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SEISMIC VULNERABILITY STUDY
LOS ALAMOS MESON PHYSICS FACILITY (LAMPF)

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ABSTRACT

The Los Alamos Meson Physics Facility (LAMPF), located at TA-53 of Los Alamos National Laboratory (LANL), features an 800 MeV proton accelerator used for nuclear physics and materials science research. As part of the implementation of DOE Order 5480.25 and in preparation for DOE Order 5480.28, a seismic vulnerability study of the structures, systems, and components (SSCs) supporting the beam line from the accelerator building through to the ends of the various beam stops at LAMPF has been performed. The study was accomplished using the SQUG GIP methodology to assess the capability of the various SSCs to resist an evaluation basis earthquake. The evaluation basis earthquake was selected from site specific seismic hazard studies.

The goals for the study were as follows: (1) identify SSCs which are vulnerable to seismic loads; and (2) ensure that those SSCs screened during the evaluation met the performance goals required for DOE Order 5480.28. The first goal was obtained by applying the SQUG GIP methodology to those SSCs represented in the experience data base. For those SSCs not represented in the data base, information was gathered and a significant amount of engineering judgment applied to determine whether to screen the SSC or to classify it as an outlier. To assure the performance goals required by DOE Order 5480.28 are met, modifications to the SQUG GIP methodology proposed by Salmon and Kennedy were used. The results of this study are presented in this paper.

INTRODUCTION

Background

The Los Alamos Meson Physics Facility (LAMPF) located at Technical Area (TA) 53 of Los Alamos National Laboratory (LANL) is a Department of Energy research facility available for use by members of the world's scientific community and is operated by the Accelerator Operations & Technology (AOT) Division of LANL. The key feature of this facility is the 800 MeV proton accelerator used for nuclear physics and materials science research. Experimental Area A, the main proton experimental area, contains two separate meson production targets operating at one milliamp of beam current. Experiments can be performed simultaneously on four separate secondary beam channels. Radioisotopes for medical use are produced in an isotope production area just upstream of the proton beam stop. Neutrinos are also produced in the beam stop and are used in experiments on the fundamental constituents of matter. The negative hydrogen ion beam from the accelerator is directed to the Los Alamos Neutron Scattering Center (LANSCE) and the Weapons Neutron Research Facility (WNR).

The project was undertaken as part of the implementation of DOE Order 5480.25 [1]and in preparation for DOE Order 5480.28 [2]. The project is a seismic vulnerability study of the structures systems and components (SSCs) supporting the beam line from the accelerator building through to the ends of the various beam stops. The technical approach is based on a simple screening approach benchmarked against the performance of similar structures, systems , and components in real earthquakes. This experienced based methodology is used to assess the capability of the various SSCs to resist a design/evaluation basis earthquake (DBE). The DBE is taken from a recent seismic hazard study [8].

The study also served as the corrective action for the second portion of finding FS-92-6 [3] of a DOE facility safety appraisal of LAMPF performed in December, 1992. Finding FS-92-6 states, "Establish a comprehensive policy for seismic hazard mitigation in the design of new experiment support equipment at TA-53. Additionally, evaluate the seismic hazard to the beam line and existing experiment support equipment." The evaluation of the seismic hazard to the beam line and existing experiment support equipment is the focus of this study.

Scope

The project performed a seismic vulnerability study. Guidance or recommendations for strengthening those components that were either judged to have low seismic capacity, or were classified as outliers in accordance with the screening rules and caveats as contained in the GIP [6] was not part of the project scope. The resolution of outliers was not a part of the project. The exception to this was shield blocks. Generic guidance was provided for increasing the stability of the various shield block configurations.

The study included SSCs supporting the accelerator and beam line delivery complex. Systems were identified and evaluated on a component basis. The operability of systems during or immediately following an earthquake was not investigated. Therefore, the evaluations did not include an assessment of relays or mercury switches. SSC's evaluated include a limited sample of those at LAMPF, the Manuel Lujan Jr. Neutron Scattering Center (LANSCE), the Weapons Neutron Research area (WNR) and the Proton Storage Ring (PSR). The buildings at TA-53 were not evaluated but were included in a site wide study being performed by others.

The project was built around the following tasks: 1) Selection of SSCs and the assignment of performance categories; 2) Establish the design/evaluation basis earthquake (DBE); 3) Perform component walkdown evaluations; 4) Perform analyses of concrete shield blocks in various generic configurations; and, 5) Document each of the first four tasks in a comprehensive report. The following is a summary of that report.

SELECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS

Selection Procedure and Conclusions:

SSCs included in the project were selected because they belong to either one or both of the following categories: 1) Loss or damage of the SSC would result in excessive replacement cost or extended down time for the facility; or, 2) The SSC protects workers or the loss/damage of the SSC would pose a worker safety concern during or after an earthquake.

SSCs were initially selected by the Facilities Management Group [10] in the AOT Division. The SSC list was more fully developed by the seismic review team through interviews with facility operators, reviews of the safety analysis report [11] and the operations manual [12], and walkthroughs of the facility. This selection procedure followed the guidance of [13] and led to the conclusions discussed below:

Performance Categorization: From the hazard evaluation [14], it was established that several of the areas at LAMPF will have transient inventories of beam-induced radionuclides which exceed the Hazard Category 3 threshold of DOE-STD-1027-92 [9]. From DOE-STD-1021-93 [4], SSC's which perform a safety function in an HC3 or LH Safety System should be placed in Performance Category (PC) 2 for natural phenomena hazard evaluations. Because there are no SSC's determined to fit in the HC1 or HC2, the highest performance category to be considered in this evaluation is PC2.

Loss of Offsite Power: Upon loss of offsite power, the accelerator and the beam cease to function and the source of radiation is dramatically reduced. Therefore, hazards to workers, the public or the environment are minimal with the loss of offsite power.

Safety Systems: The systems in place to protect the public, the environment and the workers during operation include the exhaust ventilation systems for beam stops and beam lines and shield structures at beam lines, beam stops and experimental areas. Systems in place to protect the workers during operation also include the Personnel Safety System and the Radiation Security System. There are also two systems in place to protect equipment in the event of malfunction or accident during operation. These are the Fast Protect system and Run Permit System. While the systems in place to protect the public and environment were evaluated, the systems specifically designed to protect the worker and the equipment were not. Although these systems are obviously important for worker safety and protection of equipment, because of limited resources and because the loss of offsite power dramatically reduces the source of radiation, evaluation of these systems was not made.

Unique Components: Many components associated with the accelerator and the beam line systems are unique and/or expensive. In the case of components associated with the accelerator, many are one-of-a-kind components which would be difficult to replace and would result in extended down time. In addition, for components associated with the beam lines as well as the accelerators, alignment is critical to the functioning of the facility. Severe shaking could cause misalignment, resulting in excessive down time.

Shield Blocks: Shield blocks and overhead cranes appear to be the most significant SSC's which impose a hazard to workers in the facility. Many of the shield blocks are not tied together or to the supporting structure and pose a hazard from sliding, tipping or collapse. The overhead cranes were identified not only as a potential falling hazard, but could also result in extended down time if inoperable after an earthquake.

SSC's Selected for Evaluation:

Systems evaluated include the accelerator and beam delivery complex, the water cooling systems, the exhaust ventilation systems and the electrical power distribution system. Shield blocks in different configurations are also evaluated. The accelerator and beam delivery complex is made up of a number of elements.

Components associated with the accelerator and beam delivery complex are listed in Table 1. This component list is general and allowed the seismic review team the flexibility to group large numbers of similar components into samples for evaluation. The seismic review team worked from this general list, but collected data on specific components.

DESIGN/EVALUATION BASIS EARTHQUAKE

The SSCs at TA-53 have been identified as being in either Performance Category 1 or 2. Because many of the components are unique and would required considerable expense and time to replace it was decided by the seismic review team to evaluate all components to PC-2 criteria.

LANL has recently completed a re-evaluation of the seismic hazard at the site using state-of-the-art technology. The study [8] included paleoseismic investigations, subsurface geologic investigations and evaluation of the seismicity recorded by LANL, as well as reviews of the historical record and previous seismic hazard investigations. The study resulted in an estimate of probabilistic seismic hazard curves and median centered site specific response spectra to define the design/evaluation basis earthquake (DBE) for the various performance categories. For PC2 SSCs, the DBE is defined by the response spectrum [15] shown in Figure 1 anchored to peak horizontal ground acceleration of 0.22g.

SCREENING WALKDOWN EVALUATIONS

General Approach and Acceptance Criteria

The screening walkdown evaluations followed the procedures contained in the Seismic Qualification Utilities Group (SQUG) "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment" [6], as modified in accordance with Reference 7. The GIP has been accepted by the US Nuclear Regulatory Commission as a viable method for the seismic qualification of existing equipment in nuclear power plants.

The SQUG GIP consists of four sets of criteria:

- The experience-based capacity spectrum must bound the plant seismic demand spectrum.
- The equipment item must be reviewed against certain inclusion rules and caveats
- The component anchorage must be evaluated
- Potentially significant seismic systems interactions that may adversely affect the component safe-shutdown function must be addressed.

These criteria are in the form of screening guidelines. Items not passing the screen are not necessarily inadequate, but other methods must be used to evaluate these items further. Items not passing the screening walkdowns are termed "outliers" to be evaluated later. This was the general approach taken at LAMPF.

One significant extension of the SQUG GIP has been made for its use in DOE facilities. The Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities [6] is based on an established acceptable risk for safety class systems. The acceptable risk is presented in terms of annual probabilities of failure for various categories of structures, systems, and components. Performance Category 4 SSCs aim to achieve a level of safety that is commensurate with safety class systems in commercial nuclear power plants. Performance Category 1 SSCs are designed to achieve a level of safety that is commensurate with that achieved by SSCs designed in accordance with the Uniform Building Code. To ensure that the target probability levels given in DOE Order 5480.28 are met when the SQUG GIP procedure

Table 1 - Seismic Equipment List

Building/Location	Description
MPF-3 Sector J	Overhead Crane
	Cockroft-Walton Accelerators (Including: Basement Electrical Equipment Racks & MCC's, Faraday Cage, Isolation Transformers, Instrumentation Dome, & Ceramic Column Acclerator)
	Low Energy Transport Area (Including: Magnets & Ion Pumps)
	Injector Control Room (Including: Computers, Instrumentation Racks, & Raised Floor)
MPF-Sector A	Overhead Crane
	Shield Wall at Transition from Sector J to Sector A
	Drift Tube Linear Accelerator (Including: Cooling Water Piping, Triode RF Power Amplifiers, High Voltage Capacitor Rooms, & Wave Guide Shafts)
	Transition Region (Including: Cooling Water Piping & Magnets)
MPF-3 Sectors B-H	Overhead Crane
	Side Coupled Linear Accelerator (Including: Cooling Water Piping, Klystron RF Power Amplifier, High Voltage Capacitor Rooms, & Wave Guide Shafts)
MPF-3 Sector S (Lines A & D)	Switchyard (Including: Cooling Water Piping & Magnets)
MPF-3 Sector M (Area A)	Overhead Cranes
	Shield Blocks (Including: Bulk Shielding Over Beam Line A, Shield Walls at Experimental Caves, & Bulk Shielding at the "Doghouse"
	Exhaust Ventilation (Including: HEPA Filters, Exhaust Fan and Exhaust Stack)
	Experimental Support Transformers
	Spectrometers (1 to be evaluated)
MPF-4	Operations Center (Including: Computers, Instrumentation Racks, & Raised Floor)
MPF-7 (WNR)	Exhaust Ventilation (Including HEPA Filter, Exhaust Fan, & Stack)
	Target Cooling Water System
MPF-8 (PSR)	Magnets & Cooling Water System
MPF-30 (LANSCE)	Overhead Crane
	Shield Blocks at Experimental Beam Lines
MPF-622 (LANSCE Ops)	LANSCE Operations Center (Including: Computers, Instrumentation Racks, & Raised Floor)
Yard	Cooling Water Pump Pits (Including: Pumps, Heat Exchangers, Air Eliminators, Expansion Tanks, & Deoxygenator) Cooling Towers (Including: Fans, Towers, Pumps, & MCC's)

is used, an prescribed factor of safety [7] must exist between the experience based capacity spectrum and the ground motion specified for the component.

Demand versus Capacity:

The site specific ground motion response spectrum at 5% damping shown in Figure 1 was taken as the demand for all of the components mounted at LAMPF. The LAMPF structure is a low rise facility, with the majority of components mounted at or below grade. Thus, the ground response spectrum defines the demand for the majority of components. The only exception to this is for large electrical components that are mounted on the second floor level of the experimental building at the target areas for the beam line. The experimental area building is a two story structural steel moment frame structure. The second floor has a perimeter balcony that extends around the perimeter of the facility. Several large 480/250 transformers and other power supply equipment is mounted on this level. For this level, in-structure response spectra must be estimated in order to estimate demand.

The capacity for the components was taken as the experience-based Reference Spectrum from the GIP [6].

Reference 7 lists the safety (experience data) factors that must be maintained in order to achieve the performance goals given in DOE Order 5480.28. LAMPF components have been classified as Performance Category 2. The experience data factor for use with PC 2 components is 0.67. Figure 2 shows the capacity versus the in-structure demand scaled by the experience data factor appropriate for PC2 components. This figure shows that the capacity exceeds the demand by a factor over 2 at all frequencies of interest. It is judged that this factor of safety of 2 will envelope any modest in-structure amplification not explicitly calculated by the generation of in-structure response, with the exception of the electrical components at the second level of the experimental area building.

Thus, for items mounted at or below grade, the required capacity exceeds the demand. Items mounted in the experimental area building, where it was judged by the seismic review team that in-structure amplification could exceed a factor of 2.0, were classified as outliers.

Inclusion Rules and Caveats:

The SQUG GIP is directly applicable for 20 classes of components. The seismic review team grouped components into one of these 20 classes as appropriate. The inclusion rules and caveats contained in the GIP were checked against the installation and operating parameters for those components judged to be within one of the 20 classes. Typical components that were judged to be within the 20 classes included items such as electrical transformers, motor operated valves, air operated valves, pumps, electric motors, diesel generators, electrical switchgear, control cabinets, benchboards and panel boards, and chillers. Items not meeting the inclusion rules and caveats were classified as outliers. Items meeting the inclusion rules and caveats passed this screen.

Not all of the components at LAMPF fit the 20 classes covered by the GIP. For those unique components, the seismic review team evaluated the overall design of the component, paying specific attention to internal bracing, anchorage of individual components, and the overall load path provided by the component cabinet, or anchorage. The seismic review team interviewed plant operations personnel to determine the presence of relays and other vibration sensitive devices. Finally, the seismic review team checked for the presence of anchorage, and reviewed for seismic spatial interactions. Items were either screened from further review, based upon consensus agreement between the seismic review team members or, where consensus agreement could not be reached, judged to be outliers.

Anchorage Evaluation:

Specific anchorage evaluations were not performed as part of this study. Anchorage details were noted for heavy components for later evaluation. Data was taken in the field for anchorage type, embedment depth, concrete cracking, edge distance, and anchorage tightness. The seismic review team screened lightweight components (i.e., less than 200 lb.) from further evaluation when it was judged that those components were adequately anchored. Again, consensus agreement was required prior to screening any components from further review.

Seismic Interactions:

Seismic spatial interaction concerns were specifically noted on the walkdown data sheets. The seismic review team looked for interaction concerns such as overhead components (falling), adjacent components (bumping), attached lines for flexibility, and Category II over I items. In general, the number of interaction concerns noted was acceptably low, however, several concerns were noted. These include the use of concrete masonry (CMU) walls throughout the facility. CMU walls have generally low seismic capacities, and can present falling hazards. The bulk

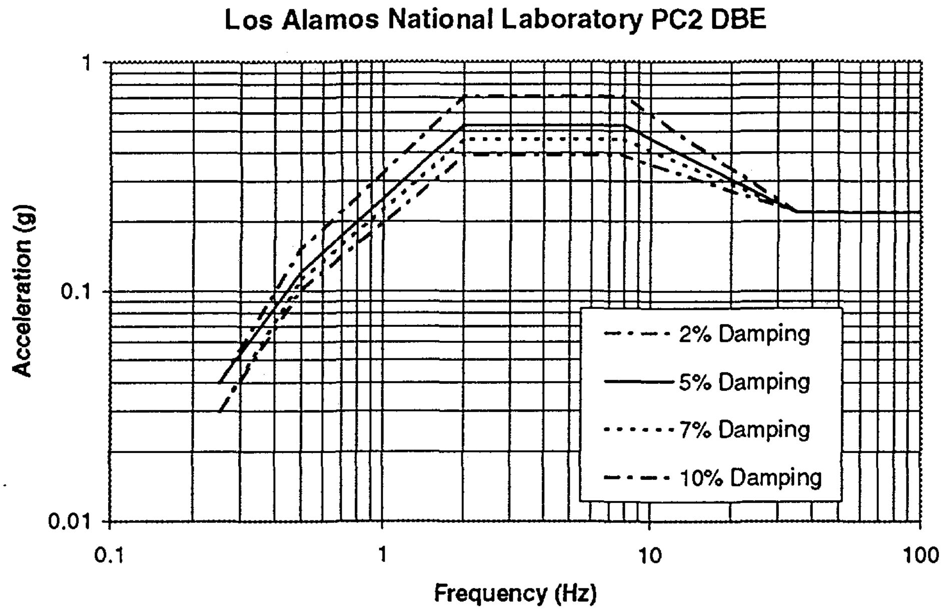

Figure 1: LANL PC2 Horizontal DBE Response Spectrum (PGA = 0.22g) [15]

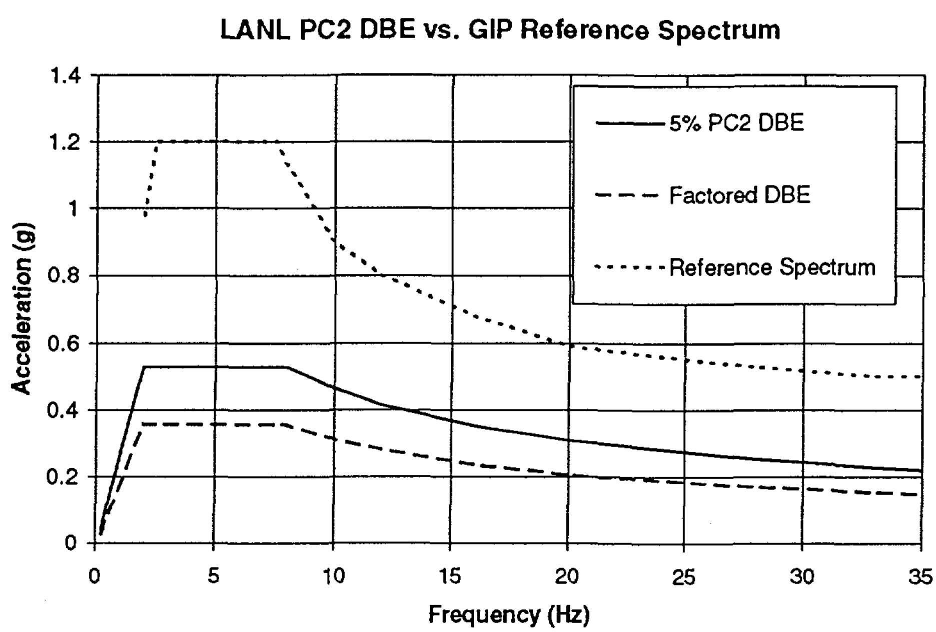

Figure 2: Comparison of Experience Based Capacity to Scaled In-Structure Demand [6], [7] and [15]

shielding and magnetite blocks used for radiation shielding present a falling hazard and are a concern. Hand carts and cabinets on wheels also are a general concern, as they represent impact hazards.

Results

A total of 506 specific components were evaluated for seismic vulnerabilities by the seismic review team. Of this amount, 117 were screened from further review. The remainder were judged to be outliers because of anchorage concerns, inadequate representation in the data base, or seismic interaction. This large number of outliers will need to be resolved in order to provide high confidence of a minimum impact on operations of LAMPF in the event of an earthquake. It is important to note that the classification of outliers is based on the performance of those components during earthquakes, and not on a perceived risk to worker safety. The bulk shielding blocks used in the experimental areas, however, may be an exception to this. Specific comments on the results of the walkdowns are provided according to individual systems evaluated.

H⁻ Injector: Components evaluated as part of the H- Injector system included transformers, anode power supply units, instrument racks, mobile carts, power supplies, and the major components inside of the Polarized Ion Source Room. A large majority of these components were unanchored. Additional components could not be screened to the specified DBE because they were unique to the database; hence, the experience based capacity spectrum could not be used as a measure of their capacity.

H⁻ Low Energy Transport Area: No components in the H⁻ low energy transport area were screened from review because they lacked vertical restraint. Components included items such as Beam Choppers, Steering Magnets, Quadropole Lens, and Current Monitors. The majority of these items are relatively lightweight (<200 lb.), however, misalignment of the beam line may be expected following the DBE due to the lack of vertical restraint. The beam line components are typically mounted using a three point attachment for vertical adjustment. A "push plate" or other device is used to align the components in the horizontal plane.

Drift Tube Linac (Support Equipment): Support equipment evaluated as part of the drift tube Linac included RF Amplifiers, wall mounted transformers, instrumentation and control cabinets, and miscellaneous support equipment. These components were unanchored and could not be screened. In addition, there are large concrete masonry unit walls adjacent to the support equipment in Sector J. These masonry walls should be evaluated.

Sector A Water Systems: Horizontal Pumps, heat exchangers, valves, a chiller, and a motor control center were evaluated as part of the sector A water systems. The valves were screened, however, the rest of the components were unanchored. The horizontal pumps were mounted on large concrete inertial blocks with spring isolators, but had no seismic stops. The Instrumentation and Control cabinets mounted in the Master Source Room are unanchored.

Drift Tube Linac - Equipment Gallery: Support equipment in the equipment gallery located above the Drift Tube Linac is unanchored. This includes the capacitors in the high voltage capacitor room, transformers, and power supplies and cabinets which are mounted on rollers.

Power Supplies for Transition Region: The power supply units supporting the bending magnets and quadropole magnets were unanchored. This is typical for all sections of the beam

Side Coupled Linac: Components evaluated as part of the Side Coupled Linac included the RF Waveguide Shafts, the Klystron RF Power Amplifiers, the Linac Tanks, and Cooling Water pumps. The waveguide shaft was screened. Anchorage checks were required for the remaining components.

Side Coupled Linac - Equipment Gallery: Distribution panels and diagnostic cabinets supporting the side coupled linac were screened. The remainder of the equipment in the equipment gallery supporting the side coupled linac could not be screened due to either missing or inadequate anchorage. Typical components included instrumentation and control cabinets, transformers, voltage regulators, and switchgear.

Cooling Tower (#2, #3): The cooling tower structure and fans were screened based on engineering judgment. Motor control centers, vertical pumps, and miscellaneous equipment in the control room could not be screened because of either missing or questionable anchorage.

Switchyard Area Beam Line Equipment: A large number of beam line components were evaluated in the switchyard area. These included items such as beam line monitoring devices (wire scanners, stoppers, beam stops), magnets (quadropole doublets, bending magnets), ion pumps, and power supplies. The majority of the in-line equipment was not screened because of a lack of vertical restraint. A three point attachment was used for major components in order to facilitate vertical and horizontal alignment; however, this feature makes the equipment vulnerable to earthquake motion. Some of the lightweight in-line monitoring equipment (scanners, harps, etc.) was screened based on engineering judgment if the load path from the component to the nearest support was judged to be good.

Equipment Support Gallery - Switchyard: Components in the equipment gallery supporting the switchyard included power supplies to magnets, instrumentation and control cabinets, transformers, motor control centers, and switchboards. None of this equipment was screened due to either missing or inadequate anchorage.

Line D Beam Equipment: The line D Beam Equipment is very similar to the beam line equipment in the switchyard. The exception is that some of the magnets in the Line D area are very large (weights exceeding 5000 pounds. These magnets are mounted using the typical three point attachment found in other beam line components. In addition, there were unrestrained shield blocks stacked around the beam line in some areas. The anchorage of some of the large magnets in the line D area were ceiling supported. Anchorage and embedment details of the ceiling supports are required. The majority of equipment in line D was not screened due to either missing or inadequate anchorage.

Proton Storage Ring Equipment: The equipment in the Proton Storage Ring is similar to the remainder of the beam line equipment. There is generally a lack of vertical restraint. Massive magnets (20,000 lbs.) are unrestrained vertically, and some support equipment is mounted on carts with wheels with no locking mechanism. Some of the lightweight monitoring equipment was screened, however, the majority of equipment in the proton storage ring was not screened due to either missing or inadequate anchorage.

MPF-7 Exhaust: Components evaluated as part of the exhaust filter plenum included the exhaust stack, fans, the exhaust filter plenum, switchboards, a transformer, and a motor control center. None of this equipment was screened due to either missing or inadequate anchorage.

WNR Target 4 Cooling Water. The components which make up the WNR Target 4 Cooling Water system are relatively small and are mounted to a common skid. Although the individual components are well anchored to the skid, and were judged to be adequate for the DBE, the skid itself is free to slide. Therefore, the system could not be screened because of interaction concerns related to excessive displacement due to sliding.

Other Components: Some of the equipment noted in Table 1 were not evaluated in detail in walkdowns. The details of the equipment fragilities, including anchorage, was either discussed with personnel familiar with its operation and structural configuration or "walked by" for comparison with similar equipment. This equipment all would fail to be screened and is discussed below.

Overhead Cranes: The seismic design of overhead cranes in the various areas comprising LAMPF was discussed with personnel responsible for maintenance and inspection of the cranes at TA-53. In general, these cranes and their support equipment do not have seismic restraints and thus cannot be relied upon to operate following an earthquake. Additional analysis would be required to determine if they represent a falling hazard.

Computers and Instrumentation on Raised Floors: The various control rooms at the facility were to be evaluated for seismic vulnerabilities. Detailed walkdowns of these facilities were not performed, but were "spot checked" to determine similarity to other instrumentation at TA-53. These checks showed that raised floors were not anchored or properly braced to resist lateral seismic loads. In addition, none of the computer equipment or instrumentation was anchored to the raised floor. These areas are vulnerable to damage caused by the DBE.

Components Comprising the Drift Tube Linear Accelerator: At the time of the walkdowns, this area was inaccessible because of RF power testing and the presence of radiation.

Components in Experimental Area A: Some amount of time was spent walking through Experimental Area A informally evaluating the equipment. Transformers, instruments on racks and power supplies at the upper levels are all unanchored with some on rollers. At the ground level, the same type of components as well as experimental equipment such as spectrometers were also unanchored with some on rollers. All of this equipment would be classified as outliers, vulnerable to seismic motion. In addition, all of the equipment on the ground level is subject to interaction with the shield blocks that define "experiment caves."

SHIELD BLOCK ANALYSIS

The LAMPF uses concrete shield blocks of various sizes for radiation shielding in experimental areas, and in areas of potential contamination. In the experimental areas, bulk shield blocks ranging in size from 2'x2'x3' to 3'x3'x18' and weights from 1.3 tons to 18 tons are stacked in various configurations to form radiation barriers. Smaller block, 6"x6"x12" (25 lb. each) is used in areas around the beam line tube for shielding. The smaller block is stacked by hand. This type of block is made of magnetite concrete. The blocks have interlocking grooves that enhance the stack stability.

The capacity of the various layouts of shield blocks subject to earthquake motion was investigated. A simple approach, designed to envelope all possible configurations of shield block layout, was used.

Approach

The approach used in evaluating the seismic capacity of shielding blocks was based upon finding the minimum capacity for block overturning from rocking or block sliding. Formulations for the rocking response of rigid blocks resting on a rigid foundation were based upon seismic demand determined at the rocking frequency of the blocks. Rocking failure requires that the blocks first have sufficient input to overcome the resisting force offered by the self-weight of the block. Simple criterion for failure of the blocks in rocking is assumed to be the point at which rocking displacements are sufficient to lead to instability of the block. The criterion for sliding is assumed to be the point at which the seismic forces overcome static friction. The HCLPF for all blocks is assumed to be the lowest HCLPF for all block configurations examined.

Results

In all cases, static friction of the blocks is sufficient to lead to block rocking prior to onset of sliding. Therefore, rocking failure governs the estimate of HCLPF. The lowest HCLPF is 0.14g and is based upon the type B-9 blocks with a height of 10 feet and a base width of 1.5 ft. Onset of overturning considering the block to be rigid also occurs at 0.14g. Therefore, rocking offers no additional capacity and the block is considered unstable as soon as rocking begins.

General Strengthening Guidelines

Reference 16 provides additional background and recommendations for the design of shielding blocks for earthquakes based upon reference research and design applications at the Lawrence Berkeley Laboratory. It is recommended that the guidance provided in [16] be followed for strengthening the existing shield block configurations.

CONCLUSIONS AND RECOMMENDATIONS

Items Screened from Review

For those components that were screened from further review, it is the opinion of the seismic review team members that no further evaluations need to be performed for those components, and that there is a high confidence that those components will function following the 1000 year return period earthquake specified by Reference 8. This is a 0.22g pga event.

Outliers

Components that could not be screened from further review because of either anchorage issues, seismic interaction concerns, or component specific vulnerabilities require either further analysis, testing, upgrade, or research in order to mitigate potential damage due to the specified seismic event.

Recommendations for Resolutions of Outliers

A multi-phased approach is recommended to resolve outliers. The initial phase is to identify the system vulnerabilities. This has been completed in this study. The subsequent phase is to rank the desired upgrades based on a risk standpoint. The risk is loss of operations due to beam misalignments and/or damaged support equipment, all of which could be the result of an earthquake. A cost/benefit analysis should be performed to provide a quantitative value to the proposed upgrades. Following the cost/benefit analysis, budgets must be obtained and set prior to completing the upgrades.

Inexpensive upgrade options should be considered prior to submitting a list of planned fixes for the cost/benefit analysis. It is far better from both a cost standpoint and a risk standpoint to implement easy solutions from an operating budget, than to spend hours completing cost/benefit studies and going through a formal capital budgeting process. Simple solutions include plant fixes that can be provided through normal plant maintenance. Examples include providing cable tie-downs to loose monitoring equipment that is stored on fixed cabinets, and moving carts on wheels to safe parked locations in order to minimize the potential for falling or sliding hazards. A large majority of the vulnerabilities at TA-53 are caused by the lack of anchorage. In many cases, simple upgrades may be accomplished by simply adding the required anchorage. Component examples include instrumentation racks, power supplies, and motor control centers (MCC's). Simple calculations could be performed to provide guidance as to the size and type of anchor bolt required to secure the component. This guidance could be given to personnel for use in the installation of anchor bolts and cabinet to cabinet attachments both of which could be performed as part of routine maintenance.

Other Recommendations

This study focused on the components in the beam line from the source room to the experimental areas and the beam stops. Safety systems designed to mitigate normal operating transients were not evaluated because it was assumed that loss of offsite power would bring the beam to a safe shutdown mode of operation. The focus of this program was to minimize downtime by providing a high degree of confidence in maintaining beam alignment and damage or loss of one-of-a-kind components. It is recommended that a further study be implemented that focuses on providing a high degree of confidence of functionality of safety systems following an earthquake. Such a program could be implemented as an extension of the work presented in this report.

REFERENCES

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