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EQUIPMENT QUALIFICATION RESEARCH PROGRAM
PROGRAM PLAN

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MASTER

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FOREWORD

This program plan was developed by the Lawrence Livermore National Laboratory (LLNL) under the sponsorship of the U.S. Nuclear Regulatory Commission (NRC). The goal was to formulate a research program which over a period of five years will identify and provide recommended resolution to the most important issues on the qualification of equipment in nuclear power plants.

The authors express their appreciation to the individuals of Table I for the thoughts and insights they contributed on equipment qualification processes and issues. The participation of LLNL personnel, C. K. Chou, L. L. Cleland, and G. E. Cummings, contributed significantly to the program plan.

INTRODUCTION

The Lawrence Livermore National Laboratory (LLNL) under the sponsorship of the U.S. Nuclear Regulatory Commission (NRC) has developed this program plan for research in equipment qualification (EQ). In this report the research program which will be executed in accordance with this plan will be referred to as the Equipment Qualification Research Program (EQRP). Covered are electrical and mechanical equipment under the conditions described in the OBJECTIVE section of this report.

The EQRP has two phases; Phase I is primarily to produce early results and to develop information for Phase II. Phase I will last 18 months and consists of six projects. The first project is responsible for program management. The second project is responsible for in-depth evaluation and review of EQ issues and EQ processes. The third project is responsible for detailed planning to initiate Phase II. The remaining three projects address specific equipment; i.e., valves, electrical equipment, and a pump. Phase II will proceed for three and one-half years. It will have a project for management and the development of the complete Phase II plan as well as several other projects to address specific equipment or EQ issues. This EQRP plan focuses on the scope of work to be executed in Phase I of the EQRP, but it includes the goals and intent of the projects to be executed in Phase II.

Issues and concerns in EQ play a major role in selecting work for the EQRP. Major headings under which issues can be categorized includes:

- o Aging and degradation (including wear).
- o Extrapolation and interpolation (scaling).
- o Sampling.
- o Characterization of loads and environments.
- o Sequencing and combination of loads and environments.
- o Margins.
- o Value impact (defined later, as used in the EQRP).
- o Uncertainties.

- o Requalification.
- o Maintaining validity of EQ throughout component life.
- o Qualification by testing and/or analysis.

Many of these issues and concerns are coupled. For example, the process of sampling introduces uncertainties which must then be considered to specify margins. The EQRP will define the above terms and determine coupling relationships.

A list of identified issues under these headings are given in Appendix A. All these headings will be considered in the EQRP. Not all are addressed by experimental or analytical efforts in Phase I, as this is partly an exploratory phase to help define and optimize Phase II. However, this list will be refined in Phase I. This refinement will include additions and priorities. The goal is to identify the important issues, and, if possible, to eliminate the less important issues.

A hierarchical format was used in writing this Plan. Each project includes paragraphs providing background, objectives, approach and scope, products and benefits information. Likewise, tasks and subtasks contained within each project have a similar format. The intent is to provide the reader with increasing detail as he peruses the project tasks and, if appropriate, subtasks.

Several tables and an appendix have been included to provide a reference for the future work and to indicate some of the sources of information used in preparing this Plan. Estimated funding by project, are included at the end of each project description, and for the total program under the Section "EQRP Phase I Budget." The estimates given represent typical DOE Laboratory costs. The authors realize the scope indicated for a given project or task may be interpreted differently by each reader. The intent of including costs is to further imply the detailed effort expected for each project and to provide the NRC with funding recommendations. Note that the costs only cover the 18-month period associated with Phase I.

The total scope for Phase I, as outlined in this Plan, may exceed the available funds. The Plan is structured such that tasks can be deleted from each project, as appropriate. Some of this is already reflected in the budget; e.g., or projects can be deleted, the authors recommend deferring Project VI to Phase II.

BACKGROUND

Current general requirements for EQ are given in General Design Criteria 1, 2, 4, and 23 of Appendix A to 10 CFR part 50; Sections III and XI of Appendix B to 10 CFR part 50; and Criterion VI of Appendix A to 10 CFR part 100[1]. More detailed requirements are established in national standards, NRC regulatory guides, and other documents. These documents are listed in Table 2. The present licensing review procedures are in the NRC Standard Review Plan [2].

Equipment qualification requirements contained in these documents are quite general, subject to interpretation, and may not be founded on adequate data. Virtually all published qualification standards address electrical equipment only, although a few are also assumed to be valid for mechanical equipment. A number of draft standards on mechanical equipment are available as shown in Table 2. In addition, the issues associated with qualification, or requalification, of equipment in operating plants are not adequately addressed in these standards.

The following steps are being taken by the NRC on EQ issues. An interim position on electrical equipment qualification to environmental conditions is contained in the DOR Guidelines [3] and NUREG-0588 [4]. A rulemaking covering this same area is in progress, and was in response to the May 23, 1980 NRC Memorandum and Order [5]. In addition, a rulemaking covering electrical equipment subjected to dynamic (including seismic) loads and mechanical equipment subjected to dynamic (including seismic) loads and environmental conditions may be initiated. The EQRP is in support of NRC regulatory decision making which includes the latter rulemaking. The EQRP is a part of a broader NRC EQ program which is presently being defined.

Several programs are planned or ongoing which address aspects of EQ. The EQRP will complement and verify these programs as required to satisfy NRC needs. Other EQ related programs sponsored by NRC are listed in the section "EQRP Interactions Within the Program and With Other EQ Related Programs." The

Electric Power Research Institute (EPRI) is sponsoring EQ related investigations, and their ongoing and completed programs are listed also in that section. Various foreign programs are pertinent to resolving EQ concerns. To the extent necessary or possible, interactions with these programs will take place. The above listing of EQ efforts is no doubt incomplete and the EQRP will seek to identify a complete list of EQ activities.

Two insights obtained from the information gathered in preparing this plan are: (1) the step-by-step profile of a typical EQ process, Table 3, and (2) the fact that unexpected, and often previously unknown, problems may be revealed only by testing. The latter was one of the most important insights obtained from a review of NRC experience with research on environmental qualification of electrical equipment. This implies that the usefulness of the EQRP would be enhanced if experimental efforts are started as early as possible.

OBJECTIVE

The objective of the EQRp is to provide a technical basis for the development of requirements and acceptance criteria for EQ procedures in support of NRC regulatory decision making for: (1) operating plants, (2) construction permit (CP) plants, and (3) new standardized plants.

These requirements and acceptance criteria will be based on value-impact* considerations and are limited to:

Electrical Equipment

- o Dynamic (including seismic) and static loads

Mechanical Equipment (active components)

- o Dynamic (including seismic) and static loads
- o Environments (including normal operations, postulated accident conditions, and post accident conditions)

*Value-impact is used in two ways in this report: (1) as it relates to the use of EQ requirements and acceptance criteria in improving plant safety, and (2) the cost-benefit aspects of a research task in producing useful results in the EQRp. Both are important considerations for the EQRp. Where no distinction is made, both meanings should be assumed.

APPROACH

The approach to achieve the objective of the EQRP is to pursue the research in two phases. Phase I will emphasize exploration of EQ issues and planning to develop a sound basis for Phase II. Phase I will also include investigations on selected issues to provide early insights on the development of EQ requirements and acceptance criteria.

The second phase is principally in-depth testing and analysis* investigations that will result in recommended EQ requirements and acceptance criteria.

Phase I is proposed to last 18 months. The early part of Phase I will be personnel intensive as equipment for investigation are selected, test facilities are surveyed, and detailed test and analysis plans are developed. The latter part will be test and analysis intensive. Phase II will be testing and analysis intensive throughout.

A Lead Laboratory will assist the NRC staff by providing general and detailed management of the EQRP. Figure 1(A) indicates the technical direction and guidance flow. It assumes the Lead Laboratory will develop scope and content, products required, cost and schedule estimates, etc., for all projects. Once approved by the NRC staff, the projects will be executed by the best qualified

*In the EQRP, "testing and analysis" means research-oriented rather than qualification-oriented testing and analysis. In research-oriented testing and analysis the emphasis is on in-depth studies and investigations, a search for and identification of potential problem areas and key EQ parameters, and identification of solutions or bounds. The ultimate aim of research-oriented testing and analysis is to develop requirements and acceptance criteria for qualification-oriented testing and analysis.

laboratory or subcontractor. Figure 1(B) indicates two possible flows of funds. The solid line flow is preferred from an overall control standpoint but the dashed line flow may be more appropriate in some instances.

Value-impact assessments will be used to recommend Phase II research projects and tasks. Differences in operating plants, CP plants, and new standardized plants will be considered, and will influence these value-impact assessments. Tasks will be selected and discussed with NRC for approval. The test and analysis plans for approved tasks will be developed and provided to NRC and consultants for review prior to execution.

Useful products will be produced and issued over the duration of the EQRP, and not just at the end of each phase. A set of products and milestones will be specified for each task.

FIGURE 1: Technical Management and Funding Flow for EQRP.

PHASE I

Objectives

The objectives of Phase I of the EQRP are to:

1. Provide early insights on EQ requirements and acceptance criteria.
2. Conduct initial studies and develop a basis for the in-depth studies in Phase II.
3. Formulate plans for initiating Phase II of the program.

Approach

The approach to achieve the objectives of Phase I is embodied in six projects:

Project I	Program Management
Project II	Review and Evaluation
Project III	Phase II Plans
Project IV	Valve Studies
Project V	Electrical Equipment Studies
Project VI	Pump Studies

This plan is based on the assumption that a "Lead Laboratory" will be selected by the NRC. The responsibilities and relationships among the NRC, lead laboratory, and supporting organizations will be more clearly defined as a part of Project I. An initial description of these relationships is given in Fig. 1.

The Lead Laboratory will be responsible for the overall management and technical direction of the EQRP. This will be accomplished by the Lead Laboratory through execution of Projects I, II, and III; however, other laboratories, subcontractors and consultants will be called upon to supply expertise and peer review. In general, the Lead Laboratory will collect and assess information, coordinate all EQRP work, integrate EQRP work with other work, review and evaluate technical work in the context of NRC needs, recommend and plan research tasks, and assure schedule and budgets are met. An important function of the lead laboratory will be to provide a communication link between the NRC staff and the large

number of individuals and organizations involved in EQ related activities. Letters and regular reports will be generated on all relevant communications, interactions, and results, as a formal means of maintaining this communication link.

To obtain insights early in the EQRP, three test and analysis projects are included in Phase I. The general objectives of these projects are to identify research EQ problems, eliminate (if possible) some issues and problems, provide insight needed for (potentially costly) Phase II experiments, and establish EQ requirements and acceptance criteria, results, and concepts. Each project focuses on fundamentally different types of equipment (i.e., valves, electrical, and pump equipment) to insure the general objectives are met. Costs and schedules exclude a complete analysis of all issues in Phase I. Thus, only important issues that can be addressed in the limited schedule of Phase I are considered, but these projects will form a significant basis for Phase II investigations. The Lead Laboratory will provide general technical direction and guidance for these projects; however, all or part of each project may be executed by other laboratories.

PROJECT I: PROGRAM MANAGEMENT

Background

This EQRP is complex and addresses diverse technical issues. To maximize benefit and minimize costs to the NRC, organizations having the required facilities and specialized staff will be involved in carrying out the various projects and tasks that make up the program. In addition, other organizations within the NRC* and the U.S. technical community* as well as foreign sources are engaged in work relating to EQ. In order to assure the maximum benefit from these efforts, it is extremely important that there be close interaction to avoid duplication and provide the opportunity for synergism. This project will insure the needed interactions take place.

Objectives

The objectives of Project I are to:

1. Manage the EQRP.
2. Coordinate with other EQ activities.

Approach and Scope

The objectives of Project I will be achieved through the following two tasks which correlate with the two objectives:

- I.1 Program Management
- I.2 Coordinate with Other EQ Activities

The details of these tasks are given below.

*See the section "EQRP Interactions Within the Program and With Other EQ Related Programs."

Products

- o Quarterly letter progress and financial reports; Task I.1.
- o Management Interface Requirements Plan*; Task I.1.
- o Technical Interface Requirements Plan*; Task I.1.

- o Detailed Schedule and Milestones; Task I.1.
- o Recommendation from Lead Laboratory to NRC regarding selection and funding of projects; Task I.1.
- o Lead Laboratory letter review, evaluation, and recommendations on products developed by participating organizations; Task I.1.
- o Letter reports on program coordination management meetings; Task I.1.
- o Letter report on organizations, programs and individuals involved in EQ; Task I.2.
- o Coordination reports; Task I.2.

These consist of letter reports following technical meetings.

Benefits to NRC and EQRP

Selecting a Lead Laboratory to manage the EQRP will insure that the appropriate technical and management resources are applied to accomplish the program objectives. This will establish for the NRC a single point of contact for dealing with the diverse EQ issues associated with the EQRP.

Interactions and coordination with other EQ activities will provide significant benefits to the EQRP through the exchange of information, avoiding duplication, and providing the opportunities for synergism.

*These plans will define the functions and responsibilities of, and interactions among; the NRC, Lead Laboratory, participating laboratories, and other organizations as deemed appropriate by the Lead Laboratory.

Tasks

I.1 Program Management

Objective

The objective of this task is to manage the EQRP to achieve program objectives within the schedule and budget.

Approach and Scope

The Lead Laboratory will work closely with the NRC-Research staff to insure the EQRP is managed to meet the overall EQRP objectives. This will require interfacing and coordination with all organizations involved with the EQP and maintaining appropriate channels of communications.

The Lead Laboratory will work with and serve as an extension of the NRC staff to identify needs and requirements. This will be an iterative process for the program's duration. This task, in conjunction with inputs from concurrent EQRP tasks, other programs, and NRC staff, will identify needed EQRP products. Schedules and budgets will then be developed to obtain these products, and NRC approval sought.

Specific management and technical interface plans will be developed that will clearly define all functions and responsibilities of the EQRP participants. The Lead Laboratory will make recommendations to the NRC on selection of the best organizations to participate in the EQRP. These organizations may conduct tasks or whole projects. These recommendations are particularly relevant for Phase I Projects IV-VI and for all Phase II tasks or projects. Once organizations are selected to execute the work, the Lead Laboratory will review and evaluate the work to assure product quality and delivery.

Program management will require frequent communications with NRC and participating organizations. It is expected the bulk of the oral communications will be telephone conversations; however, regular meetings and

visits will be scheduled and are costed as part of this task. Written communications will include the products indicated for this task and other letters and reports as appropriate.

In summary, the scope of this task encompasses the following:

- o Interact with the NRC to identify needs and requirements.
- o Identifying products that support program objectives.
- o Develop schedule and budget for products within the EQRP.
- o Provide overall EQRP technical direction and plans.
- o Provide recommendations to the NRC on the selection and funding of participating organizations.
- o Review and evaluate work performed.
- o Assure product delivery to meet schedule and objectives.
- o Early identification of problems (technical, budget, schedule, management) and their proposed resolution.
- o Communications, interfacing, and coordination within the EQRP.
- o Generate overall EQRP progress report.

Products

The products for this task will include interactions with NRC and other organizations involved with the EQRP and numerous reports as depicted by the first seven bullets under Project I Products.

I.2 Coordinate with Other EQ Activities

Background

The EQRP will need to interface or interact with other programs. Other organizations within the NRC and the U.S. technical community, as well as foreign sources are engaged in work related to EQ. Coordination and interaction is needed to avoid duplication of effort.

There are several ways to implement licensing requirements. One of the most effective ways to implement EQ requirements and acceptance criteria is through their incorporation in national standards. This will be more easily accomplished if interactions with national standards organizations are started early.

Objective

The objective of this task is to interact with organizations and individuals to maximize the benefits of their efforts and insights to the EQRP.

Approach and Scope

The approach to achieve the objective of this task is to assure that the necessary communications and informational exchanges take place. The Lead Laboratory will execute this task by carrying out the following:

- o Identify appropriate organizations, programs, and individuals involved with EQ.
- o Establish points of contact and means of communication.
- o ~~Interact with other EQ related programs.~~
- o Participate in national standards activities.
- o Seek peer review from the technical community.

These interactions and exchanges will require meeting time and travel expenses. Projected and budgeted meetings with other than NRC are:

1. Technical Coordination Meetings: 3 total, 3 days each.
2. Quarterly meetings with EPRI, 1/2 day each.
3. IEEE SC 2 meetings, 2 per year anticipated.
4. SWRI Peer Review meetings, 1 per year anticipated.
5. ASME Standards meeting, 3 per year anticipated.
6. Other national standards meetings, 3 per year.

Products

- o Letter report on identified organizations, programs, and individuals involved with EQ, established point contacts, and means of communication.
- o Letter report following meetings of types 1 through 6.

BUDGET⁽¹⁾ AND SCHEDULE

PROJECT i: PROGRAM MANAGEMENT

Tasks		Year				
		1	2			
I.1 Program Management	1	▽	1 1 1	1 1		
	2	▽	▽ ▽ ▽	▽ ▽		
	3	▽				
	4					
	5	390K	260K	130K		
I.2 Coordinate with Other EQ Activities			6 6 6			
			▽	▽		
		114K	76K	38K		
Meetings:						
Tech. Coord: 2/yr, 3 days ea. 105K						
Mtgs with EPRI: 4/yr, 1/2 day ea. 1K						
IEEE SC 2 mtgs: 2/yr 2 days ea. 7K						
SwRI Peer Review: 1/yr, 3 days ea. 5K						
ASME stds mtgs: 3/yr, 2 days ea. 10K						
Other stds mtgs: 3/yr, 2 days ea. 10K						
138K			91K	47K		
Topical Reports			▽ 2 ▽ 3			
Totals ⁽¹⁾		642K	427K	215K		
(1) Costs are in terms of FY 82 dollars						

Milestones: Project I

1. Quarterly letter progress and financial reports.
2. Management interface requirements plan developed.
3. Technical interface requirements plan developed.
4. Detailed schedule and milestones for Phase I formulated.
5. Recommendation from Lead Laboratory to NRC regarding selection and funding of projects.
6. Letter reports on program coordination management meetings.

Topical Reports: Project I

- o Milestone 2: Management Interface Requirements Plan.
- o Milestone 3: Technical Interface Requirements Plan.

PROJECT II: REVIEW AND EVALUATION

Background

The technical issues associated with EQ are many and varied. Many of the issues lack experimental verification and many are controversial. An understanding of EQ processes and all associated technical issues, is necessary to understand the research needs and to develop EQ requirements and acceptance criteria.

Objectives

The objective of this project is to identify and evaluate EQ issues and processes from which insights into EQ requirements and acceptance criteria and associated research needs can be specified.

Approach and Scope

The objective of this project will be achieved through the following two tasks:

II.1 Technical Issues

II.2 EQ Processes

Details on these tasks are given below.

Products

- o Report summarizing all issues; Subtask II.1.1.
- o Reports of studies on: seismic-aging interactions, seismic checklist, scaling, aging technology, tests vs. analyses, and input characterization, Subtasks II.1.2-II.1.7, respectively.
- o Letter report on EQ review procedure checklist; Task II.2.
- o *Letter report on EQ processes; Task II.2.*

Tasks

II.1 Technical Issues

Background

The EQRP addresses a diverse set of technical issues, many of which do not have an adequate basis of experimental data, and some of which are

controversial. In addition, many individuals and organizations have different results and views on EQ issues. Many of these issues have not been summarized and evaluated as to their implications on EQ research needed to develop EQ requirements and acceptance criteria.

Objective

The objectives of this task are to:

1. Identify and evaluate EQ issues.
2. Identify needed EQ research.

Approach

These objectives will be met through execution of the following subtasks:

- II.1.1 General and Summary
- II.1.2 Seismic-Aging Interaction
- II.1.3 Seismic Checklist
- II.1.4 Scaling Studies
- II.1.5 Aging Technology Studies
- II.1.6 Test vs. Analysis Studies
- II.1.7 Characterization of Input

Subtask II.1.1 will examine issues not identified in Subtasks II.1.2 to II.1.7, and will also summarize the results for the entire Task II.1.

Products

Reports on each of the individual specific studies (Subtasks II.1.2 to II.1.7) and a report summarizing and evaluating the entire investigation in this task (Subtask II.1.1) for use in Task III.2.

Benefit to NRC and EQR

The execution of this task will insure that some progress will be made in Phase I on all EQ issues. Limited resources are anticipated to be available in Phase I. While significant progress can be expected from

the specific efforts described in Projects IV, V, and VI, some mechanism must be established, in spite of resource constraints, to insure all EQ issues are addressed at some level.

Subtasks

II.1.1 General and Summary

Background

A general, extensive compilation and review and evaluation of EQ issues does not exist. Without such a compilation, the identification of needed research for the EQRP would be difficult and questionable.

Objective

The objective of this subtask is to develop and evaluate an extensive compilation of EQ issues for use in Task III.2.

Approach

The approach to achieve the objective of this subtask is to devote the effort of one person approximately one-half time over the duration of Phase I to identify, organize, and evaluate all EQ issues, including those specific issues described in Subtasks II.1.2 to II.1.7. The effort will address the issues in a manner appropriate for use in the EQRP. This effort will seek to find groupings and synergisms that may be appropriate for research investigations. For example, issues associated with scaling of valves may be one group and those associated with accelerated aging another group. This subtask is recommended to be executed by the Lead Laboratory to insure the evaluation of all issues is performed from the perspective of developing needed EQ requirements and acceptance criteria rather than from a limited specific technical perspective.

Product

a Report on EQ issues.

II.1.2 Seismic-Aging Interaction

Background

If preaging a component affects its seismic test response, then a seismic-aging interaction is present. Sequencing of preaging and seismic testing may then be required in EQ testing and research testing. With this requirement the cost and complexity of testing is considerably increased. If areas can be identified where reasonable assurance that seismic-aging interaction is not likely, then EQ tests would be simplified. Addressing this issue as part of the EQRP may have significant impacts. The results will likely lead to the identification of areas where seismic-aging interaction research is needed to establish the appropriate EQ requirements and acceptance criteria.

Objective

The objective of this subtask is to identify components where seismic-aging interaction is, or is not, likely to impact equipment.

Approach

The approach to achieve the objective of this subtask will be based on judgment and experience. For example, some valve stem packing can be expected to retain most of its function as leak mitigator after an earthquake even if aged. This is because the packing material is tightly confined, and may be expected to remain so during and after an earthquake, for some packing materials and valve types. Examinations of seismic-aging interactions will be carried out on as many electrical and mechanical components as feasible. Close interaction will be maintained with the Electrical Equipment Environmental Research Program at Sandia to avoid duplication.

Product

Report on seismic-aging interaction evaluation. This product is required for Subtask II.1.1.

II.1.3 Seismic Checklist

Background

It is often asserted that certain seismic-related deficiencies can be readily identified simply by a "walk-down" to observe as-constructed details. A number of knowledgeable professionals have participated in such walk-downs; however, a clear, concise checklist of specific areas such individuals include in their review does not exist in a well-reviewed document. Besides being useful in developing important EQ requirements and acceptance criteria, such a check list represents identification of possible research issues that are not otherwise easily obtained.

Objective

The objective of this subtask is to seek the identification of seismic-related EQ issues through the development of a walk-down checklist.

Approach

The approach to achieve the objective of this subtask is to:

- o Request 5 experienced professionals to develop checklists independently.
- o Hold a meeting to develop a consensus checklist and identify associated issues.

Products

- o Report on the identification of issues through development of a walk-down checklist. This product is required for Subtask II.1.1.
- o Letter report on the meeting.

II.1.4 Scaling Studies

Background

The term "scaling" has been used to describe extrapolations or interpolations of effects with respect to various parameters; e.g., size, loads, environments, and flow medium. Generally, scaling is used when a complete coverage of such parameters by test is impractical or impossible. Often, the scaling techniques used are inadequately verified, or they may be based on a simple approximation of a more complex, but undetermined, relationship. Consequently, many scaling procedures are subject to question, and in some cases no satisfactory scaling procedure exists.

Objective

The objective of this subtask is to identify research on scaling that is necessary to support the program objectives.

Approach

The approach to achieve the objective of this subtask is to:

- o Survey where, and what kind of, scaling is used in EQ processes.
- o Assess the relative importance of the equipment with respect to power plant safety.
- o Identify what research is needed to develop EQ requirements and acceptance criteria.

Product

Report on identified needed research on scaling. This product is required for Subtask II.1.1.

11.1.5 Aging Technology Studies

Background

To assure a component remains functional over the life of the plant, the effects of aging and degradation must be included in the qualification process. Because testing under normal aging and degradation is usually not practical in EQ, accelerated aging and degradation techniques are normally employed. However, the adequacy of available accelerated techniques is uncertain due to insufficient experimental confirmation.

Objective

The objective of this subtask is to identify research on the effects of aging and degradation that is necessary to support the program objectives.

Approach

The approach to achieve the objective of this subtask is to, through available information:

- o Assess the state of understanding of aging and degradation phenomena.
- o Identify aging and degradation mechanism(s) in equipment.
- o Determine what research is needed to develop EQ requirements and acceptance criteria.

Product

Report on identified needed research on the effects of aging and degradation. This product is required for Subtask II.1.1.

II.1.6 Test versus Analysis Studies

Background

Three major EQ testing and analysis issues must be addressed in order to develop acceptable EQ requirements and acceptance criteria. These issues are the following conditions:

- o When EQ through testing is not feasible (for example, for large diesel-generator sets).
- o When EQ through analysis is feasible but quite expensive (for example, through detailed nonlinear modeling of active mechanical components).
- o When EQ is accomplished through a combination of testing and analysis (for example, the seismic qualification of electrical components mounted in a cabinet).

Objective

The objective of this subtask is to obtain insights on EQ requirements and acceptance criteria related to the issue of testing versus analysis.

Approach

The approach to achieve the objective is through a review, comparison and evaluation of EQ through testing versus analysis as practiced in the United States and foreign industries including:

- o Nuclear.
- o Automotive.
- o Aerospace.
- o Military.
- o Oil production and refining.

Product

- o Report on testing versus analysis issues for Subtask II.1.1.

II.1.7 Characterization of EQ Loads

Background

All qualification tests must specify the input parameters. Ideally, these input parameters would reproduce the conditions that represent the maximum or most severe loads and environments expected during the design life of the component. However, it is not always possible to exactly reproduce the actual loading and environmental conditions. It may be quite possible and even desirable to represent the loading and environmental conditions by specifying simplified loads and environments in various combinations and sequences that adequately represent the key input parameters and subject the test component to conditions which will provide assurances that the component will function under all normal operating, transient, and postulated accident conditions.

Objective

The objective of this task is to

1. Identify what qualification input loads and environments need to be characterized.
2. Identify what additional research needs to be conducted to characterize these loads and environments to support the program objectives.

Approach

The approach to achieve the objectives of this subtask will be to review existing NRC practice on loads and environments and use the data and knowledge gained from the above subtasks.

Product

Report on loads for EQ for use in Subtask II.1.1.

II.2 EQ Process

Background

The objective of this program is to develop EQ requirements and acceptance criteria. While it is not expected that final requirements and acceptance criteria will be developed in Phase I, some mechanism must be established early in the program to insure that:

- o Development of acceptable EQ requirements and acceptance criteria for all EQ areas is initiated in Phase I.
- o Resources are focused on research that will lead to acceptable EQ requirements and acceptance criteria rather than just advance the state-of-the-art.

Objective

The objective of this task is to develop early insights on EQ requirements and acceptance criteria for all EQ areas.

Approach

In order to evaluate the EQ process, it is necessary to understand the EQ review procedures. Therefore, the first part of this task will develop a review checklist that will delineate the step-by-step review procedures for EQ. This checklist will then serve as a guide for the remaining part of this task.

The approach to accomplish the objective of this task will be to identify all the possible "parameters" pertinent to the EQ process. These parameters will be different depending on the type of equipment

(e.g., pumps, valves, relays, etc.), the challenge for which it must be qualified (e.g., seismic), and the method of qualification (e.g., test, analysis, or combination of test and analysis). In addition, viable options for the parameters will be identified. Then research required to establish EQ requirements and acceptance criteria will be identified.

Products

- o Letter report on EQ review procedure checklist. This checklist will provide a guide to the evaluation effort on the EQ process and may also be useful to the NRC in establishing EQ review procedures.
- o Letter report on the evaluation of EQ processes to provide input to Task III.2.

Benefit to NRC and EQRP

This task will be useful in two different ways:

- o It will force the development, to the extent possible, of EQ requirements and acceptance criteria at an early stage in the EQRP. This will insure the EQRP addresses the program objective across the breadth of all EQ issues.
- o It will provide results which may be used to evaluate whether and how subsequent EQRP research tasks will lead to the program objective.

BUDGET⁽¹⁾ AND SCHEDULE

PROJECT II: REVIEW AND EVALUATION

Tasks		Year			
		1	2		
II.1 Technical Issues			▽ 1		
II.1.1 General and Summary	120K				
		80K	40K		
II.1.2 Seismic-Aging Interaction	35K	▽ 2			
II.1.3 Seismic Checklist	55K	▽ 3			
II.1.4 Scaling Studies	35K	▽ 4			
II.1.5 Aging Technology Studies	35K	▽ 5			
II.1.6 Test vs. Analysis Studies	35K	▽ 6			
II.1.7 Characterization of Input	35K	▽ 7			
	350K	310K	40K		
II.2 EQ Process	160K	▽ 8	▽ 9 ▽ 10		
		160K			
Topical Reports		8 ▽ ▽ 6 2 ▽ ▽ 7 3 ▽ 4 ▽ 5 ▽	▽ 1 ▽ 10		
Totals ⁽¹⁾	510K	470K	40K		
(1) Costs are in terms of FY 82 dollars					

Milestones: Project II

1. General review and evaluating of EQ issues completed.
2. Seismic-aging interaction evaluation completed.
3. Issues identified through development of a walk-down checklist.
4. Scaling studies completed.
5. Aging technology studies completed.
6. Test versus analysis studies completed.
7. Review on loads to be included in EQ completed.
8. EQ review procedure checklist completed.
9. Project II results input to Project III.
10. Completion of Phase I review of EQ processes.

Topical Reports: Project II

1. Milestone 1: Report on EQ issues.
2. Milestone 2: Report on seismic-aging interaction evaluation.
3. Milestone 3: Report on identification of issues through development of a walk-down checklist.
4. Milestone 4: Report on identified needed research on scaling.
5. Milestone 5: Report on identified needed research on effects of aging and degradation.
6. Milestone 6: Report on testing versus analysis issues for Subtask II.1.1.
7. Milestone 7: Report on loads for EQ for use in Subtask II.1.1.
8. Milestone 8: Report on EQ review procedure checklist.
9. Milestone 10: Report on the evaluation of EQ processes.

PROJECT III: PHASE II PLANS

Background

Phase II of the EQRP will involve potentially expensive research-oriented tests and analyses in order to develop qualification requirements and acceptance criteria. Thus, it is important that Phase I efforts provide the basis for detailed planning to initiate Phase II to maximize the research benefits and minimize costs to meet the program objectives.

Objectives

The objective of this project is to develop detailed work plans for the initial Phase II testing and analysis tasks.

Approach and Scope

The objective of Project III will be achieved through the following four tasks:

- III.1 Test Facilities for EQRP
- III.2 Task Identification
- III.3 Task Selection
- III.4 Phase II Work Plans

The details of these tasks are given below.

Products

- o Letter report describing available test facilities; Task III.1.
- o Letter report listing tasks and priorities; Task III.2
- o Letter report on options and recommendations on five initial tasks for Phase II tasks; Task III.3.
- o Report on Phase II planning, including detailed work plans; Task III.4.

Benefits to NRC and EQRP

Phase II planning assures that Phase II will be initiated in a timely manner with appropriate considerations given to proper directions, priorities, facilities, and budget. The information developed in the planning will be useful to NRC for other purposes. For example, a comprehensive description of available test facilities will be useful regarding decisions on the need for new test facilities.

Tasks

III.1 Test Facilities for EQRP

Background

The EQRP will encompass a wide range of testing. Success of the EQRP in coming up with acceptable EQ requirements and acceptance criteria will require a match of test facility capabilities with research test demands. An identification of available test facility capabilities will thus help determine which proposed research tasks are feasible using existing facilities and what new test facilities are required.

Objective

The objective of this task is to describe the type of testing which might be done and develop a comprehensive description of the experimental capability of available test facilities which would be useful for such testing.

Approach

The approach to achieve the objective of this task is based on contacts with and, if necessary, visits to test facilities. Limited information has been compiled by SwRI [6], EDAC [7], and EERI [8]. Existing compilations may not be up-to-date or sufficiently comprehensive for the EQRP.

Product

Letter report description of the types of tests which may be required and the available test facilities and their capabilities. This product is required for the decision in Task III.3.

III.2 Task Identification

Background

Opinions on relative importance of tasks for EQ research vary and the value-impact of the tasks is not always clear. Identification and establishment of priorities of potential tasks for Phase II of the EQRP is necessary to maximize the effectiveness of the program.

Objective

The objective of this task is to identify and establish priorities of potential tasks for Phase II of the EQRP.

Approach

The approach to achieve the objective of this task is to use available information, licensing issues, experiences, and lead laboratory's judgement. Potential tasks will be identified based on EQ issues compiled in Task II.1 and current EQ practice. Priorities will be based on current EQ practices, available results from the SSMRP and PRA's, opinions of knowledgeable individuals, judgement of the Lead Laboratory, and NRC needs. Value-impact will be taken into consideration.

Product

- o Letter report list of potential tasks, with priorities, including rough estimates of the cost of task execution for Phase II. This product is required for the decision in Task III.3.

III.3 Task Selection

Background

It would be unwise and would hinder the effectiveness of the EQRP to start every high priority task identified in Task III.2 at the start of Phase II. For example, too rapid an expansion of test efforts may result in a wasteful use of resources. Careful selection of a limited number of initial tasks is, therefore, an important part of Phase II

planning. Since even the development of detailed work plans for selected tasks can be costly, we must address the expenditure of such funds carefully, and restrict the number and scope of initial tasks.

Objective

The objective of this task is to select the five initial tasks for Phase II of the EQRP.

Approach

The approach to achieve the objective of this task will be to select and recommend five of the tasks from Task III.2. The selection will be based on a balance of resource allocations, research testing vs. research analysis, mechanical vs. electrical components, short vs. long range results, and dynamic (including seismic) vs. environmental effects, as well as value-impact assessments. The final decision on the selection of the tasks will be made by the NRC.

Product

- o Letter reports on options and recommendations on the five initial tasks for Phase II. These will be used by the NRC to decide the initial Phase II work.

III.4 Phase II Work Plans

Background

Successful execution of the tasks selected in Task III.3 requires detailed work plans covering the necessary research testing and research analyses.

Objective

The objective of this task is to develop detailed work plans for the tasks selected in Task III.3.

Approach

The approach to achieving the objective of this task is to use Lead Laboratory judgment and consultation with experienced individuals. The EQRP objectives will be a key element in developing task objectives, scope, and products of the work plans. The budget for Task III.4 is based on the assumption that five tasks will be selected. This will be the basis to start Phase II without an interruption of program activities. The detailed plans will include a reconciliation of the proposed work with the program objectives. The cost estimates for task execution will be revised as appropriate from the rough costs estimated in Task III.2.

Product

- o Report on Phase II planning including detailed work plans.

BUDGET⁽¹⁾ AND SCHEDULE

PROJECT III: PHASE II PLANS

Tasks		Year			
		1	2		
III.1 Test Facilities for EQRP	30K	▽ 1			
III.2 Task Identification	110K		▽ 2		
III.3 Task Selection	30K		▽ 3		
III.4 Phase II Work Plans	230K		▽ 4		
Topical Reports			▽ 4		
Totals ⁽¹⁾	400K	170K	230K		
(1) Costs are in terms of FY 82 dollars					

Milestones: Project III

1. Test facilities for the EQRP surveyed.
2. Potential tasks for Phase II identified.
3. Tasks for Phase II selected.
4. Phase II work plans developed.

Topical Reports: Project III

1. Milestone 4: Report on Phase II planning, including detailed work plans.

PROJECT IV: VALVE STUDIES

Background

Valves are key components in nuclear power plant safety systems. The development of EQ requirements and acceptance criteria for valves will probably become one of the significant parts of the EQRP.

Valves of various sizes and types are used throughout a nuclear power plant. For example, pressurizer pilot operated relief valves (PORV) of the globe type range from 2-1/2 to 4 inch in diameter, other safety/relief valves from 2-1/2 to 6 inch in diameter, and butterfly containment purge valves from 18 inches to over 60 inches in diameter. Valves in general are a major qualification concern because of their importance to safety and because of observed anomalous behavior under normal operation. For example, in the case of butterfly valves, non-uniform approach flows may increase dynamic torque above design values, break-out torque has been observed to be high at least for some designs, reseating is a problem in the opinions of some, and excessive cycle time has been observed. NRR has indicated an interest in establishing an empirical data base to evaluate the effects of upstream piping variations on flow induced dynamic torques in butterfly valves.

In view of these concerns and the need for information, an investigation of butterfly valves is proposed as part of Phase I experimental and analytical research. Also proposed is a review of available information on valves to reveal needed research with an emphasis on safety/relief and motor operated valves (MOV).

Objectives

The objectives of this project are to:

1. Develop preliminary requirements and acceptance criteria for the qualification of a limited category of butterfly valves.
2. Develop insights and approaches to address scaling in Phase II efforts on butterfly valves.
3. Identify research required to develop EQ requirements and acceptance criteria for other valve types.

Approach and Scope

The approach to achieve Objective 1 will be through a combination of testing (using air flow) and analysis of a limited number of butterfly valves. This will include investigations of:

- o Effects of non-uniform flow
- o Break-out torque issues
- o Reseating torque issues
- o Bearing torque issues

The approach to achieve Objective 2 will be through the identification of which key scaling parameters are associated with scaling. The approach to achieve Objective 3 will be through review and evaluation of available information on PORV's and MOV's.

The objectives will be accomplished by executing the following tasks:

IV.1. Testing and Analysis of Butterfly Valves

- IV.1.1 Survey of Purge and Vent System Butterfly Valves.
- IV.1.2 Test and Analysis Plan.
- IV.1.3 Procure Selected Valves and Actuators and Other Materials.
- IV.1.4 Test and Analysis Plan Execution.
- IV.1.5 Preliminary Review of Results.
- IV.1.6 Final Testing and Analysis.
- IV.1.7 Preliminary EQ Requirements and Acceptance Criteria.
- IV.1.8 Documentation.

IV.2 Identification of Needed Research in PORV's and MOV's.

Products

- o Letter report on the results of a survey of purge and vent system butterfly valves in existing nuclear power plants, and the recommendation of valves for Phase I investigations; Subtask IV.1.1
- o Report on the results and conclusions of the investigation on butterfly valves; Subtask IV.1.8.
- o Letter report on research required for PORV's and MOV's; Task IV.2.

Benefits to NRC and EQP

Additional investigations on valves is almost certain in Phase II. The completed list of purge and vent system butterfly valves in existing plants will provide a basis for selecting valves for the investigations.

Although purge and vent system valves range from 18 to 36 inches or more in size, 8 and 18 inch valves are proposed for Phase I studies to allow studies on scaling phenomena, without incurring the large costs associated with 36 inch valves. The results will provide a basis for developing plans for Phase II investigations in a prudent, economical way. Observations that are expected to carry over to larger sized valves include: (1) the existence or nonexistence of non-uniform approach flow effects on dynamic torque, (2) the existence or nonexistence of other torques, (3) failure modes such as leaks, and (4) the significance of non-uniform flow on scaling.

The review of information on valves will help identify needed research. In particular, conclusions concerning PORV's and MOV's would be included in the review.

For the EQRP, the benefits derived from this investigation will principally be information useful for guiding the next steps in butterfly and other valve investigations.

Tasks

IV.1 Testing and Analysis of Butterfly Valves

Subtasks

IV.1.1 Survey of Purge and Vent System Butterfly Valves

Background

It is generally believed that some attributes of butterfly valve response are similar regardless of size; e.g., effects of non-uniform approach flow on dynamic torque, reseating problems, and excessive cycle time. Consequently, for ease of testing and

without taxing available test capabilities the size of valves to be tested will be smaller than and at the low end of the range of valves used in existing nuclear power plants. Aside from size, the selected valves will be as representative of the population of purge and vent system butterfly valves in existing nuclear power plants. A reasonable selection is not possible without a survey of existing plants. The recommended valves will be representative of the designs found in the survey.

Objectives

The objectives of this subtask are to:

1. Establish the population of purge and vent system butterfly valves in existing nuclear power plants.
2. Recommend the valves for Phase I investigations. (The final decision will be made by the NRC.)

Approach

The survey will be made mainly by correspondence, and if necessary by plant visits. Existing plants will be included. Attributes to be covered may include:

- o Manufacturer and model.
- o Physical size.
- o Disk configuration.
- o Number of each valve kind.
- o Separation distance, in cases of two valves in series.
- o Upstream piping configuration.
- o Downstream piping configuration.
- o Mounting.
- o Environments.
- o Malfunctions (including leak) and failure modes observed, if any.

Product

Letter report on the results of the survey, and recommendation of valves for Phase I investigations.

IV.1.2 Test and Analysis Plan

A well thought out test and analysis plan is required for the successful execution of the investigation. Development of the plan will involve review by NRC and other individuals experienced with butterfly valve testing and analysis such as manufacturers and selected staff of qualification organizations. The plan will cover such topics as:

- o Test fixture design and construction.
- o Test parameters; e.g., upstream and downstream piping configurations, valve open/close states, flow rates, and differential pressure.
- o Predictive analyses to provide guidance for testing, and interpretative analyses to extract conclusions from test data.
- o Valves will be operated while tested.
- o Instrumentation, data collection, and interpretation.

IV.1.3 Procure Selected Valves and Actuators and Other Materials

This task for procurement is separately identified for budgetary purposes.

IV.1.4 Test and Analysis Plan Execution

Testing and analyses will follow the plan developed by Subtask IV.1.2. If early results and findings deviate significantly from what is expected, the plan will be modified if necessary. The data will be analyzed and reduced as it is obtained.

IV.1.5 Preliminary Review of Results

The results of Subtask IV.1.4 will be reviewed by the NRC and consultants. Additional testing and analyses may be recommended for Phase I.

IV.1.6 Final Testing and Analysis

Any additional testing and analysis recommended and approved in Subtask IV.1.5 will be carried out.

IV.1.7 Preliminary EQ Requirements and Acceptance Criteria

Develop preliminary requirements and acceptance criteria from, testing and analyses results, for qualification of butterfly valves to accomplish Objective 1 of Project IV.

IV.1.8 Documentation

A report documenting the investigation will include:

- o Preliminary EQ requirement and acceptance criteria.
- o Recommendations for how project results should impact national standards.
- o Preliminary conclusions on the need to perform EQ on equipment similar to the selected butterfly valves.
- o Effects of non-uniform approach flow on dynamic torque.
- o Dynamic torques and bearing torques.
- o Malfunctions (including leaks) and failure modes observed.
- o Evaluations, conclusions, and recommendations.

IV.2 Identification of Needed Research on PORV's and MOV's.

Background

Various other programs are addressing PORV's and MOV's. For example, a program handled by EPRI is studying the operability of such valves on PWR's, General Electric is addressing similar issues on BWR's, and Wyle Laboratory has a data bank on valve test response. Some of these results are proprietary, and ways need to be found to extract usable results without disclosing proprietary information.

Objective

The objective of this task is to identify needed research on PORV's and MOV's.

Approach

Available information on valves will be reviewed to identify needed research on PORV's and MOV's. Contacts will be made to identify current and future efforts in other programs.

Product

A letter report will summarize the review.

BUDGET⁽¹⁾ AND SCHEDULE

PROJECT IV: VALVE STUDIES

Tasks	Year				
	1	2			
IV.1 Testing and Analysis of Butterfly Valves.					
IV.1.1 Survey of Purge & Vent System Butterfly Valves 40K	▽ 1
IV.1.2 Test & Analysis Plan 30K	▽ 2
IV.1.3 Procure Selected Valves, PC ⁽²⁾ Actuators, and Other Materials	▽ 3
IV.1.4 Test & Analysis Plan Execution 300 ⁽³⁾	▽ 4 200K 100K				
IV.1.5 Preliminary Review of Results 0K ⁽⁴⁾
IV.1.6 Final Testing and Analysis 0K ⁽⁴⁾
IV.1.7 Preliminary EQ Requirements & Acceptance Criteria 60K	▽ 5 10K 50K				
IV.1.8 Documentation 50K		▽ 6
IV.2 Identification of Needed Research on PORV's and MOV's 80K	▽ 7 55K 25K				
Topical Reports	1 ▽	7 6 ▽ ▽			
Totals (1,2,3) 560K	335K	225K			
<p>(1) Costs are in terms of FY 82 dollars.</p> <p>(2) Procurement cost (PC) not included on this page due to uncertainty of amount. Please see Table 4 for estimates for PC.</p> <p>(3) Testing cost estimates are based on representative national laboratory rates.</p> <p>(4) To decrease the cost of Phase I, LLNL is recommending Subtasks IV.1.5 and IV.1.6 not be pursued in Phase I.</p>					

Milestones: Project IV

1. Survey of purge and vent valves completed.
2. Test and analysis plan developed.
3. Test valves, actuators, and other materials procured.
4. Test and analysis plan execution completed.
5. Preliminary EQ requirements and acceptance criteria developed.
6. Valve studies documented.
7. Needed research on PORV's and MOV's identified.

Topical Reports: Project IV

1. Milestone 1: Letter report on the results of the survey, and recommendation of valves for Phase I investigations.
2. Milestone 6: Report documenting the valve studies.
3. Milestone 7: Letter report summarizing the review on needed research on PORV's and MOV's.

PROJECT V: ELECTRICAL EQUIPMENT STUDIES

Background

Seismic qualification of electrical equipment is believed by many to be a major safety-related problem. Failures of electrical equipment have been observed in seismic qualification testing. Thus, the survivability of equipment not tested may be in question. SSMRP studies have shown that 4 kv switchgears are dominant in important risk-related seismic failure sequences [9]. A survey involving over 40 operating plants revealed electrical equipment as a significant qualification concern [10]. The AFWS (and therefore its control and switchgear) is an important safety system as shown by the SSMRP and other studies [11]. The issue of qualification of electrical equipment, such as switchgear, in operating plants is an important concern of the Seismic Qualification Utility Group.

Electrical equipment is thus proposed for one of the Phase I experimental and analytical investigations. A 4 kv switchgear is a logical candidate for study since it has been identified as critical to safety. However, in the remainder of this project description the actual equipment that will be studied will be referred to as the "selected electrical equipment."

Objectives

The objectives of Project V are to:

1. Develop preliminary requirements and acceptance criteria for the seismic qualification (by a combination of testing and analysis) of electrical cabinet assemblies.
2. Develop preliminary conclusions on whether or not seismic EQ requirements and acceptance criteria need to be applied to equipment similar to the selected electrical equipment.

Approach and Scope

The approach to achieve the objectives is through a combination of testing (possibly while the assembly is energized) and analysis of a single item of selected electrical equipment. Testing will be performed on a shaker table to successively higher levels to establish the level at which:

- o Degradation of electrical function occurs.
- o Degradation of structural integrity occurs.

Data will be acquired at many locations to:

- o Provide data for analytical efforts to achieve Objective 1.
- o Insure any anomalous behavior will be detected.
- o Identify key parameters (for Task II.2) related to EQ requirements and acceptance criteria.

Objective 2 will be achieved by developing information to estimate whether or not the selected electrical equipment is significant in important seismic failure sequences.

The objectives will be accomplished through the following tasks:

- Task V.1 Select Electrical Cabinet Assembly.
- Task V.2 Test and Analysis Plan.
- Task V.3 Procure Selected Electrical Equipment and Other Materials.
- Task V.4 Test and Analysis Plan Execution.
- Task V.5 Preliminary Review of Results.
- Task V.6 Final Testing and Analyses.
- Task V.7 Preliminary EQ Requirements and Acceptance Criteria.
- Task V.8 Dominance Studies.
- Task V.9 Documentation.

Products

- o Letter report on the results of the survey of electrical cabinet assemblies in existing nuclear power plants, and selection of a unit for Phase I investigation; Task V.1.
- o Report on the results and conclusions of the investigation; Task V.9

Benefits to NRC and EQR

Further investigations on electrical equipment is likely in Phase II. The compiled list of electrical cabinet assemblies in existing nuclear power plants will be important in determining which investigations to pursue.

Although only one electrical cabinet assembly will be used, the seismic capacities determined in this project will be indicative of the capacity of similar assemblies, and can provide an estimate of margins. Therefore, estimates of the adequacy or inadequacy of such assemblies in existing plants may be possible. This research will provide information to estimate whether or not similar assemblies are significant in seismic failure sequences. Results from this research will provide part of the information for the decision on whether or not seismic EQ requirements and acceptance criteria need to be applied to similar assemblies.

The observed failure modes can be applied to similar assemblies. Consequently, areas where added attention would be prudent in EQ requirements and acceptance criteria and in further investigations in the EQR will be identified.

Since electrical cabinet assemblies are comprised of similar components (e.g., sensing relays, transfer circuits, fuse assemblies or breakers, control relays, thermal box, transformers, etc.), this research will allow the development of preliminary requirements and acceptance criteria for seismic qualification (by a combination of testing and analysis) of similar assemblies.

The benefits of the investigation to the EQRP is mainly in terms of information for Phase II planning. This includes insight on electrical equipment strengths and weaknesses, typical seismic capacities, capabilities and limitations of testing and analyses, identification of key EQ parameters, and directions for further investigations.

Tasks

V.1 Select Electrical Cabinet Assembly

Background

The electrical cabinet assembly, quite likely a 4 kv switchgear unit, to be selected for investigation should represent the population in existing nuclear power plants. The wide diversity of manufacturers, design, size, mounting, and installation means the selection should follow a survey of the plants.

Objectives

The objectives of this task are to:

1. Establish the population of electrical cabinet assemblies in existing nuclear power plants.
2. Recommend the electrical cabinet assembly for Phase I investigations. (The final decision will be made by the NRC.)

Approach

The survey will be made mainly by correspondence and, if necessary, by plant visits. Attributes to be covered may include:

- o Manufacturer and model.
- o Electrical capacity.
- o Physical size.
- o Type of unit; e.g., switchgear, motor control center, etc.
- o Number of each kind of assembly.
- o Internal components and their mounting.

- o Cabinet mounting.
- o Physical arrangement of installation including building location.
- o Environments.
- o Associated safety system and function in the system.
- o Malfunctions and failure modes observed, if any.

Product

Letter report on the results of the survey, and recommendation of an electrical cabinet assembly for Phase I investigations.

V.2 Test and Analysis Plan

Successful execution of the investigation requires a well thought-out test and analysis plan. The plan will be reviewed by NRC and other individuals experienced in the qualification of electrical equipment such as selected staff of qualification organizations. The plan will cover such topics as:

- o Test fixture design and construction.
- o Characterization of the seismic signature for testing at sequentially higher levels.
- o Predictive analyses to provide guidance for testing, and interpretative analyses to extract conclusions from test data.
- o Electrical components will be energized or operating while tested.
- o Component functionality.
- o Instrumentation, data collection and interpretation.

Interaction with the Sandia research on environmental impacts on electrical equipment will insure no duplication of effort occurs.

V.3 Procure Selected Electrical Equipment and Other Materials

This task for procurement is separately identified for budgetary purposes.

- V.4 Test and Analysis Plan Execution
Testing and analyses will follow the plan developed by Task V.2. If results deviate significantly from expected, the plan will be modified as necessary. The data will be analyzed and reduced.
- V.5 Preliminary Review of Results
The results of Task V.4 will be reviewed by NRC and consultants. Additional testing and analyses may be recommended for Phase I.
- V.6 Final Testing and Analyses
Any additional testing and analyses recommended and approved in Task V.5 will be carried out.
- V.7 Preliminary EQ Requirements and Acceptance Criteria
Preliminary requirements and acceptance criteria from testing and analyses results for seismic qualification of electrical cabinet assemblies will be developed to accomplish Objective 1 of Project V.
- V.8 Dominance Studies
Studies will be performed to determine the risk dominance of the selected equipment. The results of these studies will provide the basis to accomplish Objective 2 of Project V.
- V.9 Documentation
A report documenting the investigation will include:
- o Preliminary EQ requirement and acceptance criteria.
 - o Recommendations for how project results should impact national standards.
 - o Preliminary conclusions on the need to perform EQ on equipment similar to the selected equipment.
 - o Functional and structural capacities found.
 - o Malfunctions and failure modes observed.
 - o Evaluation, conclusions, and recommendations.

BUDGET (1) AND SCHEDULE

PROJECT V: ELECTRICAL EQUIPMENT STUDIES

Tasks		Year				
		1	2			
V.1 Select Electrical Cabinet Assembly	40K	▽ 1 []				
V.2 Test and Analysis Plan	30K	▽ 2 []				
V.3 Procure Selected Electrical Equipment & Other Materials	PC (2)	▽ 3 []				
V.4 Test & Analysis Plan Execution	355K (3)	▽ 4 []	▽ 4 []			
V.5 Preliminary Review of Results	OK (4)	245K	110K			
V.6 Final Testing and Analysis	OK (4)		[]			
V.7 Preliminary EQ Requirements and Acceptance Criteria	60K	▽ 5 []	▽ 5 []			
V.8 Dominance Studies	15K		▽ 6 []			
V.9 Documentation	50K		▽ 7 []			
Topical Reports		1 ▽	7 ▽			
Totals (1,2,3)	550K	325K	225K			
(1) Costs are in terms of FY 82 dollars (2) Procurement cost (PC) not included on this page due to uncertainty of amount. Please see Table 4 for estimates for PC. (3) Testing cost estimates are based on representative national laboratory rates. (4) To decrease the cost of Phase I, LLNL is recommending Tasks V.5 and V.6 not be pursued in Phase I.						

Milestones: Project V

1. Survey of electrical cabinet assemblies completed.
2. Test and analysis plan developed.
3. Test valves, actuators, and other materials procured.
4. Test and analysis plan execution completed.
5. Preliminary EQ requirements and acceptance criteria developed.
6. Completion of dominance studies on the importance of the selected electrical cabinet assembly to safety.
7. Electrical cabinet assembly studies completed.

Topical Reports: Project V

1. Milestone 1: Letter report on the results of the survey, and recommendation of electrical cabinet assembly for Phase I investigations.
2. Milestone 7: Report documenting the electrical cabinet assembly studies.

PROJECT VI: PUMP STUDIES

Background

Since the accident at Three Mile Island great attention has been focused on the ability of pressurized water reactors to reliably provide for shutdown decay heat removal. While it is recognized that alternate methods may be available to remove decay heat following transients or accidents, heat removal via the steam generators is the first proven choice for accomplishing a safe shutdown of the plant. The SSMRP and other studies have shown the auxiliary feedwater system (AFWS) to be an important seismic safety system. Therefore, AFWS should satisfy the seismic safety requirements for the Safe Shutdown Earthquake (SSE), consistent with other safety-related systems in the plant. However, only those facilities licensed recently have been reviewed against the NRC Standard Review Plan which treats the AFWS as an engineered safety feature. Thus, some questions have arisen as to the adequacy of the seismic capacity of the various components which make up the AFWS and especially with respect to AFWS pumps.

Two major seismic-related EQ issues of concern for pumps are:

- o The development of approaches for scaling, and
- o The development of procedures to qualify equipment by a combination of testing and analysis.

A report is available on the seismic capacity of a motor-driven pump typical of those in residual heat removal (RHR) systems [12]. If a similar investigation were carried out on a similar (but different) motor-driven pump, particularly one used in AFWS, it would lead to insight on seismic EQ scaling issues on motor-driven pumps as well as AFWS pump seismic adequacy.

Objectives

The objectives of this project are to:

1. Develop preliminary requirements and acceptance criteria for the seismic qualification of horizontal centrifugal pumps.

2. To develop preliminary conclusions on whether or not seismic EQ requirements and acceptance criteria need to be applied to equipment similar to that investigated in the project.

Approach and Scope

The approach to achieve the objectives is through a combination of testing (possibly while the pump is operating) and analysis of a single motor-pump assembly. Testing will be performed on a shaker table to successfully higher levels to establish the level at which:

- o Degradation of pump function occurs.
- o Degradation of structural integrity occurs.

Data will be acquired at a number of locations to:

- o Provide data for analytical efforts.
- o Insure any anomalous behavior will be detected.
- o Identify key parameters (for Task II.2) related to EQ requirements and acceptance criteria.

The data will provide results to achieve Objective 1. Objective 2 will be achieved by developing information to estimate whether or not the selected motor-pump assembly is significant in important seismic failure sequences.

The objectives will be accomplished through the following tasks:

- Task VI.1 Select Motor-Pump Assembly.
- Task VI.2 Test and Analysis Plan.
- Task VI.3 Review and Coordinate with Japanese Testing.
- Task VI.4 Procure AFWS Motor-Pump Assembly and Other Materials.
- Task VI.5 Test and Analysis Plan Execution.
- Task VI.6 Preliminary Review of Results.
- Task VI.7 Final Testing and Analysis.
- Task VI.8 Preliminary EQ Requirements and Acceptance Criteria.
- Task VI.9 Dominance Studies.
- Task VI.10 Documentation.

Products

- o Letter report on the survey of AFWS pumps in existing nuclear power plants, and selection of a unit for Phase I investigation; Task VI.1.
- o Report on the results and conclusions of the investigation; Task VI.10.

Benefits to NRC and EQR

Motors, turbines, and pumps may be a high priority area for (seismic-related or other) investigation in Phase II. The compiled list of such components in existing nuclear power plants will be important in arriving at decisions on Phase II investigations.

The seismic capacities determined in this project will be indicative of the capacity of similar components, although determined for one motor-pump assembly, and can provide an estimate of margins. Therefore, estimates of the adequacy or inadequacy of such assemblies in existing plants may become possible. This research will provide information to estimate whether or not similar assemblies are significant in seismic failure sequences. This research will provide part of the information for the decision on whether or not seismic EQ requirements and acceptance criteria need to be applied to similar assemblies.

Observed failure modes can be applied to similar assemblies. Consequently, areas where added attention would be prudent in EQ requirements and acceptance criteria and in further investigations in the EQR will be identified.

The results of this project will also provide insights on seismic EQ requirements and acceptance criteria in the area of scaling. This will be done through a comparison and evaluation of the results of this project and the study reported on in Ref. 12. This is the second significant scaling effort proposed in Phase I (the other is in Project IV).

Although only a single motor-pump assembly is proposed for Phase I investigation, the results will be used to develop preliminary EQ requirements and acceptance criteria for the seismic qualification of similar components.

The benefit of the investigation to the EQRP is mainly in terms of information for Phase II planning. This includes insight on mechanical equipment strengths and weaknesses, typical seismic capacities, capabilities and limitations of testing and analysis, identification of key EQ parameters, and directions for further investigations.

Tasks

VI.1 Select Motor-Pump Assembly

Background

The recommendation of the AFWS motor-pump assembly for test and analysis in this project will be based on a review of those in-service in operating plants or planned (or installed) for NTOL plants. The purpose of such a review is to insure the component selected for this project is as representative as possible.

Objectives

The objectives of this task are to:

1. Establish the population of AFWS motor-driven and turbine-driven pumps in existing nuclear power plants.
2. Recommend the motor-pump unit for Phase I investigations. (The final decision will be made by the NRC.)

Approach

The survey will be made mainly by correspondence and, if necessary, by plants visits. Attributes to be covered may include:

- o Manufacturer, model, functional description, capacities, etc.
- o Physical size.
- o Number of each kind.
- o Mounting and building location.
- o Environments.
- o Malfunctions and failure modes, if any.

Product

Letter report on the results of the survey, and recommendation of a motor-pump for Phase I investigations.

VI.2 Test and Analysis Plan

The testing and analysis will include the following attributes or elements:

- o The seismic testing will be conducted while the motor and pump are operating.
- o Pump efficiency testing will be performed before and after seismic testing.
- o Feasibility of mounting the motor-pump assembly on a reinforced concrete base in an attempt to replicate actual mounting conditions will be investigated, at least for one test series.
- o Analyses will include that of the predictive type (prior to seismic testing).
- o The pump will be disassembled and inspected prior to and after extreme seismic testing to identify any damage.
- o Real-time x-ray recording of the pump response during seismic excitation will be investigated as a data source to insure the cause of any anomalous pump behavior during high seismic-excitation is identified and to acquire additional data for analysis.

The plan will be reviewed by the NRC and other individuals experienced in qualification.

VI.3 Review and Coordinate with Japanese Testing

Although information received to date does not reveal that testing has been carried out in Japan on an AFWS motor-pump assembly, this will be investigated prior to final testing and analysis execution.

VI.4 Procure AFWS Motor-Pump Assembly and Other Materials

This separate task is established for procurement for budget purposes.

VI.5 Test and Analysis Plan Execution

Special test fixtures will be fabricated. The test and analysis plan formulated in Task VI.2 will be carried out. The data will be analyzed and reduced. Analytical efforts will be performed to address issues associated with scaling and qualification by a combination of analysis and testing.

VI.6 Preliminary Review of Results

The results of the testing and analysis efforts will be reviewed by the NRC and consultants. Additional testing and analysis may be recommended, especially to address anomalous results.

VI.7 Final Testing and Analysis

Any additional testing and analysis recommended (and approved) in Task VI.6 will be carried out.

VI.8 Preliminary EQ Requirements and Acceptance Criteria

Preliminary requirements and acceptance criteria from testing and analysis results for seismic qualification of motor-driven horizontal centrifugal pumps will be developed to accomplish Objective 1 of Project VI.

VI.9 Dominance Studies

Studies will be performed to determine the risk dominance of the selected equipment. The results of these studies will provide the basis to accomplish Objective 2 of Project VI.

VI.10 Documentation

A report documenting the investigation will include:

- o Preliminary EQ requirements and acceptance criteria.
- o Recommendations for how project results should impact national standards.
- o Preliminary conclusions on the need to perform EQ on equipment similar to the selected equipment.
- o Functional and structural capacities found.
- o Malfunctions and failure modes observed.
- o Evaluation, conclusions, and recommendations.

BUDGET (1) AND SCHEDULE

PROJECT VI: PUMP STUDIES

Tasks		Year				
		1	2			
VI.1 Select Pump	OK (3)
VI.2 Test and Analysis Plan	OK (3)
VI.3 Review & Coordinate with Japanese Testing	OK (3)
VI.4 Procure Selected Pump and Other Material	PC (2)
VI.5 Test and Analysis Plan Execution	OK (3)
VI.6 Preliminary Review of Results	OK (3)
VI.7 Final Testing and Analysis	OK (3)
VI.8 Preliminary EQ Requirements and Acceptance Criteria	OK (3)
VI.9 Dominance Studies	OK (3)
VI.10 Documentation	OK (3)
Topical Reports						
Totals (1,2,3)						
(1) Costs are in terms of FY 82 dollars (2) Procurement cost (PC) not included on this page due to uncertainty of amount. Please see Table 4 for estimates for PC. (3) To decrease the cost of Phase I, LLNL is recommending Project VI not be pursued in Phase I.						

PHASE II

Objectives

The objectives of Phase II are to:

1. Conduct test analyses and studies, complementary to Phase I tasks, that provide the technical basis for developing requirements and acceptance criteria for EQ procedures.
2. Interpret and compile the results from this EQRp and other programs such that they best satisfy NRC's needs.

Approach

This phase is a continuation of some of the research begun in Phase I; however, more emphasis will be placed on testing and analysis. In some cases, the testing efforts of Phase I will be extended to address other EQ issues. In other cases different equipment will be considered and/or different types of tests will be performed. The task plans developed in Phase I, Project III will set the initial course for Phase II efforts. Phase II research needs, priorities, and the approach to be taken (e.g., analytical vs. experimental) should be evident as a result of the Phase I work. However, many unexpected issues will likely surface from Phase II research which will require Phase II plan revisions.

The Lead Laboratory will be responsible for the overall management and technical direction of this portion of the EQRp. Thus, Phase II will contain one or more projects similar to Projects I, II, & III of Phase I. It is expected additional supporting laboratories and subcontractors will be used to assist the Lead Laboratory in executing this program phase. This additional support reflects the anticipated expanded scope and the need to use the best facilities and staff available to maximize benefit and minimize costs.

Important functions of the Lead Laboratory in Phase II will be to insure the research focuses on NRC needs and to review, interpret, and document research

results in the context of NRC's needs. Some specific equipment type results may be appropriate for regulatory guidance while other results should be put forward as standards. In the latter case, NRC's needs may be best served by encouraging the professional societies to develop the appropriate standards. Some results may be generic in the sense that they apply to many types of equipment. In this case, the Lead Laboratory must recognize this synergism and recommend the best use of the results.

Funding estimates for Phase II are not included as part of this plan. Clearly the results of Phase I must be scrutinized and priorities based on value-impact analyses must be determined before specific research scope and content are developed for Phase II. Since costs for experimental research is generally high and the need for such research is expected, the authors of this plan expect a funding rate exceeding that of Phase I will be required.

PROGRESS REPORTING

Progress in the EGRP will be reported by quarterly progress letters and through delivery of the products described in this plan. The responsibility for reporting will reside with Project I.

EQRP INTERACTIONS WITHIN THE PROGRAM AND WITH
OTHER EQ RELATED PROGRAMS

The following charts describe the projected interactions within the EQRP and with other EQ related programs. Detailed information on products, milestones, and schedules of the other programs were not available at the time of this writing; therefore, many of the dates when information are to be exchanged are either estimates or LLNL's judgment as appropriate. Interactions with other EQ related programs will also take place during the 3rd, 4th, and 5th years, although these are not indicated on the charts at this time since work scope of Phase II of the EQRP is not yet firm.

Assume 7-1-82

*Roman numerals indicate EQRP projects

NRC Sponsored EQ Related Programs	Years				
	1	2	3	4	5
Develop Bases for Selecting Equipment to be Qualified. Sponsor: NRC/NRR/EOB Contractor: BNL Δ1 Preliminary results Δ2 Final results	II II ↑ ↑ Δ1 Δ2				
Seismic Qualification of Nuclear Mechanical and Electrical Equipment. Sponsor: NRC/RES/MSEB Contractor: SWRI Δ1 Preliminary results Δ2 Review of EQ methods Δ3 Fragility results Δ4 Final results	II III III ↑ ↑ ↑ Δ1 Δ2 Δ3	II, III EQRP ↑ Δ4	Phase II		
Develop Methods for In-Situ Testing of Equipment in Operating Plants. Sponsor: NRC/NRR/GIB Contractor: INEL Δ1 Preliminary results Δ2 Final results	II III ↑ ↑ Δ1 Δ2				
The Seismic Qualification of Equipment Using Non-Nuclear Plant In-Service Dynamic Response Information. Sponsor: NRC/NRR/GiB Contractor: LLNL Δ1 Preliminary results Δ2 Final results	II III ↑ ↑ Δ1 Δ2				

Assume 7-1-82

NRC Sponsored EQ Related Programs (Cont.)	Years				
	1	2	3	4	5
Guidelines and Criteria for Development of Qualification Response Spectra. Sponsor: NRC/NRR/EQB Contractor: ANL Δ1 Preliminary results Δ2 Final results	II, III ↑ Δ1 — Δ2				
Establish Guidelines for Seismic Qualification for Equipment in Operating Plants. Sponsor: NRC/NRR/GIB Contractor: None Δ1 Preliminary information Δ2 Intermediate information Δ3 Final results	II, III ↑ Δ1 — Δ2 — Δ3	EQRP Phase II ↑			
Systematic Evaluation Program Sponsor: NRC/NRR/SEPB Contractor: LLNL, INEL, FRC Δ1 Phase II results and conclusions	II, III ↑ Δ1 — — — — —				
Equipment Qualification Testing Methodology Research Program. Sponsor: NRC/RES/EEB Contractor: Sandia Δ1 Pressure switch tests	II, III ↑ Δ1 — — — — —	EQRP Phase II ↑			
Qualification Testing Evaluation Sponsor: NRC/RES/EEB Contractor: Sandia Δ1 Motor tests	II, III ↑ Δ1 — — — — —	EQRP Phase II ↑			
Independent Verification Program Sponsor: NRC/RES/EEB Contractor: FRC Δ1 Solenoid valve tests	II, III ↑ Δ1 — — — — —				

Assume 7-1-82

NRC Sponsored EQ Related Programs (Cont.)	Years				
	1	2	3	4	5
Analysis of Reliability Data from Nuclear Power Plants.	II II				
Sponsor: NRC/RES/RMDB	III III				
Contractor: ORNL	VI IV				
Δ1 Report on pumps	↑ ↑				
Δ2 Analysis methodology report					
Δ3 Report on valves	Δ1 Δ3				
	Δ2				

Assume 7-1-82

EPRI Sponsored EQ Related Programs	Years				
	1	2	3	4	5
Identification of Mechanical Equipment Important for Qualification. Sponsor: EPRI/NPD/E&OD Contractors: To be selected Δ1 Preliminary results Δ2 Final results		II, III ↑ ----- Δ1 ----- Δ2 -----	EQRP Phase II ↑		
Radiation Effects Study. Sponsor: EPRI/NPD/S&AD Contractor: JPL	II, III ↑ -----				
Aging and Seismic Correlation Study. Sponsor: EPRI/NPD/S&AD Contractor: Wyle	II, III ↑ -----				
Definition of Seismic Data that Should Go into the EPRI Data Bank. Sponsor: EPRI/NPD/S&AD Contractor: To be selected		II, III ↑	EQRP Phase II ↑ -----		
Hydrogen Burn Experimental Survivability Scoping Tests. Sponsor: EPRI/NPD/S&AD Contractor: To be selected		II, III ↑ -----	EQRP Phase II ↑		

Assume 7-1-82

EPRI Sponsored EQ Related Programs (Cont.)	Years				
	1	2	3	4	5
Generic Qualification of Switches and Recorders. Sponsors: EPRI/NPD/S&AD Contractor:	II, III ↑ []				
Review of Condition Monitoring Techniques for Nuclear Plants. Sponsor: EPRI/NPD/S&AD Contractor:	II, III ↑ []				
Performance Testing of PWR Safety and Relief Valves. Sponsor: EPRI Contractors: Combustion Engineering and Duke Power ΔI Final results and conclusions	II, III, IV ↑ [] --- ΔI ---				

Assume 7-1-82

EQ Related Programs Sponsored by Others	Years				
	1	2	3	4	5
A Pilot Program for the Development of an Alternative Approach to Seismic Equipment Qualification. Sponsor: Seismic Qualification Utility Group Contractor: EQE Δ1 Final results	II, III ↑ ----- Δ1 -----				
PORV and SV for BWR Sponsor: BWR Owner's Group Contractor: GE	II, III ↑ ----- -----				

EQRP Phase I BUDGET

The following chart summarizes the projected budget needs of the work described for Phase I in this program plan.

EQRP PHASE I BUDGET⁽¹⁾

Projects		Year			
		1	2		
I	Program Management 642K	427K	215K		
II	Review and Evaluation 510K	470K	40K		
III	Phase II Plans 400K	170K	230K		
IV	Valve Studies ^(2,3) 560K	335K	225K		
V	Electrical Equipment Studies ^(2,4) 550K	325K	225K		
VI	Pump Studies ⁽⁵⁾ OK	OK	OK		
Totals ^(1,2,3,4,5) 2662K		1727K	935K		
(1) Costs are in terms of FY 82 dollars. (2) Procurement cost (PC) not included on this page due to uncertainty of amount. Please see Table 4 for estimates for PC. Testing cost estimates are based on representative national laboratory rates. (3) To decrease the cost of Phase I, the Project IV budget excludes Subtasks IV.1.5 and IV.1.6. (4) To decrease the cost of Phase I, the Project V budget excludes Task V.5 and V.6. (5) To decrease the cost of Phase I, LLNL is recommending Project VI not be pursued in Phase I.					

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APPENDIX A
Issues Associated with EQ

Compiled in this appendix are issues associated with EQ obtained during the course of information gathering for this program plan. The informational sources include the individuals of Table 1. The compilation is not professed to be complete, but it will provide a good starting point for Project II. It should be pointed out that some of the issues are based on actual data and some are largely based on reasonable engineering intuition. Thus, for Project II at least two aspects need to be considered: (1) how much of a problem does an issue represent, and (2) what is the value impact relative to increased plant safety if the issue were resolved.

The compiled issues are placed under 11 categories:

- o Aging and degradation (including wear).
- o Extrapolation and interpolation (scaling).
- o Sampling.
- o Characterization of loads and environments.
- o Sequencing and combination of loads and environments.
- o Margins.
- o Value impact.
- o Uncertainties.
- o Requalification.
- o Maintaining validity of EQ throughout component life.
- o Qualification by testing and/or analysis.

A list of identified issues under these headings are given in this appendix. All these headings will be considered in the EQRP. Not all are addressed in Phase I, as this is partly an exploratory phase to help define and optimize Phase II. However, this list will be extended considerably in Phase I.

Aging and Degradation (Including Wear)

- o Available accelerated aging and degradation models have not been adequately experimentally verified, and the use of these models is one of the major sources of uncertainty in the current qualification process.
- o The Arrhenius model is used as the basis for a variety of accelerated aging and degradation simulations. It is formulated for a single activation energy phenomenon. However, most real situations are not single activation energy in nature; e.g., aging and degradation driven by multiple, simultaneous chemical reactions. Evidence is found in the form of temperature and/or time dependence in measured activation energies. Consequently, the adequacy of the Arrhenius model, as it is currently used, is subject to question.
- o Ignored in accelerated aging and degradation are such parameters as rate of circulation of air and rate of input of fresh air. These parameters could effect the rate of aging and degradation in the test and, therefore, the validity of the test.

Extrapolation and Interpolation (Scaling)

- o The capability and limitations of commonly used scaling techniques are not adequately established, and thus contribute to the uncertainty of current EQ processes.
- o Controversy and confusion exist as to how and when scaling should be applied in EQ.
- o Experimentally confirmed techniques are not always available for areas where scaling appears advantageous in EQ processes.

Sampling

- o Current requirements allow the qualification of a prototype to represent a group of similar equipment. The adequacy of this procedure is not fully established.
- o Current sampling procedures are generally not founded on probabilistic considerations. How much this contributes to the uncertainty of the EQ process is not known.

Characterization of Loads and Environments

- o To envelope the required response spectrum, the ~~aps~~ response spectrum is often composed of several tests each embodying a different frequency range. The adequacy of this procedure needs to be addressed. For example, are the failure modes triggered the same, and are the strength capacities being probed the same?
- o Artificial time histories used in EQ are allowed to be derived from the required response spectrum. However, such artificial time histories are not unique or necessarily stationary. What does this mean to the uncertainty and adequacy of the qualification?
- o Simulation of actual input by certain simplified wave forms are allowed in EQ. However, much controversy exists with respect to the degree of conservatism or nonconservatism of some of these wave forms. In addition, the bases of simulation do not appear to include a consideration of how a component fails or its strength capacity.
- o Actual inputs to components are three-dimensional in nature. Because independently controlled three-dimensional testing is not generally available, simulation by one- and two-dimensional inputs are allowed in EQ. The adequacy of this simulation is not fully established.

- o In the qualification of electrical cabinet assemblies, door rattling could generate high frequency inputs detrimental to component functionality. If dummy components are used in the cabinet to establish simulated seismic input for an electrical component qualification test, the enveloping of this high frequency portion of the input could result in unsatisfactory simulation of lower frequency portions of the input, and vice versa.
- o Early qualification by test use sine dwells, sine decays, and sine sweeps. Later, sine beat emerged. Still later, sequential application of signals at various frequencies was used to simulate broader frequencies. More recently, shaped random signals are used for improved simulation of ground level motion. A pertinent question arises as to whether the previously conducted tests are conservative compared to more recent and complex tests.
- o Current practice for piping system qualification is to use the envelope of all design response spectrum at all support or anchor points and apply this envelope during qualification to all support and anchor points. The adequacy of this procedure is subject to question.
- o A proof test qualification method that is currently suggested by A/E's is known as "Envelope Qualification". In this method, the specimen is subjected to a Required Input Motion (RIM) which is based upon the expected maximum floor spectra for any equipment locations at any site in the U.S. This method is recommended for line-mounted items such as valves. This seems, in general, to be a severe overtest, and there is, therefore, concern as to the validity of the procedure.
- o Loads induced by top entry conduits into electrical cabinet assemblies are considered a problem by some and not by others. The importance of such loads for qualification needs to be clarified.

- o The response spectrum technique has been commonly used to describe seismic input in EQ. However, the power spectral density approach is considered by some to be superior. The advantages of one over the other for EQ use need to be examined.
- o For some equipment, such as valves, it is not clear how much of the pipe system of which it is a part should be included in the qualification assessment.
- o Mounting failure could be the dominant failure mode particular for some mechanical equipment. This includes, for example, mounting bolt pull-out from the concrete foundation. Should simulation of mounting condition be a part of the qualification process for certain equipment?
- o The adequacy of design loads to account for vibrations induced by rotating equipment is questioned due to the regular occurrence of failures of nozzles and attached piping.
- o Seismically induced loads in excess of the ZPA of the required response spectrum generated, for example, by impact of equipment with nearby objects, or by building impact. However, qualification is not required *beyond the ZPA of the required response spectrum.*
- o Testing is not performed to qualify equipment for certain loads, such as long term vibrational loads.

Sequencing and Combination of Loads and Environments

- o An increased awareness of the potential effects of various seismic and dynamic loads and environments has lead to a need to reassess which such loads and environments should be included in qualification requirements.
- o Synergistic effects are not described by current aging and degradation models, and very little guidelines are available.

- o Recent trends have included the possibility of earthquake and LOCA levels occurring simultaneously. Uncertainty exists as to how to include the effects of both simultaneously in a test. (However, recent findings by LLNL's Load Combination Program may have eliminated the need to consider simultaneous occurrence of earthquake and LOCA [13].)
- o In IEEE Standard 323-1974 a test sequence is suggested as the most severe. However, the standard noted that only in a few cases is the test sequence verified as being most severe. This lack of justification reflects the scarcity of data on synergistic effects or the current questionable methods of accelerated aging and degradation.
- o Test sequences typically include five OBE level tests followed by one SSE level test. Three-axis testing would leave no confusion as to how to execute this sequence. However, with two-axis testing allowed, significant latitude is created by which to interpret this test sequence. It is uncertain which is the most appropriate interpretation.

Margins

- o Current methods of qualification by testing does not assure a significant margin between design loads and equipment strength. Thus, a low probability of failure under the design load is not assured.
- o There appears to be essentially no commonly accepted procedure identified for fragility measurements in equipment today.
- o Unless fragility testing is included in the EQ process, the margin existing in the qualified equipment will not be known.
- o An increasing number of risk studies are being performed, and such studies require knowledge of the strength of equipment at excitation levels far beyond the level at which current qualification is performed.

- o The philosophy behind specified single-frequency testing is that the equipment is assumed to experience at least as much, or more, damage than it would in a more representative multi-frequency test. However, this philosophy suffers from the uncertainty that the exact form of damage cannot always be identified.

Value impact

- o The identification of equipment which shall be qualified is based on precedent and practice, is not always uniform, and is subject to disagreement.
- o There is no established method for performing value-impact assessment for EQ.

Uncertainties

- o A realistic characterization of uncertainties has not been used to develop qualification requirements.
- o Methods for quantifying the uncertainties in equipment qualification methods have not been developed.
- o Virtually no nuclear power plant has experienced a strong earthquake. Therefore, we have no direct evidence from natural events to determine the adequacy of the seismic capacity of equipment used in the industry. Consequently, the adequacy of qualification tests and analyses has not been directly tested.
- o More than one method is used to test line-mounted equipment. For valves, for example, one method is to mount the valve by its flanges to rigid bookends and excite by predicted translational response spectra only. In such cases, the torsional rocking is ignored. Other specifications require that the input motion be of a sine beat type to simulate response at a narrow pipe resonance, and be of sufficient amplitude to include the effects of torsion. It is not clear which test method is more appropriate.

- o Analytical modeling can contain a significant amount of uncertainty.
- o The analytically derived response spectrum at an equipment location subsequently used to qualify the equipment by test is uncertain due to uncertainties in structural modeling.
- o No universal equivalence exists between sine dwell, swept sine, and random. The relationships between the various combinations of wave forms are significantly different and depend on the postulated failure mechanism. Thus, this is a significant source of uncertainty in current EQ procedures.
- o It is assumed in equipment qualification that each material which may contribute to component failure has an equal contribution to the failure. This assumption is unsupported, and is therefore a source of uncertainty in the qualification process.
- o All resonance frequencies cannot always be accurately determined. Therefore, EQ processes which rely on knowing the resonance frequencies are subject to this source of uncertainty.
- o Typically, analytical models are linear. However, nonlinear mechanisms such as rattling have not been addressed in analytical qualification methods. Nonlinear effects can cause significant errors and are a source of uncertainties if not included.
- o Valves are assumed rigid in qualification processes; however, they are in fact not entirely rigid. Their natural frequencies have been observed to be as low as 14 Hz.

Requalification

- o Equipment in a system which was not originally considered safety-related but is now considered safety-related face a reassessment of adequacy.
- o Equipment qualified to original design requirements but the requirements and qualification methods have evolved also face reassessment of adequacy.
- o Equipment previously qualified, but new definition of hazards or evolved qualification requirements raise the issue of the adequacy of the equipment. Can some form of scaling be used to assess the adequacy or inadequacy of the equipment.
- o It is not clear what method is best to perform requalification, and it may depend on the equipment and the specific plant involved.

Maintaining Validity of EQ Throughout Component Life

- o Conformation of actual practice to the existing EQ and EQ maintenance requirements has not been totally established.
- o The quality of the procedure used in EQ testing, EQ analyses, surveillance, and maintenance has not been adequately assessed.
- o EQ requirements and acceptance criteria should be established such that it could provide guidelines for the checking of equipment conditions after a maintenance operation.
- o How should EQ and the uncertainties of qualification mesh together.

Qualification by Testing and/or Analysis

- o The requirement for simulated full steam flow in the testing of large prototype pumps is currently unachievable by the available testing laboratories.

- o Available recommended damping value, for various structures and equipment are rather diverse. It is not clear what values are most appropriate to use in EQ testing and/or analysis.
- o Damping in analysis is usually handled as viscous even though the actual damping may not be a viscous type. This is a choice of convenience as it has provided reasonable results that can be economically derived. However, the adequacy of this practice should be examined.
- o Two methods are available to derive a damping value for composite materials based on proportioning the damping factors according to the mass or the stiffness of each element. These methods have not been validated experimentally.
- o Equipment too large to test are often qualified by analysis. The adequacy of this procedure is not fully confirmed.
- o For motor driven pumps, fluid structure interaction is not commonly considered. However, the mass of fluid is included in the analysis.
- o For systems with more than two resonances in the amplified region of the design spectra, the static coefficient method with a loading factor of 1.5 may not be conservative relative to a dynamic analysis.

TABLE 1

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TABLE 2

NATIONAL STANDARDS, NRC REGULATORY GUIDES, AND
OTHER DOCUMENTS ASSOCIATED WITH EQ

National Standards

IEEE Std. 317-1976	Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.
IEEE Std. 323-1974	Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.
IEEE Std. 334-1974	Standard for Type Tests of Continuous Duty Class 1E Motors for Nuclear Power Generating Stations.
IEEE Std. 344-1975	Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations.
IEEE Std. 381-1977	Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations.
IEEE Std. 382-1980	Standard for Qualification of Safety-Related Valve Actuators.
IEEE Std. 383-1974	Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.
IEEE Std. 387-1977	Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.

IEEE Std. 467-1980	Standard Quality Assurance Program Requirements for the Design and Manufacture of Class 1E Instrumentation and Electric Equipment for Nuclear Power Generating Stations.
IEEE Std. 501-1978	Standard Seismic Testing of Relays
IEEE Std. 535-1979	Standard for Qualification of Class 1E Lead Storage Batteries for Nuclear Power Generating Stations.
IEEE Std. 627-1980	Standard for Design Qualification for Safety Systems Equipment Used in Nuclear Power Generating Stations.
IEEE Std. 649-1980	Standard for Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations.
IEEE Std. 650-1979	Standard for Qualification of Class 1E Static Battery Charges and Inverters for Nuclear Power Generating Stations.
ANSI/ASME N-551.1 DRAFT	Standard for Qualification of ASME Code Class 2 & 3 Pump Assemblies for Safety Systems Service - General Requirements
ANSI/ASME N-551.2 DRAFT	Standard for Qualification of ASME Code Class 2 & 3 Pumps for Safety System Service
ANSI/ASME N-551.3 DRAFT	Standard for Qualification of Shaft Seal Assemblies for ASME Code Class 2 & 3 Pumps for Safety System Service
ANSI/ASME N-551.4 DRAFT	Standard for Qualification of Motor Drivers for ASME Code Class 2 & 3 Pumps for Safety Systems Service

ANSI/ASME N-551.5
DRAFT

Standard for Qualification of Turbine Drivers for ASME
Code Class 2 & 3 Pumps for Safety System Service

NRC Regulatory Guides

- RG 1.40 Qualification Tests of Continuous Duty Motors Installed
Inside the Containment of Water-Cooled Nuclear Power
Plants (this guide supplements IEEE Std. 334-1974),
March, 1973.
- RG 1.63 Electric Penetration Assemblies in Containment
Structures for Water-Cooled Nuclear Plants (this guide
supplements IEEE Std. 317-1976), Rev. 2, July, 1978.
- RG 1.73 Qualification Tests of Electric Valve Operators
Installed Inside the Containment of Nuclear Power
Plants (this guide supplements IEEE Std. 382-1980),
January, 1974.
- RG 1.89 Qualification of Class 1E Equipment for Nuclear Power
Plants (this guide supplements IEEE Std. 323-1974),
November, 1974.
- RG 1.100 Seismic Qualification of Electric Equipment for Nuclear
Power Plants (this guide supplements IEEE Std.
344-1975), Rev. 1, August, 1977.
- RG 1.131 Qualification Tests of Electric Cables, Field Splices,
and Connections for Light-Water-Cooled Nuclear Reactors
(this guide supplements IEEE Std. 383-1974), August,
1977.

Other Documents

- DOR Guidelines "Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors," U.S. Nuclear Regulatory Commission, Division of Operating Reactors, November, 1979.
- NUREG-0588 "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment," Rev. 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, July, 1981.
- NUREG-0718 Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License, U.S. Nuclear Regulatory Commission, Office Nuclear Reactor Regulation.
- NUREG-0737 Clarification of TMI Action Plan Requirements, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, November 1980.

TABLE 3

STEP-BY-STEP PROFILE OF A TYPICAL EQ PROCESS

1. Define the function of the equipment in the nuclear power plant.
2. Define the design loads and environments.
3. Define the qualification loads and environments.
4. Select the qualification method.
5. Perform the qualification.
6. Document the qualification.

TABLE 4

PROCUREMENT COST ESTIMATES FOR
NUCLEAR PLANT EQUIPMENT AS TEST SAMPLES
FOR PROJECTS IV, V AND VI

The procurement costs listed below are estimates based on limited information from one architectural and engineering firm and two manufacturing firms. Variations with respect to manufacturers, model, sizes in some cases, etc., were not determined. The amounts should be regarded as highly uncertain. Procurement periods are one year minimum, which is not compatible with the 18 months duration of Phase I of the EQRP. For this reason, as well as the high cost, sources other than direct purchased from a manufacturer should be explored, and this will be the responsibility of the Lead Laboratory.

Butterfly Valves and Other Materials for Project IV

One 18 inch valve	30K
One 8 inch valve	15K
Two actuators	60K
Other materials	<u>30K</u>
	135K

Electrical Cabinet Assembly and Other Materials for Project V

One 4 kv switchgear	380K
Other materials	<u>10K</u>
	390K

TABLE 4 (Continued)

Pump and Other Materials for Project VI

One AFWS pump	350K
Other materials	<u>20K</u>
	370K
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Total Procurement Cost	895K