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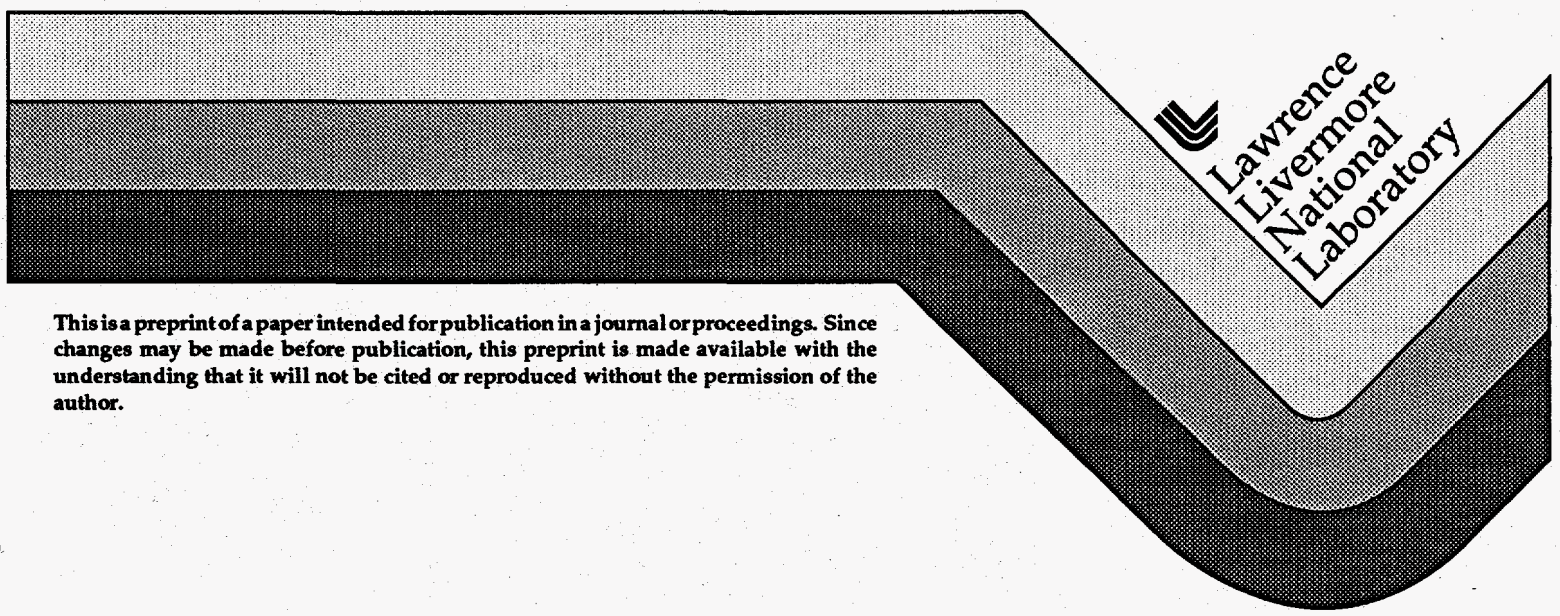

USE OF EXPERIENCE DATA FOR SEISMIC EVALUATIONS AT DEPARTMENT OF ENERGY FACILITIES

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ABSTRACT

Seismic evaluations of essential systems and components at Department of Energy (DOE) facilities will be conducted over the next several years. For many of these systems and components, few, if any, seismic requirements applied to the original design, procurement, installation, and maintenance process. Thus the verification of the seismic adequacy of existing systems and components presents a difficult challenge.

DOE has undertaken development of the criteria and procedures for these seismic evaluations that will maximize safety benefits in a timely and cost effective manner. As demonstrated in previous applications at DOE facilities and by the experience from the commercial nuclear power industry, use of experience data for these evaluations is the only viable option for most existing systems and components. This paper describes seismic experience data, the needs at DOE facilities, the precedent of application of nuclear power plants and DOE facilities, and the program underway for the seismic verification task ahead for DOE.

SEISMIC EXPERIENCE DATA

Seismic experience data document performance of systems and components that have been subjected to earthquake motion. This set of data includes items in commercial and industrial facilities that were in the strong motion regions of major earthquakes, and items that underwent shake table tests.

Earthquake Experience

Over the past several years, the Seismic Qualification Utility Group (SQUG) and the Electric Power Research Institute (EPRI) have developed a seismic experience data base that includes the response of systems and components in about 100 (typically non-reactor) facilities located in areas of strong ground motion from 20 past earthquakes. The earthquakes have Richter magnitudes in the range of 5.2 to 8.1, with peak ground accelerations from 0.10g to 0.85g, for about 3 to about 50 seconds duration. Soil conditions, building structure types, and location of equipment vary considerably within the data base.

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Note: This paper extends an earlier paper dated May 25, 1993 prepared by the Existing Facilities Steering Group. The group is composed of Mark Barlow (Chairman), Westinghouse Savannah River Company; Allen Burnett, Martin Marietta Utility Services; Leon McGovern, EG&G—Rocky Flats Plant; Dave Post, Los Alamos National Laboratory; and Richard Stroud, Battelle–Pantex. Effective July 23, 1993 Fred Loceff, WSRC, replaced Mark Barlow as Chairman of the Steering Group.

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The facilities surveyed and documented contain a large number of mechanical and electrical equipment, and control and distribution systems identical or very similar to those found in DOE facilities. Information sources consist of interviews with facility management and operating personnel, walkdown inspections of facilities, photographs and performance data records of systems and components, facility operating logs, and the facility's inspection reports. Available design criteria and specifications, component data books, and design drawings were collected. There is diversity in equipment design, size, configuration, age, application, operating conditions, manufacturer, and quality of construction and maintenance.

The earthquake experience data are useful for determining common sources of seismic damage or adverse effects of equipment and facilities, thresholds of seismic motion corresponding to various types of seismic performance, and standards in equipment construction and installation to ensure the ability to withstand anticipated seismic loads.

Seismic Testing

As an expansion of the earthquake experience data, EPRI and SQUG also collected data on shake-table qualification tests from utilities, manufacturers, and test laboratories. Results were compiled from about 300 shake table tests of equipment components, covering 15 generic classes of equipment which are representative of much of the equipment found in DOE facilities. The objective was to compile the information by class, and to obtain generic insights, if any, by class, that could be used to assist utilities in evaluating these equipment classes in their plants. These generic equipment ruggedness data represent substantially higher levels of seismic motion than the earthquake experience data, but in most cases are applicable to a narrower range of equipment parameters. EPRI and SQUG also obtained available electro-mechanical relay chatter shake table tests and performed additional tests for other relays. The relay test experience data base provides capacities for about 150 specific models of relays.

Anchorage Testing

Another important element of seismic experience data is information on the anchor bolts that are commonly used in many DOE facilities to attach systems and components to the supporting building structure. EPRI and SQUG have summarized capacity information for expansion anchor bolts, covering about 1200 ultimate capacity tension and shear tests. Capacity data have also been compiled for other anchor types including welded attachments, cast-in-place bolts and headed studs, grouted-in-place anchors, and cast-in-place J-hooks.

NEEDS OF DOE FACILITIES

DOE facilities need to have adequate measures of ensuring hazardous material confinement for protection of the public health and safety, on-site worker life safety, and investment protection in the event of natural phenomena hazards including earthquakes. Due to the evolutionary nature of design and operating requirements, and developments in engineering technology, existing DOE facilities embody a broad spectrum of design features for earthquake resistance. The earliest facilities often have the least seismic design documentation, yet potentially exhibit the greatest difference between their design basis and what DOE would require today for seismic design criteria for new facilities.

Compliance with the recent DOE Order 5480.28 (Reference 1) for the seismic evaluation of systems and components leads to consideration of the following alternatives:

Seismic qualification by testing.
Seismic qualification by analysis.

Verification of seismic adequacy using experience data.

As was concluded in the nuclear power industry (References 2 to 4), the first two alternatives, testing or analysis, are most often not viable due to problems of removal, decontamination, shipment of equipment for testing, access and potential damage from in-situ testing. As demonstrated in previous applications at DOE facilities and by the experience from the commercial nuclear power industry, use of experience data for these evaluations is the only viable option for most existing systems and components.

PRECEDENTS

Application to Nuclear Power Plants

In the late 1970s, the U.S. Nuclear Regulatory Commission (NRC) expressed the concern that nuclear equipment seismically qualified to standards preceding IEEE-344-1974 might not provide sufficient assurance of seismic adequacy. This concern was reinforced through field inspections of earlier nuclear power plants where equipment lacked adequate anchorage. This NRC concern resulted in issuing Unresolved Safety Issue (USI) A-46, "Seismic Qualification of Mechanical and Electrical Equipment in Operating Nuclear Power Plants" (Reference 2). The NRC pursued several options for the resolution of USI A-46, including use of shake table testing, in-situ testing, deterministic and probabilistic analytical methods, and seismic experience data. Most options proved not to be viable because of the unavailability of older model components for testing, the high costs of component replacements, and complications of testing radiologically contaminated equipment.

The NRC concluded, based on research by the National Laboratories, that use of experience data could provide a reasonable alternative for resolution of USI A-46 (Reference 4). The NRC also endorsed the methodology developed by SQUG, EPRI and the Senior Seismic Review and Advisory Panel (SSRAP) (Reference 5). In 1987, NRC Generic Letter (GL) 87-02 required utilities to respond to USI A-46, and encouraged participation in generic resolution by using the SQUG approach, documented in the Generic Implementation Procedure (GIP) (Reference 6). NRC has accepted the SQUG GIP by a generic safety evaluation report (Reference 7), taking a few exceptions, which have since been resolved and are being incorporated into Revision 3 of the GIP.

The SQUG GIP consists of four sets of criteria:

1) the experience-based capacity spectrum must bound the plant seismic demand spectrum,

2) the equipment item must be reviewed against certain inclusion rules and caveats,

3) the component anchorage must be evaluated, and

4) any potentially significant seismic systems interaction concerns that may adversely affect component safe shutdown function must be addressed.

These SQUG criteria are in the form of screening evaluation guidelines. Items not passing the screen are not necessarily inadequate, but other seismic engineering methods must be used to evaluate these items further.

An important element of the SQUG GIP is its application by the use of specially trained and experienced seismic review teams who must exercise considerable judgment while performing the in-plant screening evaluations. Besides establishing strict qualification requirements for

review team engineers, SQUG and EPRI provide a training course in the use of the implementation guidelines and procedures.

The seismic evaluation method based on experience data has become a key element in the ongoing earthquake evaluations for commercial nuclear power plants. The experience based evaluation methods address most plant components needed for safe shutdown in the event of a design basis earthquake, including 20 classes of electrical and mechanical equipment, cable trays and conduit systems, relays, anchorage capacity, tanks and heat exchangers.

Application at DOE Facilities

The SQUG experience-based seismic evaluation approach has already been used at a few DOE facilities. The most extensive application has been at the Savannah River Site (SRS). The SRS reactors were built in the 1950s when seismic qualification requirements were in their infancy. SRS became a member of SQUG in 1988, and used the GIP at its K, L and P reactors to evaluate the seismic adequacy of selected safety systems for their design basis earthquake. The SRS reactor program included definition of the system scope requiring review, development of SRS plant specific procedures, use of seismic screening evaluation walkdowns and calculations, and identification, resolution, and upgrading of outliers. This application at SRS has been reviewed and accepted by DOE oversight personnel.

The SRS seismic evaluation program represents an expansion of the SQUG GIP in several areas. Programmatic changes were incorporated to enhance engineering assurance. Several technical changes were added to address unique needs at SRS such as additional steps for expansion anchor verification, development of capacity for lead cinch anchors, implementation of consistent guidelines for HVAC ducting, and use of experience-based screening guidelines for piping.

The SRS seismic evaluation program was a major success. Roughly 60 percent of the items were verified to be seismically adequate as-is. For the others, about 11 percent were resolved by additional evaluation; the remainder were resolved by upgrade. The typical upgrades consisted of anchorage enhancement and elimination of seismic interaction concerns by providing restraint or removal of the interaction source. The use of the experience-based evaluation approach enabled efficient identification of realistic seismic concerns at SRS. Maximum safety enhancement was achieved with reasonable engineering effort. This seismic experience-based approach is currently being used at SRS to evaluate non-reactor facilities.

Similar benefits from use of experience data were realized at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). Prior to plant restart, seismic verification of essential systems and components had to be demonstrated. Experience-based in-plant screening evaluations were used as a key part of the seismic evaluation and upgrade program. Several items were determined to be acceptable in their as-installed configuration. Backfit modifications were installed to increase seismic adequacy as needed. This included providing anchorage for some components, additional restraint for items where deflection considerations were governing capacity, and correction of potential seismic systems interaction hazards.

Other successful applications of experience data for seismic design issues at DOE facilities include the Princeton Plasma Physics Laboratory and the Idaho Chemical Processing Plant (ICPP). At Princeton, active electrical and mechanical equipment, fluid pressure boundary components, and seismic interaction effects were evaluated and resolved by use of experience-based methods. At ICPP, seismic adequacy of critical fire protection components was verified using the experience-based approach.

The applications at SRS, HFIR, Princeton, and ICPP have proven the viability of the experience data base approach for DOE facilities. Many of the results of these evaluations have withstood strict scrutiny during technical audits, peer reviews, quality control audits, and other independent reviews. Given the experience from the nuclear power industry, coupled with previous applications at DOE sites, the controlled and proceduralized application of experience data provides DOE sites with an efficient tool for performing the necessary seismic evaluations.

DOE PROGRAM

The DOE facility evaluations can take direct advantage of the experience data base compilations and guidelines developments by SQUG and EPRI. As a first step, through special agreement between Lawrence Livermore National Laboratory (LLNL) and EPRI, the SQUG and EPRI reference documents (References 6, 8, and 9 through 20) for use of experience data are available to DOE for the facility reviews. Two orientation workshops and a 5-day training course have already been conducted by LLNL to provide DOE facility personnel with an overview of the SQUG and EPRI reference materials and detailed training on its application. The attendance at the training course is currently a mandatory step for any DOE site wishing to obtain the documents. The training program will be continued to permit use of these documents for safety-basis evaluations.

Because the systems and components in DOE facilities are so diverse, other experience-based tools are needed for the DOE efforts beyond those currently included in the EPRI/SQUG data base. Additional needs include other equipment groups beyond the SQUG classes of equipment. Examples include piping systems, HVAC ventilation equipment, filter compartments, glove boxes, and fire protection piping. A questionnaire was used to help determine the types of safety systems and equipment components that will require seismic evaluation at DOE facilities. A list of DOE unique items has been developed

In contrast to the SQUG deterministic criteria, DOE facilities are required to demonstrate the ability to achieve probabilistic performance goals (Reference 1 and 21). The larger the potential risk, the stricter the performance requirements. DOE and its contractors are therefore assessing the performance goals achieved when seismic experience-based screening evaluation methods are used. This effort is complete and documented in Reference 24.

Overview of Program Plan

DOE has implemented a program for the development of seismic evaluation guidelines for systems and components at existing facilities. The program plan intends to maximize the use of past experience, in conjunction with a walkdown screening evaluation process.

The program will provide walkdown guidelines such that systems and components can be identified, assessed, and remedied as needed in an efficient manner. The program will also provide screening guidelines whereby systems and components that have demonstrated ability to withstand known levels of seismic motion, based on past experience, can be verified as meeting applicable DOE orders without needing additional analysis or testing. Guidelines will be developed for analysis or testing of systems and components that do not meet the screening criteria. Documentation requirements will be developed to streamline the evaluation process yet still provide sufficient traceability and accountability for the reviews.

Implementation of these procedures will require experienced, well-trained engineers applying sound engineering judgment. As a result, the program will provide for the transfer of the necessary technology to DOE sites and the training of DOE and contractor personnel to conduct

evaluations. In addition, peer review requirements will be established to provide an independent verification of the judgments made during the screening evaluations.

Steering Group and Technical Review Team

DOE facility management and operations personnel will play an important role in the development and review of the guidelines. A Steering Group of selected individuals from the operating contractors will ensure that appropriate priorities are established from the facility operations perspective. The Steering Group has also chartered a team of industry experts for technical review of the implementation guidelines. The Technical Review Team determines the adequacy of the technical content of the screening evaluation guidelines, including the safety margins that will result from implementation of the criteria. The Steering Group has met seven times since December 1992 to guide the overall program.

Progress to Date

The first phase of the program was to obtain a DOE license for use of the EPRI/SQUG Seismic Evaluation Material (References 8 through 20) at DOE facilities. This was followed by orientation and training on the use of this material within the DOE complex. This seismic assessment material was arranged into 8 volumes and 100 sets were distributed throughout the DOE. Procedures are being developed for current SQUG certificate holders to obtain DOE certificates of training.

A Walkthrough Field Guide (Reference 22) was developed to assist in identifying major deficiencies at DOE facilities. The document was developed based on walkdown experience at nuclear power plants and then tested and revised by applying it to walkdowns at selected DOE facilities. This document was also distributed throughout DOE as part of the training course.

The need for screening criteria to identify potential sources of seismically induced failure in piping systems was identified early in the program. A team of industry experts was lead by WSRC to develop practical screens over the last year. This effort has been reviewed by the Technical Review Team and documented in Reference 23. Training on the use of this screening criteria is currently under development.

Development of screening criteria for seismically evaluating unreinforced masonry walls began in mid-1994 and is nearing completion. Preparation of a draft document is underway. The draft document will then be reviewed by the Technical Review Team.

Identification of equipment, important to safe operation of DOE facilities, has been completed. This was accomplished by use of a questionnaire and discussions with facility operators. This list of 20 DOE unique items has been reviewed by the Steering Group and is ready for development of screening approaches beyond the original SQUG 22 classes.

Lessons learned from the Northridge Earthquake are also being assembled jointly with EPRI and NRC. Part of this effort may include a detailed study of DOE's Energy Technology Engineering Center (ETEC) located a few miles from the epicenter. This will expand the experience data base of equipment located at DOE facilities.

DOE's NPH Policy is performance based and uses a graded approach; therefore every structure, system, and component is placed into a Performance Category (PC). These range from PC 0 with no requirements, to PC 1 and 2 which are like conventional building code criteria, to PC 4 which approaches commercial nuclear power plant criteria. A study has been completed which quantifies the performance of structures, systems, and components whose seismic capacity is defined using experience data. This study proposes experience data factors to scale in-structure

response spectra which need to be bounded by experience-based capacity spectra such as the Reference Spectrum, GERS Spectra, or Qualification Test Results.

Planned Work

The primary emphasis during this year will be to develop the DOE Implementation Procedure for the SQUG 22 classes of equipment. This will be followed by developing screening tools for the 20 DOE unique items along with the associated training.

The Steering Group plans to monitor applications at DOE sites during the initial implementation phase which may take place in 1996.

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