in the SQUG program and contained in the GIP.

POST-A-46 APPLICATION OF THE SQUG METHODOLOGY

The earthquake experience data, seismic evaluation criteria and application procedures developed and proved out by SQUG and EPRI are expected to provide long-term benefits to the nuclear industry beyond resolution of USI A-46. First, and perhaps most important, the systematic study of the results of strong earthquakes has shown that the seismic hazard to typical power plant equipment and structures is not a significant safety concern. It has also identified apparent conservatisms in traditional seismic analysis methods which may warrant further research and refinement. These findings point up the need for reevaluation of the cost benefits of the sophisticated and costly seismic design approaches currently being applied in newer nuclear plants, and activities have already been initiated by EPRI, the NRC and U.S. code-writing bodies to reflect this important conclusion in nuclear criteria and standards. As indicated above, elements of the SQUG approach have been incorporated in the NRC's requirements for the IPEEE. Second, the use of seismic experience data has already been recognized in recent IEEE qualification standards and is being evaluated and used in several industrial and governmental applications.

Finally, the methodology will provide a practical and efficient method for verifying the seismic acceptability of replacement and spare equipment in nuclear plants for years to come. For these reasons, EPRI, through agreement with SQUG, is presently making arrangements to ensure the long-term availability of the key parts of the process - the experience data base, the GIP and the training program.

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