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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
PRIVATE FUEL STORAGE L.L.C.	)	Docket No. 72-22-ISFSI
	)	
(Private Fuel Storage Facility)	)	

APPLICANT'S REPLY TO THE PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW OF THE STATE OF UTAH AND THE NRC STAFF ON UNIFIED CONSOLIDATED CONTENTION UTAH L/QQ (SEISMIC)

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Pursuant to 10 C.F.R. § 2.754 and the Order of the Atomic Safety and Licensing Board ("Licensing Board" or "Board") dated October 8, 2002, Applicant Private Fuel Storage L.L.C. ("Applicant" or "PFS") submits its reply to the proposed findings of fact and conclusions of law filed by the State of Utah ("State")[1] and the NRC Staff ("Staff")[2] concerning Unified Consolidated Contention Utah L/QQ (Seismic) ("Contention Utah L/QQ"). PFS's reply follows the organization of and responds to the proposed findings

[1] State of Utah's Proposed Findings of Fact and Conclusions of Law on Unified Contention Utah L/QQ (September 5, 2002) ("State Findings"). Specifically numbered findings by the State will be referred to as "State F."

[2] NRC Staff's Findings of Fact and Conclusions of Law Concerning Unified Contention Utah L/QQ (Geotechnical Issues) (Aug. 30, 2002) ("Staff F.").

of the State,[3] because the Staff's proposed findings are in general agreement with those of PFS.[4]

I. INTRODUCTION

At the outset, we must apologize for the length of these reply findings. One would expect that most of what needed to be said about Contention L/QQ, complex as it is, would already have been covered in the extensive proposed findings filed by the parties on September 5, 2002. Unfortunately, that is not the case. The State Findings take extreme liberties with the facts, the evidence presented by all parties, and even the applicable law and regulations. The misleading nature of the State's filing is regrettable because it tends to hinder, rather than assist, the Board in reaching a decision that is supported by the record. It is also requires a far more detailed refutation than what would normally be necessary at this stage of the proceeding.

Following is a summary of the most objectionable features of the State Findings. While the specifics of each feature are discussed in the rest of this Reply, PFS believes it is important that they be pointed out at the outset so the Board can be aware of these problems with the State's submittal, which PFS fear will be reproduced in the State's reply Findings to which no response is permissible.[5]

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[3] It is not the intent of this reply to respond to every erroneous, overstated, or unsupported finding proposed by the State. Rather, PFS will address only those among the State's proposed findings which would be material to the ultimate ruling by the Board, or which raise the risk of creating confusion.

[4] Applicant's Proposed Findings of Fact and Conclusions of Law on Unified Contention Utah L/QQ (September 5, 2002) ("PFS F.").

[5] For example, in the State's Reply to the Proposed Findings of Fact and Conclusions of Law of the Applicant and the NRC Staff on Contention Utah K/Confederated Tribes B, dated October 7, 2002, the State, after failing to raise the issue in its initial proposed findings, repeatedly accuses PFS's expert witnesses of bias. See id. at 2 ("subjective opinion of the Applicant's hired witnesses"), 3, 4, 14, 18, 74.

A. The State takes extreme liberties with the record in this proceeding

The State Findings are replete with gross mischaracterizations of the record. The State repeatedly claims that "no evidence exists" on a particular point where there is ample evidence in the record, sometimes introduced by the State itself or provided in response to State requests. Conversely, the State proposes many findings for which there is no supporting evidence in the record. The State Findings also often distort what the evidence says. They go beyond giving the State's own interpretation of the meaning of the evidence to misquoting and otherwise distorting the contents of the exhibits and testimony in the record. A very few of the most egregious examples follow.

1. Examples of findings of fact wholly unsupported by evidence

- State F. ¶ 92: "The samples of the upper Bonneville clays that PFS has used for testing may not be representative of actual field conditions." No record citation is offered, because there is no record support for this claim.
- State F. ¶ 96: "Attaining the target cement-treated soil properties in the field will be affected by the quantity and timing of cement-treated soil production and placement as well as by the competency of the contractors in ascertaining what measures they will take to ensure adequate adhesion between interface layers." No evidence supports this finding.

2. Examples of incorrect claims that "no evidence exists."

- The State claims that "there are no design calculations to support the Applicant's assumption that the foundation mat is rigid. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 21." State F. ¶ 243. In reality, a design calculation that establishes that the CTB is rigid was performed by PFS, was in-

troduced into evidence as PFS Exh. YY, and was thoroughly discussed at the hearing. See Tr. 6391-6424.

- The State claims that no document in evidence lists every input value for each of the VisualNastran simulations. State F. ¶ 289. However, a compilation of input values for each of the VisualNastran simulations was developed by Holtec at the State's request during the hearing and was provided to the State (Tr. 6480-81). The State subsequently introduced this compilation of input parameters as State Exh. 179 and used it during cross-examining Dr. Luk. See Tr. 6941-42.

B. The State takes extreme liberties with the testimony of most witnesses, including the State's own

The State Findings commonly misrepresent the oral testimony presented at the hearing, including that of the State's own witnesses. Also, on many occasions the State proposes findings that simply ignore contradicting testimony, including that of its own witnesses. Again, for illustration purposes, the following examples can be cited:

1. Mischaracterization of testimony

- State F. ¶ 312 cites Dr. Soler for the proposition that "there is no single correct contact stiffness value that is appropriate for the non-linear analyses of the cask." In fact, Dr. Soler and Dr. Singh testified that there is a range of values of contact stiffness that are appropriate for a cask stability analyses. See, e.g., Tr. 6039-41 (Singh).

- The State quotes an excerpt from the testimony of PFS witness Dr. Cornell in an attempt to cast doubts on the reliability of nonlinear analyses. State F. ¶ 256; see also State F. ¶ 398. Contrary to the State's misleading gloss

on his testimony, Dr. Cornell actually opined that the nonlinear analyses by Holtec and Sandia had served to reduce uncertainty in the estimation of cask performance. Tr. 8022 (Cornell). Indeed, in responding to a question from Judge Lam on whether non-linear analysis is generally suspect or "unreliable," Dr. Cornell's response was: "Absolutely not. No. Typically they are reliable." Tr. 8010 (Cornell).

2. **Ignoring contrary testimony by the State's own witness**

- State F. ¶ 467 indicates that the design basis earthquake for the PFSF should have a minimum return period of 2,500 years because that is the return period used in interstate highway bridges in Utah, certain buildings and the International Building Code. Both Dr. Bartlett and Dr. Arabasz disavowed choosing earthquake return period solely on the basis of what was done for other facilities. Tr. 9187-88 (Arabasz); Tr. 12808-09 (Bartlett).

- State F. ¶ 524 rejects as "cutting edge probabilistic approach to seismic performance" the consideration of design conservatisms inherent in the industry codes and standards in evaluating overall risk. That rejection wholly contradicts with the testimony of Dr. Arabasz and Dr. Bartlett, both of whom embraced the "two-handed approach" to seismic design margins propounded by PFS witness Dr. Cornell. Tr. 9120-21 (Arabasz); Tr. 12809 (Bartlett).

C. The State Ignores or Misconstrues Applicable Legal Standards

The State presents unprecedented legal theories as if they were established jurisprudence; advances legal arguments that are contrary to Commission case law and ignores Commission guidance, some of it issued in this very proceeding.

Section II below discusses in detail the State's departures from applicable legal standards. Some of the most egregious examples include:

1. Asserting in its proposed findings new claims not within scope of Contention L/QQ

On numerous occasions, the State's proposed findings raise new issues that were not asserted in Contention L/QQ. For example, in State F. ¶ 226 the State raises as a "major concern" involving "uncertainties" in the pad overturning calculation. This issue is not part of the contention and was never raised by the State's witnesses in their hearing testimony.

The State's attempt to expand its claims under the guise of proposed Board findings is contrary to the October 1, 2002 Commission ruling on the importance of sticking to the scope of admitted contentions. See Private Fuel Storage L.L.C. (Independent Fuel Storage Installation), CLI-02-20, 55 NRC ___, slip op. at 14-15 (October 1, 2002); and see Section II.2, infra. It is also unfair for the State to raise new issues at a time where the other parties have no opportunity to present evidence to disprove the claims.

2. Expanding the Board's role to include performing a de novo review of licensing materials and other documents that do not directly relate to Contention L/QQ

Commission case law makes it clear that the Licensing Board has the responsibility for reviewing the record developed before it and for formulating the agency's initial

decision based on that appraisal. The Board's role is limited to evaluating the testimony in the record. See Section II.5 below.

The State, however, in numerous occasions claims that data or analyses, not specifically put into issue by the parties, should be reviewed by the Board and that the failure to introduce these documents in evidence constitutes a failure by PFS to meet its burden of proof. For example, in State F. ¶ 282 the State argues that since the training manual for the DYNAMO code is not in evidence, the Board cannot verify its capability to accurately analyze the nonlinear seismic response of a free standing cask at the PFS site.

3. Imposing new requirements on the qualifications of experts and the supporting evidence that experts must submit

The State would have the Board find that the experts testifying on behalf of PFS and the Staff are insufficiently qualified because they have not worked on the seismic design or analysis of a facility identical in all respects to the PFSF, even though neither case law nor Commission practice impose such a requirement. See Section II.6.b below. For example, Dr. Vincent Luk of Sandia National Laboratory is said not have sufficient qualifications because he does not have "experience in the nonlinear modeling of the seismic behavior of cylindrical free standing casks supported by cement-treated soil and a relatively soft clay foundation at ground motions equal to or greater to [sic] the 2,000-year earthquake at PFS." State F. ¶ 392.

The State would also deny weight to the opinions by PFS experts because some of the reports or data underlying the opinions are not part of the record. For example, the State would not give credence to Dr. Singh and Dr. Soler's uncontroverted opinion that the fuel-enclosing canister will not be breached upon a tipover because the tipover analyses performed by Holtec was not introduced into evidence. State F. ¶ 365.

4. Seeking to elevate Staff guidance to the status of licensing requirements when it suits the State's interests

When it suits its hearing positions, the State argues that NRC Staff guidance documents have the force of regulations and PFS must comply with them to achieve licensing of the PFSF. See, e.g., State F. ¶¶ 10, 11,44, 67, 132, 244, 247. Yet at other times the State argues that the Staff guidance should carry no weight. See, e.g., State F. ¶ 569. However, as explained in Section II.7, NRC guidance documents are not binding. They serve to help applicants and licensees comply with regulations, but "nonconformance with such guides does not equate to noncompliance with the regulations."

* * *

PFS takes no pleasure in focusing on these shortcomings in the State Findings. Our job would be much easier were we only called upon to address differences of technical opinion among experts. There is much of that in this case, of course. However, the bulk of the State Findings is of a different nature, and thus calls for a different, longer, and often more arduous effort from the other parties.

Despite the State's efforts to bend the law and the record on the seismic issue, the evidence overwhelmingly shows that the PFSF will be a safe facility from the seismic standpoint and that it will operate in accordance with Commission regulations and without undue risk to public health and safety.

II. LEGAL STANDARDS

1. "Decisional framework" and cost considerations

The State opens the legal section of its proposed findings with the proposition that "[n]owhere in the Atomic Energy Act is there a clear statement of the Commission's au-

thority to issue a license for storage of spent nuclear fuel in an ISFSI." State F. at 4.[6] From that starting point, the State concocts the following argument: since there is no express authority in the Atomic Energy Act ("AEA") to authorize construction of ISFSIs, such authority must be derived from Section 161(a) of the AEA, which contains a general grant of authority to the Commission to "establish ... standards ... to govern the possession and use of special nuclear material, source material, and byproduct material." 42 USC § 2201(a). Id. at 4-5. However, if the Commission's authority is derived from Section 161, that section cannot be read as allowing the consideration of economic costs in the licensing of ISFSIs. State F. at 3-8. This is an incorrect reading of the AEA in numerous respects.

The State's reference to costs is perplexing because no party, other than the State in its proposed fundings, has raised costs or economic considerations as relevant to any issue in this proceeding. PFS does not rely on any cost-based argument in this proceeding, nor does Contention L/QQ framed by the State relate to costs in any way.[7] It is only the State who makes reference to costs at various points in its proposed findings.[8] Therefore, though irrelevant to resolving any of the contested issues in this matter, we consider the State's arguments below.

The State seeks to bolster its interpretation of the AEA by citing Union of Concerned Scientists v. NRC, 824 F.2d 108 (D.C. Cir. 1987). The State acknowledges that UCS held that Section 161 "empowers – but does not require – the Commission to estab-

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[6] This premise fits poorly, if at all, with the States' parallel argument that the NRC has no jurisdiction to license an ISFSI such as the PFSF. See State of Utah Suggestion of Lack of Jurisdiction, dated February 11, 2002

[7] See Section II.2 below with respect to the need to reject any issues raised by the State outside the scope of Contention L/QQ.

[8] In addition to the legal argument, the State makes explicit cost arguments in State F. ¶¶ 171, 172, and 587. The State also refers to the PFSF design as "cheap". State F. ¶ 144.

lish safety requirements," and is a discretionary provision that allows the Commission to impose additional safety precautions "on nuclear power plants already satisfying the adequate protection standard," and may take costs into account in so doing. State F. at 4-6. The State argues, however, that this holding was premised on Section 182(a) of the AEA mandating adequate protection of the public health and safety absent any consideration of costs. The State therefore reasons that, because there is no source in the AEA analogous to Section 182(a) providing authority to license ISFSIs, Section 161 cannot be discretionary in the context of ISFSIs. Thus, all that Section 161 can do is impose safety requirements, and economic factors cannot be taken into account in licensing an ISFSI. Id.

Aside from the tortured logic, the State's argument makes no sense from a statutory interpretation perspective, and misinterprets the holding in UCS. If the State's novel interpretation of the AEA and UCS were correct, the Commission could not provide any additional measures for ISFSIs beyond those needed just to ensure adequate protection to public health and safety. The argument clearly proves too much.

In reality, the AEA authorizes the Commission to license and regulate the possession, use, and transfer of source, byproduct, and special nuclear materials as constituent materials regardless of their aggregate form. See AEA §§ 53, 62, 63, 81, 161(b), 42 U.S.C. §§ 2073, 2092, 2093, 2111, 2201(b). Source, byproduct, and special nuclear material can all be found in spent nuclear fuel. 10 C.F.R. § 72.3. Because the constituents of spent nuclear fuel include source, byproduct, and special nuclear materials, these provisions of the AEA, among others identified in 10 C.F.R. Part 72 under "Authority," provide the Commission broad plenary power to license and regulate the possession of spent

nuclear fuel – including its storage in an ISFSI – independent of the general grant of authority in Section 161, and the courts have so held.[9]

Since the Commission has authority beyond Section 161 to license spent fuel storage facilities, the provisions in Section 161 can be used – following the State's theory – to establish requirements for which cost considerations may be appropriate. The Court in UCS held that "Section 161 of the Act empowers (but does not require) the Commission to establish safety requirements that are not necessary for adequate protection and to order holders of or applicants for operating licenses to comply with these requirements" and that when the Commission is deciding whether to impose additional requirements, "the NRC may take economic costs into account, even to the extent of conducting strict cost-benefit analyses. In sum, the Act precludes the NRC from taking costs into account in establishing or enforcing the level of adequate protection, but allows the NRC to consider costs in devising or administering requirements that offer protection beyond that level." UCS, 824 F.2d at 119.

The State further argues that even if the Commission has the authority to consider economic costs in the licensing of an ISFSI, that does not mean that cost considerations may be entertained when deciding whether a license applicant meets established health and safety standards. State F. at 7. The State cites Cincinnati Gas & Electric Co. (William H. Zimmer Nuclear Station), LBP-79-24, 10 NRC 226 (1979) for that proposition. The issue of cost was raised in Zimmer by an intervenor trying to stop pre-licensing shipment of unirradiated fuel, on the grounds that the shipping costs would not produce any benefit to the ratepayers if the plant's operating license were not issued. Id. at 227.

[9] See, e.g., Jersey Cent. Power & Light Co. v. Lacey Township., 772 F.2d 1103, 1112 (3d Cir. 1985), cert. denied, 475 U.S. 1013 (1986); Illinois v. General Elec. Co., 683 F.2d 206, 215 (7th Cir. 1982), cert. denied, 461 U.S. 913 (1983).

The Zimmer holding is therefore inapposite because it does not deal with cost considerations in the context of protecting public health and safety.

NRC case law is clear that economic factors may be considered in various aspects of Commission decision-making. See, e.g., UCS, supra; see also Cleveland Electric Illuminating Company (Perry Nuclear Power Plant, Units 1 and 2), ALAB-841, 24 NRC 64, 99 (1986) (an exemption may be based, at least in part, on a desire to reduce costs). Cost considerations are germane in evaluations of the public interest that must be found in certain Commission actions. For example, in amending 10 CFR § 50.12, which concerns the standards for granting exemptions under 10 C.F.R. Part 50, the Commission addressed what constitutes the public interest under its exemption regulations. In its statement of considerations for the new regulation, the Commission specifically rejected the assertion that the Commission may not consider economic factors in granting an exemption, stating:

> The Commission believes that judicial precedent and long-standing Commission practice confirm that, within the confines of carrying out its paramount responsibility to protect public health and safety, it may consider economic factors in its decision making. The Commission's regulatory mandate is couched in terms of "adequate protection of the public health and safety," 42 U.S.C. 2232. The courts have held that absolute safety or zero risk is not required, and have interpreted the Atomic Energy Act to confer considerable discretion on the Commission to determine what level of protection is adequate. Consequently, the basic standard is inherently broad and general, rather than precise. As long as a Commission decision adheres to the primary "adequate protection" standard, the decision can legitimately take into account cost considerations.[10]

Thus, as long as the Commission assures adequate public health and safety, it can legitimately take cost considerations into account in its regulatory and licensing functions.

[10] 50 Fed. Reg. 50,764, 50,767 (Dec. 12, 1985) (footnote omitted).

2. Scope of Proceeding and Expansion of Issues in Controversy

Throughout its reply findings, the State repeatedly attempts to broaden the scope of the Contention L/QQ. First, the State tries to expand the bases of its contentions by raising new issues that it has not previously specified such as, for example, the issues concerning public interest discussed in Section II.3 below. Second, as the State asserts that PFS has the burden of proof on showing that it complies with all regulations applicable to an ISFSI without limiting its assertions to regulations related to issues properly raised in Contention L/QQ.

The Board must reject all attempts to broaden the scope and bases of the Contention L/QQ. As the Commission has recently reiterated, "'longstanding practice requires adjudicatory boards to adhere to the terms of the admitted contentions' in order to give opposing parties 'advance notice of claims and a reasonable opportunity to rebut them.'" Private Fuel Storage L.L.C. (Independent Spent Fuel Storage Installation), CLI-02-20, 55 NRC ___, slip op. at 14 (Oct. 1, 2002) (quoting Louisiana Energy Services, L.P. (Claiborne Enrichment Center), , CLI-98-3, 47 NRC 77, 105 (1998). The Commission underscored the importance of requiring that contentions "include a 'specific statement of the issue of law or fact to be raised or controverted.'" Id. (citing 10 C.F.R. § 2.714(b)(2)).

The State's attempt in its proposed findings to raise issues outside the scope of the Contention L/QQ is an clear violation of CLI-02-20, by seeking to raise after the eleventh hour issues such as: allegations that the seismic design of the PFSF has evolved "in response to cost cutting measures" and that the "pieces" of the PFS seismic design "have not been fully thought out and integrated," State F. ¶ 171; alleged failure by PFS to demonstrate that the cask storage pads are "flexible enough for the cask drop and tip over constraint and rigid enough to produce significant radiation damping and provide a smooth (*i.e.*, undeformed) surface for cask sliding," State F. ¶ 196; an alleged deficiency in the PFS design in failing to conduct soil-structure interaction analyses, State F. ¶¶ 198-

204; the allegedly incorrect use by PFS in its pad stability calculation G(B)-04 of peak ground acceleration to calculate the inertial forces acting on the pad, State F. ¶¶ 205-211; alleged deficiencies in the PFS calculation of pad stability against overturning, State F. ¶¶ 225-27; allegations of bias due to economic interest by the Holtec witnesses, State F. ¶¶ 256-260.

3. Appropriate Consideration of Public Interest

a) State's Public Interest Claims Are Beyond the Scope of the Contention

The State asserts that design of the PFSF has not met the "public interest" standard required by 10 C.F.R. § 72.7. State F. at 11-13 and ¶¶ 586-588. The State cites Connecticut Yankee Atomic Power Co., 2 AEC 393, 394 n.2 (1964) for the proposition that "[t]he determination to be made if '. . . otherwise in the public interest' is not limited merely to safety considerations, since the word 'otherwise' is defined as 'in other respects.' It is concluded that 'public interest' is not needless repetition to the safety factors in the term 'endanger life or property, but constitutes a distinct and separate aspect to be resolved.'" State F. at 11. The State interprets this language to mean that the public interest should consider, inter alia, the 1951-1962 above-ground testing of nuclear weapons in Nevada, whether the PFS design is "untested", and the "moral obligation" of the NRC as the successor to the AEC. Id. at 11-12. The State's legal analysis and the factual assertions on which it relies are both faulty.

It is important to emphasize that the State has never challenged the granting of the seismic exemption sought by PFS on public interest grounds, neither in the initial submittal of the contention, see State of Utah's Request for Admission of Late-Filed Modification to Basis 2 of Contention Utah L, November 9, 2000, nor in the final text of Conten-

tion L/QQ. See PFS Exh. 237. It is entirely too late now to raise such claims in its proposed findings, and such an attempt must be rejected. See Section II.2, supra.

Moreover, the State's analogy of the PFSF to the nuclear weapons testing is preposterous and wholly unsupported both legally and factually. Indeed, the State asserts that "public interest "constitutes a distinct and separate aspect" from a "needless repetition" of the safety issues to be resolved by the Board, yet it claims that using Utah as "a test case" for storing 4,000 spent fuel casks "smacks as another untested experiment that will again cause undue risk to Utah citizens." State F. at 12. Whether the PFSF would present undue risk to the citizens of Utah is precisely the question of health and safety that will be decided in determining whether the exemption adequately protects public health and safety. If it were determined that the exemption would cause undue risk to Utah citizens, the exemptions would not be granted and the consideration of public interest within the meaning of 10 C.F.R. § 72.7 would never be reached. To the extent that the State is talking about fear of undue risk from the licensing of the PFSF, that is not properly a consideration for NRC licensing decisions. Metropolitan Edison Co. v People Against Nuclear Energy, 460 U.S. 766 (1983).

Thus, the State's claims of public interest are beyond the scope of the contention and must be rejected. In any event as discussed below, granting of the exemption is clearly within the public interest as that term is broadly utilized by the Commission.

b) Necessity of Exemption from Regulations

Central to the State's "public interest" claim is the idea that exemptions from regulations are generally not in the public interest. See, e.g., State F. at 11("the effect of the exemption...is to dilute the margin safety"); see also id. at ¶¶ 535-36. This notion, however, is contrary to law. It is a well-established principle of administrative law that exemptions or waivers are a key "safety valve" for effective regulation. See, e.g., WAIT

Radio v. Federal Communications Comm'n, 418 F.2d 1153, 1159 (D.C. Cir. 1969). Indeed, due process may be denied a regulated entity in the absence of an exemption procedure. See, e.g., Chemical Mfrs Ass'n. v. Natural Res. Defense Council, Inc., 470 U.S. 116, 133 n.25 (1985) (citations omitted). In areas of complex regulations the authority of an agency to provide exemption procedures is well established. United States v. Allegheny-Ludlum Steel Corp., 406 U.S. 742, 755 (1972). Thus, having an exemption scheme is not inconsistent with the public interest, and is actually a requirement of due process.

c) Public Interest in Granting of the PFS Exemption

The State specifically asserts, in reference to the PFS exemption request, that "[t]here was no evidence presented that the Staff considered the public interest in agreeing to PFS's exemption request." State F. ¶ 586. This is factually incorrect. The Staff witnesses, under questioning by counsel for the State, advanced a public interest for granting of the exemption. Dr. Stamatakos testified that the use of probabilistic seismic hazard analysis in establishing the design basis of the PFSF was in the public interest because, inter alia, it was a better way to achieve the purposes of the regulations governing the siting of ISFSIs:

> . . . the exemption request takes advantage of significant advances in understanding of how best to quantify earthquake seismic hazard assessments, compare to an approach that, by all accounts, the deterministic approach has significant flaws. So in that aspect, we can argue that by moving toward a probabilistic society we're moving toward a better understanding and evaluation of hazards without incorporating unrealistic effects into our seismic hazard assessment. And again, our analysis is based on technical evaluation of the application and the exemption requests.

Tr. 8253 (Stamatakos); see also Tr. 8259-60 (McCann). Dr. Cornell similarly identified the advantages of a probabilistic approach. Cornell Dir. at A16.[11]

The exemption thus allows use of the significant advances in understanding of how best to quantify earthquake hazards since Part 100, Appendix A was initially promulgate, and implements a risk graded approach consistent with the probabilistic risk approach adopted by the Commission. Cornell Dir. at A14-A24, A55. Such a probabilistic risk-graded approach allows "a rational and equitable allocation of safety resources. Id. at A16. All of the experts concurred that a probabilistic risk-graded approach for determining the design basis earthquake for the PFSF was preferable to the deterministic method provided by Part 100 Appendix A.Cornell Dir. at A11-A18; PFS Exh. EEE at 44-45; Tr. 9116-19 (Arabasz); Tr. 8253 (Stamatakos); Tr. 8259-60 (McCann).

Indeed, the Commission has just published a notice of proposed rulemaking for amending 10 C.F.R. Part 72 to provide for a probabilistic risk approach instead of the deterministic method of the current regulations. Proposed Rule: Geological and Seismological Characteristics for Siting and Design of Dry Cask ISFSIs and MRSs, 67 Fed. Reg. 47,745 (July 22, 2002). In the statement of considerations accompanying the proposed rule the Commission has identified analogous reasons for changing the Part 72 regulations to use a probabilistic method. 67 Fed. Reg. at 47,746. Among other considerations, the Commission notes that use of a probabilistic approach for 10 C.F.R. § 72 facilities is "based on developments in the field over this past two decades" and parallels the changes made to 10 CFR Part 100. Id. Further, the Commission notes that, because ISFSIs pose

[11] As stated by Dr. Cornell: (1) the probabilistic approach captures more fully the current scientific understanding of earthquake forecasting than the deterministic method; (2) the probabilistic approach is capable of reflecting the uncertainties in professional knowledge of key elements of the seismic hazard; and (3) the probabilistic approach can be used to set design criteria that are consistent among different regions and among different failure consequences, thus allowing a rational and a equitable allocation of safety resources. Id.

less risk than nuclear power plants, design earthquake motions for an ISFSI need not be as high as those for a nuclear power plant. Id. at 47,749.

It is certainly within the public interest to utilize what all the experts as well as the interpreting agency agree is a preferable approach for evaluating the appropriate design basis earthquake for the PFSF. See, generally, Federal Communications Comm. v. WNCN Listeners Guild, 450 U.S. 582, 600-601 (1981) (deferring to the "board discretion" of an agency to determine the public interest and pursue policies to promote it.) While we are ware of no case law discussing the scope of the public interest under 10 C.F.R. § 72.7, NRC case law and the Commission's own pronouncements have discussed a number of the factors that may be considered in determining the public interest. For example, in the promulgation of 10 CFR § 50.12(a), the Commission recognized " . . . that it is not possible for its regulations to predict and accommodate every conceivable circumstance. Consequently, it has historically provided mechanisms to grant exemptions where application of the regulation would not serve the public interest and no undue risk to the public health and safety would occur as a result of not requiring literal adherence to a particular requirement." Final Rule: 10 C.F.R. Part 50, Specific Exemptions; Clarification of Standards, 50 Fed. Reg. 50,764 (Dec. 12, 1985).

Such are the circumstances here. As discussed, the uncontroverted testimony of all parties is that the PSHA and probabilistic risk graded approach for establishing seismic safety standards is superior to the currently required deterministic seismic hazard methods. Thus, it is not necessary to conduct a deterministic seismic hazard analysis in order to achieve the underlying purpose of the rule. Cf. 10 C.F.R. § 52.12(a)(2)(ii). In

addition, the exemption is supported by two other recognized public interests: provision of an interim spent fuel storage facility[12] and cost-effective administration[13].

d) Consideration of Costs under the Public Interest Standard

The State argues that the Staff, in its consideration of the public interest with respect to the PFS request for a seismic exemption, improperly took cost into consideration.[14] State F. ¶ 587. The State references the testimony of Dr. McCann:

> 4,000 [year mean return period] gives you more safety, obviously. Is it more for, you know, too much money, thinking of the public's general interest? That's I think where you would argue that yeah, maybe 4,000 is not they way to go. (Tr. at 8278).

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[12] The NRC Staff in the FEIS explicitly address the public benefit that would accrue from the construction of the PFSF. Specifically, the FEIS states:

> The purpose of the proposed PFSF is to satisfy the need for an interim facility that would serve as a safe, efficient, and economical alternative to continued SNF storage at reactor sites. PFS has indicated that such an interim facility would ensure that (1) the operation of a nuclear power plant would not cease because of lack of SNF pool storage capacity; (2) permanently shut-down reactors could be decommissioned sooner, resulting in a savings to the reactor licensees and earlier use of the land for other activities; and (3) for some reactor licensees, an economical alternative to at-reactor ISFSIs would be available.

FEIS at xxxii-iii.

[13] As discussed next below, cost may be considered by the Commission in making decisions. Moreover, cost-effectiveness has been recognized consistently as in the public interest. As discussed next below, cost may be considered by the Commission in making decisions. Moreover, cost-effectiveness has been recognized consistently as in the public interest. See, e.g., Philadelphia Electric Company (Limerick Generating Station, Unit 1), DD-86-1, 23 NRC 39 (1986) ("[T]he Commission may give appropriate consideration to the effect on the public interest of any delay from not granting an exemption, including power needs and delay costs to the applicant and to the consumer."). See also, Tennessee Valley Authority (Clinch River Breeder Reactor, Plant), CLI-82-4, 15 NRC 362 (1982) (". . . cost would be a significant factor and would weigh heavily on the side of granting an exemption in the public interest.")

[14] The Chief of the Technical Review Section in the NRC's Spent Fuel Project Office testified that neither he nor anyone under him considers financial interests in reviewing a licensing application. He testified that their licensing decisions are based "on the technical merits of the analysis." Tr. 6989 (Guttman).

Id. The State goes on to argue that "[t]he Board cannot take cost considerations into account as part of its health and safety analysis. Consequently, we see no basis to consider cost saving to the Applicant as part of the public interest. To do otherwise would allow cost considerations in through the back door." Id.

The State argument is clearly incorrect. Under 10 C.F.R. § 72.7, the Commission may grant exemptions only upon determining that they "are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest." Thus, by definition, an exemption can only issue if it adequately protects public health and safety, which the PFS exemption request does. If the requested exemption does not adequately protect public health and safety, the exemption would be denied wholly apart from any consideration of public interest.

Thus, under 10 C.F.R. § 72.7, public interest would be considered only after a determination has been made that the exemption will protect the public health and safety. The Commission can take costs into account in granting an exemption once it has determined that the exemption "adheres to the primary 'adequate protection' standards." 50 Fed. Reg. 50,764 at 50,767. Here, it is well established on the record that the 2,000 year DBE adequately protects public health and safety in accordance with the Commission's probabilistic risk-graded approach. Therefore, the costs that an applicant would need to bear to meet a more stringent standard would be an appropriate consideration in deciding whether to grant the exemption.

4. Evidentiary Burdens on the Parties

The State correctly notes that in an adjudicatory proceeding an applicant bears the ultimate burden of proving its case by a preponderance of the evidence "on each con-

tested factual issue." State F. at 8.[15] The State, however, seeks to extend this burden far beyond contested factual issues that it has placed in dispute in this licensing proceeding. It broadly asserts that the "burden is on PFS to show by a preponderance of the evidence that it has meets all [of a series of regulations it lists] prior to license issuance." State F. at 9 (emphasis in original). For example, it claims that the PFS must slow by the preponderance of the evidence that "[s]ite characteristics have been investigated and assessed that may directly affect the safety or environmental impact or the proposed ISFSI." State F. at 9 (citing 10 C.F.R. § 72.90). Enforcement of such a standard in this proceeding would require adjudication by the Board of a broad range of issues that are not factually disputed. Indeed, the adequacy of the seismic site investigation was the subject of Section A of the Contention L/QQ (formerly Basis 1 of Contention Utah L), which is no longer before the Board. Similarly, the State expansively asserts that PFS "must prove" that it complies with all Part 72 seismic siting criteria from which it does not seek an exemption and establish that the PFSF structures, systems and components ("SSCs") are designed to provide adequate protection to the public health and safety. State F. at 10.

The State thus impermissibly seeks to expand the scope of this proceeding far beyond the contentions admitted by the Board. The Commission has recently restated the process by which a contention is litigated:

> The Commission reemphasizes that licensing boards should continue to require adherence to section 2.714(b)(2), and that the burden of coming forward with admissible conten-

[15] See also, e.g., Advanced Medical Systems, Inc., CLI-94-06, 39 NRC 285, 302 & n.22 (1994); 10 C.F.R. § 2.732. A preponderance of the evidence requires "only that the record underlying a finding makes it slightly more likely than not." Inquiry into Three Mile Island Unit 2 Leak Rate Data Falsification, LBP-87-15, 25 NRC 671, 690 (1987); Commonwealth Edison Company (Zion Station, Units 1 and 2), ALAB-616, 12 NRC 419 (1980). Under this standard, the applicant need only provide slightly more evidence than that provided by the intervenor in order to carry the burden of persuasion. See, e.g., Southern California Edison Company (San Onofre Nuclear Generating Station, Units 2 and 3), LBP-82-3, 15 NRC 61, 146 (1982) (holding applicant meets its burden when evidence tilts slightly in applicant's favor).

> tions is on their proponent. A contention's proponent, not the licensing board, is responsible for formulating the contention and providing the necessary information to satisfy the basis requirement for the admission of contentions in 10 C.F.R. § 2.714(b)(2). The scope of a proceeding, and, as a consequence, the scope of contentions that may be admitted, is limited by the nature of the application and pertinent Commission regulations.

Statement of Policy on Conduct of Adjudicatory Proceedings, CLI-98-12, 48 NRC 18, 22 (1998). "The scope of a particular proceeding is limited to the scope of the admitted contentions and any issues the Commission authorizes the board to raise sua sponte." Id. at 23. The NRC's "longstanding practice requires adjudicatory boards to adhere to the terms of admitted contentions."[16] Thus, only those factual issues raised within the scope of Utah L/QQ are before the Board for resolution, and they do not include the multitude of technical issues underlying compliance with the numerous regulations cited by the State. The State's expansive arguments must therefore be rejected.[17]

Moreover, even for matters within the scope of Contention Utah L/QQ, the State bears the burden of coming forward with sufficient evidence at the hearing to support its claims. See, e.g., Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), LBP-85-12, 21 NRC 644, 698 (1985). The burden of going forward is heavier than that required to get a contention admitted into a proceeding. General Public Utilities (Three Mile Island Nuclear Station, Unit 2), LBP-89-07, 29 NRC 138, 141-143 affr'd, ALAB-926, 31 NRC 1, 15-16 (1990). The party opposing the licensing action must develop sufficient evidence to require reasonable minds to inquire further. Vermont Yankee Nuclear Power Corp. v. National Resources Defense Council, Inc., 435 US 519, 553 (1978); Met-

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[16] Private Fuel Storage, CLI-02-20, 55 NRC ____, slip op. at 14 (quoting Clairborne Enrichment Center, CLI-98-3, 47 NRC AT 105.

[17] It would also be unfair and in violation of due process to raise previously uncontested issues in an adjudicatory proceeding at the post-hearing briefing stage.

ropolitan Edison Co. (Three Mile Island Nuclear Station, Unit No. 1), ALAB-697, 16 NRC 1265, 1271 (1982); Public Service Co. of New Hampshire (Seabrook Station, Units 1 and 2), LBP-83-20A, 17 NRC 586, 589 (1983). If an intervenor fails to directly address an issue raised in its contention or fails to provide sufficient evidence to require reasonable minds to inquire further, the intervenor has not met its burden of going forward and the applicant prevails. See, e.g., Shoreham, LBP-85-12, 21 NRC at 698. On a contested issue of fact, once the applicant has made a showing that a contention lacks safety significance, the intervenors must rebut the applicant's showing or the applicant must be deemed to have met its ultimate burden of proof. Commonwealth Edison Co. (Braidwood Nuclear Power Station, Units 1 and 2), ALAB-890, 27 NRC 273, 287 n.82 (1988).

There are numerous instances where the State in its proposed findings claims that the PFS had not meet its burden of persuasion when in fact the State never met its burden of going forward. For example, the State charges that Dr. Tseng did not offer "any basis for his conclusion" that the maximum deviation of local displacement of a pad from rigid body displacements is ⅛ of an inch. State ¶ 195. Dr. Tseng did provide an extensive discussion of these displacements in his rebuttal testimony. Tseng Reb. At A1-A5, PFS Exh. 227. Even if he had not, the State could have cross-examined him on the basis for his conclusion. It failed to do so, thereby failing to meet its burden of going forward. In reality, as demonstrated in Section IV below, PFS has met its burden of persuasion as to every issue that the State has raised within the scope of Contention Utah L/QQ.

5. Relative roles of ASLB and Staff

a) Extent of the Board's Review Role

The State repeatedly claims that the Licensing Board does not have enough factual information to conduct an independent reviews of PFS's analyses or calculations

and, therefore, cannot make a finding in favor of the Applicant on particular issues.[18] See, e.g., State F. ¶¶ 281, 282, 284, 286, 290-292, 341, 342, 350, 365, 376. The State incorrectly presumes that it is the Licensing Board's role to duplicate the functions of the Staff and review every calculation and analysis that in any way relates to a contested issue in the proceeding. That is clearly not the case, particularly where the State has failed to challenge those analyses and calculations during the hearing.

Commission case law makes it clear that the Licensing Board has the responsibility for reviewing the record developed before it and for formulating the agency's initial decision based on that review. Wisconsin Electric Power Co. (Point Beach Nuclear Plant, Unit 2), ALAB-78, 5 AEC 319, 322 (1972). A Board must assess the facts on disputed issues. Waterford, ALAB-732, 17 NRC at 1087 n.12, citing Public Service Co. of New Hampshire (Seabrook Station, Units 1 and 2), ALAB-422, 6 NRC 33, 41 (1977), aff'd, CLI-78-1, 7 NRC 1 (1978). The Board's role, however, is limited to evaluating the testimony in the record and it is not to independently review underlying data or analyses that have not been put into issue by the parties.[19] Consumers Power Co. (Midland Plant, Units 1 & 2), ALAB-123, 6 AEC 331, 334-35 (1973); Boston Edison Co. (Pilgrim Nuclear Power Station), ALAB-83, 5 AEC 354 (1972), aff'd, Union of Concerned Scientists v. AEC, 499 F.2d 1069 (D.C. Cir. 1974). By contending that the Licensing Board must review all underlying analyses that may relate to the parties' evidence, particularly where

[18] This allegation is related to the claim that PFS's experts have not provided backup for their opinions. As discussed in Section II 6(a) infra, that claim is also without merit.

[19] The limited review function of the Board is also consistent with the different roles of the NRC Staff and the Licensing Board. The Licensing Board "performs the important task of judging factual and legal disputes between parties". Sequoyah Fuels Corp. and General Atomics (Gore, Oklahoma Site), CLI-95-16, 42 NRC 221, 225 (1995). For the State to assert that the Licensing Board is required to independently review all data that supports the opinion of an expert, or all calculations and documents related to an issue in a proceeding, flies contrary to logic and cannot be supported by principles of separation of powers within agencies, Commission regulations, or case law.

those analyses have not been called into question by the State, the State is in effect asking the Licensing Board to perform a *de novo* review of PFS's application, including those portions that are uncontested. That is clearly not the role of the Board.[20]

With respect to contested issues, the burden to go forward required the State to call into question those data or analyses on which the PFS experts relied through cross-examination or by the testimony of its own witnesses. In none of the areas where the State claims the Board lacks underlying data or analyses did the State actively seek to bring these issues to the Board's attention.

Indeed, in most instances, the State had in its possession the documents in question, often well in advance of the hearings.[21] There were thus no impediments to the State's ability to raise any issues it believed existed with those data or analyses. It did not. It should not be allowed to sit back during the hearing and then assert in its proposed findings that, for lack of underlying analyses, an inadequate review of data or analyses relating to an issue in a contention was undertaken by the Board.[22] Such "gotcha" tactics should have not role in NRC hearings, and are inconsistent with the State's burden to go forward with evidence to prove its claims.

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[20] For example, the State asserts that PFS did not proffer to the Board supporting calculations for impact damping of a metal cask (State F. ¶ 341), the Holtec cask tipover analysis, (State F. ¶ 365), or additional test data (State F. ¶ 156). The State would have in each instance have the Board rule that it cannot make findings favorable to PFS due to the absence of the materials, even though their suitability had never been challenged by the State.

[21] One exception is the DYNAMO Code itself which the State never sought to obtain. See State F. ¶ 279, and Section IV.F.6 below.

[22] Where the State felt it needed additional information, it could have done so in discovery even while the hearing was in progress. The State in fact did so on numerous occasions, and in every instance it was provided with the requested information. See, e.g., Tr. 5764, 5796, 5870, 5873 (Soper); Tr. 5764, 5803, 5850-51, 5869-70, 5974, 5982, 6131 (Gaukler); Tr. 5961 (Soler); Tr. 5980-81, 6299-6300, 6304, 6306-07, 6309, 6312, 6401, 6403-04, 6422-25 (Chancellor); Tr. 6303, 6313, 6353, 6403, 6424-25 (Travieso-Diaz).

The State cannot criticize the record when it had the opportunity to cross-examine the testifying experts on the underlying data. It is well-established that "the extent to which the evidence, including underlying data, has been subject to cross-examination, or is available for cross-examination, is a factor which must be taken into account by a licensing board," when giving it an appropriate weight. Wisconsin Electric Power Co. (Point Beach Nuclear Plant, Unit 2), ALAB-78, 5 AEC 319, 333 (1972). The State's failure to cross-examine PFS' witnesses on underlying data available to the State is either indicative of that witnesses' conclusions were well founded, or constitutes a failure on the part of the State to meet its burden to come forward.

Since the State has had ample opportunity through discovery and cross-examination at a hearing to raise any specific concerns with the data it claims is not in the record, the Board is free to conclude that the reason State has not identified any material deficiencies in the analysis is that none exists. Where an issue is already adequately considered, to avoid being patently unfair and inconsistent with developing a sound record, "more detailed comments might be required to focus the commission's attention to specifics." Northern States Power Co., (Tyrone Energy Park, Unit), LBP-77-37, 5 NRC 1298, 1301 (1977). See also, Public Service Co. of Oklahoma (Black Fox Station, Units 1 and 2), LBP-78-26, 8 NRC 102, 114 (1978) (finding the discussion of radioactive waste shipping adequate considering that "[t]he Intervenors neither presented direct evidence nor cross-examined Applicants' witness upon the instant contention, and thus failed to meet their burden of going forward.")

b) Role of the Commission Staff: Ministerial acts versus application of judgment

As will be discussed in detail in Section IV.B below, the State argues that the PFS soil cement testing program must be completed prior to licensing and submitted for the

Board's review. State F. ¶ 129-130. For example, the State insists on pre-licensing testing to demonstrate that the Young's modulus of the cement-treated soil to be installed in the pad emplacement area of the PFSF will not exceed a limit of 75,000 pounds per square inch (psi) imposed by the design. The State asserts that:

> . . . as PFS's modulus testing is intended to be done at some time in the future, it will likely require an exercise of discretion on the part of the Staff to determine whether PFS has, in fact, met a 75,000 psi over time and under dynamic loading conditions. This process would grant Staff post-licensing decision-making authority that is much more than ministerial in nature.

State F. ¶ 103. However, the State fails to explain how or why the Staff's determination of whether PFS has shown that the cement-treated soil has a Young's modulus of less than 75,000 psi would involve discretion on the part of the Staff, or why it has to be made prior to licensing, and no such evidence exists in the record.

The Commission has made it clear in this proceeding that:

> Longstanding agency practice holds that matters may be left to the NRC staff for post-hearing resolution "where hearings would not be helpful and the Board can 'make the findings requisite to issuance of the license.'" Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), ALAB-788, 20 NRC 1102, 1159 (1984), quoting Consolidated Edison Co. of New York, Inc. (Indian Point Station, Unit 2), CLI-74-23, 7 AEC 947, 951-52 (1974). Post-licensing resolution is appropriate for matters where a hearing would be unlikely to affect the result. See Southern California Edison Co. (San Onofre Nuclear Generating Station, Units 2 and 3), LBP-82-39, 15 NRC 1163, 1216 (1982) (relying on Indian Point Station). The key to the validity of post-licensing Staff reviews is whether the NRC Staff inquiry is essentially "ministerial" and "by [its] very nature requires post-licensing verification." See Hydro Resources, Inc., CLI-00-08, 51 NRC 227, 240 (2000).

Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), CLI-00-13, 52 NRC. 23, 33 (2000). Ministerial tasks include those tasks where the readily ascertainable nature of the item allows it to be left for Staff verification outside of the litigation.

See e.g., Southern California Edison Co. (San Onofre, Units 2 and 3), LBP-82-46, 15 NRC 1531, 1535-36 (1982) (straightforward and objective decibel measurements of sirens). NRC case law is clear that tasks such as that, which require only a "purely objective determination," are appropriate for post-licensing resolution by the Staff. Louisiana Power & Light Co. (Waterford Steam Electric Station, Unit 3), LBP-82-100, 16 NRC 1550 (1982) (detailing various license conditions regarding transportation for special persons as part of the emergency response plan).

As set forth below, the relevant issues for the Board to determine with respect to soil cement testing program proposed by PFS is : (1) whether the property values specified by PFS for the soil cement are attainable, (2) whether satisfaction of the specified property values can be verified by testing, and (3) whether an appropriate program for conducting such tests has been developed. The answer to all three questions is in the affirmative, as acknowledged by the State's own soil cement expert. See Section IV.B.6 below. Thus, confirmation that the tests have yielded appropriate results is a ministerial task that does not call for the exercise of discretion on the part of the NRC Staff. Accordingly, further Board involvement is unnecessary and the tests may be conducted after licensing.

In reality, the State's insistence in having the soil cement testing program conducted prior to licensing seems rooted in a lack of confidence in the Staff's ability or properly review the licensee's activities.[23] However, it is well established that doubts

[23] In response to the argument from PFS counsel that Staff verification of testing is a routine part of post-licensing verification, counsel for the State opined:

> I don't know, Your Honor. Region IV I think is in Grand Junction, Texas. We don't know how often the staff is going to go [to the PFSF site]. We don't know the competence of the staff inspector who will go out and whether that person has any knowledge of soils. How they will do it and whether they are competent to do it, I'm not going to agree to that.

about the Staff's ability to discharge its duties are not cognizable in Commission licensing proceedings, since to entertain such a challenge would imply the Board's authority to oversee the Staff in the performance of its duties, a power which the Board does not have.[24] See Louisiana Power & Light Company (Waterford Steam Electric Station, Unit 3), ALAB-812, 22 NRC 5 (1985); Carolina Power & Light Co. (Shearon Harris Nuclear Power Plant, Units 1, 2, 3, and 4), CLI-80-12, 11 NRC 514, 516-17 (1980). Thus, the State's demand that the testing be done prior to licensing, so that its experts can review the results independently of the NRC Staff, is untenable as a matter of law.

6. Challenges to Expert Witness Testimony

In its proposed findings, the State attempts to find ways to reduce the weight that should be accorded to the expert testimony provided by PFS and Staff witnesses and to minimize the impact of relevant, material and persuasive testimony. The State raises three main arguments: (1) some of the underlying data and analyses on which an expert's opinion is based are not part of the record; (2) various PFS and Staff witnesses allegedly have limited or no expertise in the areas covered by their testimony; and (3) some of the witnesses have an economic stake in the PFSF and therefore are biased; hence their testimony, and that of any other witness that relies on it, is unreliable. In each instance, the State tries to create new admissibility standards that are contrary to law and logic.

a) Evidentiary basis required for an expert opinion

The State argues that the Board cannot make findings of fact regarding expert opinions unless all the data (such as calculations, analyses or reports) underlying those

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Tr. 10949-50 (Chancellor).

[24] Even assuming for the sake of argument that the claim were cognizable, the State never raised this claim in the Contention L/QQ or the bases supporting it and cannot litigate it now.

opinions have been made part of the record.[25] For example, the State asserts that testimony concerning the Holtec cask tipover analysis cannot be relied upon to of fact because the entire analysis was not entered into the record by PFS. State F. 365. There is, however, no evidentiary requirement that all data, or any particular data, underlying an expert opinion be in the record of a proceeding. Indeed, expert testimony is "typically a mixture of scientific principles (known to the expert through his or her training and experience), data derived from analyses or perception, and the expert's opinions based on these principles and data." Limerick, ALAB-819, 22 NRC at 720 (emphasis in original) (footnote omitted); see also, Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), ALAB-669, 15 NRC 453, 475 (1982). The absence of backup data, particularly unchallenged backup data, does not preclude a licensing board from finding facts based on the opinion proffered. A licensing board makes determinations of fact on the record before it, including the expert opinions that are part of the record. See, e.g., Limerick, ALAB-819, 22 NRC at 720.

While a testifying expert witness must provide (either in the prepared testimony or on the stand) sufficient information for the basis of his or her opinion to be evaluated, an expert testifying to the results of an analysis need not have at hand every datum utilized in performing the analysis. Virginia Electric and Power Co. (North Anna Nuclear Power Station, Units 1 and 2), ALAB-555, 10 NRC 23, 27 (1979).[26] Information sup-

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[25] This allegation is related to the State's erroneous claim (see Section II.5(a), supra) that it is the function of the Board to independently review the analyses and calculations, even those that have not been brought into question by the State's contention.

[26] In North Anna, the licensing board took up two safety related issues on its own initiative. The board wanted to probe the basis of the witness' conclusions and sought additional underlying data. In *dicta*, the Appeal Board further noted that "had another of the parties to this proceeding evinced an interest in probing the basis for [the witness'] conclusions," such data would have to have been provided or the testimony would risk being stricken. Id. at 27. This further underscores where the State has the underlying data and analyses, it is incumbent upon the State to probe the basis of a conclusion with which it disagrees.

porting the opinions of PFS's experts was provided by PFS through discovery responses (including depositions of the PFS experts), written testimony, and by the experts' oral testimony at the hearing. Thus, it is beyond dispute that sufficient evidence has been presented to support the opinion of PFS's expert witnesses. No further information needs to be made part of the record.

b) Expert qualifications

The State asks the Board to reduce the weight it gives to the testimony of the experts testifying on behalf of PFS and the Staff because the witnesses have not worked on the seismic design or analysis of a facility identical in all respects to the PFSF. For example, the State asks the Board to give limited weight to the testimony of Dr. Singh and Dr. Soler, because they have not analyzed the stability of free standing storage casks either under ground motions as large as those used for the 2,000-year design basis earthquake at the PFSF site or for sites at the cask storage pads are supported by soil cement or cement-treated soil. State F. ¶¶ 261-267. Likewise, the State would deny weight to the testimony of Mr. Paul Trudeau and Dr. Goodluck Ofoegbu because they have not previously been involved in the analysis of facilities at high-seismicity sites in the Basin and Range techtonic Province featuring Upper Lake Bonneville clay soils. State F. at 2-3.

The standard proposed by the State cannot be sustained logically, and is inconsistent with the law of evidence. In effect, the State argues that no expert could testify regarding any design that was found to be unique in some respect. As such, no one would be deemed to have expertise in designing or analyzing a facility unless they had designed or analyzed a facility identical in all respects to the one under consideration. This view is not only contrary to commonsense and case law, but it also goes against this Board's rulings on expert testimony that have emphasized the transferability of experience and ex-

pertise. Indeed, were this rule to be applied, none of the State's witnesses would meet the standard the State proposes.

The State cites Daubert v. Merrell Dow Pharms., 509 U.S. 579 (1993), in support of its position. State F. 261. However, Daubert lends no aid to the State's argument. In Daubert the Supreme Court held that expert testimony should be admitted if it "rests on a reliable foundation and is relevant to the task at hand." 509 U.S. at 597. In order to rest on a "reliable foundation," the proposed testimony "must be supported by appropriate validation – i.e., 'good grounds,' based on what is known." Id. at 590. The Court observed that many factors may bear on the reliability determination in a particular case, but did offer a list of four factors that might be helpful in assessing the reliability of a proposed expert's scientific methodology: (1) whether the methodology "can be (and has been) tested;" (2) whether it has been subjected to "peer review and publication;" (3) the "known or potential rate of error;" and (4) the "general acceptance" of the methodology. Id. at 593.[27] Nowhere in Daubert is it said or implied that prior experience with identical situations is a factor in determining what weight to give to expert testimony.

The State does not argue that the testimony of the PFS experts fails to meet any the factors enumerated in Daubert or any other factor that may be relevant to determining the reliability of expert testimony. Indeed, the testimony of the PFS experts fits well within the ambit Daubert and its progeny. The PFS witnesses have showed relevant knowledge, skill, experience, training, or education, consistent with NRC case law.[28]

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[27] The four factors set forth in Daubert are means by which a court can evaluate the reliability of scientific expert testimony, but "Daubert's list of specific factors neither necessarily nor exclusively applies to all experts or in every case." Kumho Tire Co. v. Carmichael, 526 U.S. 137, 141 (1999). Rather, the ultimate goal is to "ensur[e] that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand." Id.

[28] See Section III below for a summary of the qualifications and experiences of the PFS witnesses.

Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), ALAB-669, 15 NRC 453, 474-75 (1982) (citing Fed. R. Evid. 702). Therefore, their testimony should be given full weight.

c) Witness Credibility

In addition to questioning their expertise, the State assails the credibility of the Holtec witnesses Drs. Singh and Dr. Soler on the grounds that Holtec has a pecuniary interest in the outcome of the proceeding, since it wants to sell thousands of storage casks to PFS. State F. at 18-9; see also State F. ¶¶ 257-260. However, the existence of an economic interest in a case is not, in and of itself, a basis for discounting expert testimony. Indeed, equipment vendors have been providing evidentiary support to applicants for at least 40 years and have invariably been found by licensing boards to have provided reliable testimony. In this respect, equipment vendors are under legal duties to provide full and complete information to the Nuclear Regulatory Commission; giving testimony tainted by bias would put them in criminal and civil jeopardy. Also, technical issues, such as those involved in Contention L/QQ, are generally impervious to biased testimony.

It must be emphasized at the outset that the State offers only rhetorical accusations of pecuniary interests and points to no actual evidence of bias on the part of Holtec. Nor does it cite any exhibits, written or oral testimony or other representations by Holtec that are in error owing to the interest of the witnesses. Thus, what we have here are accusations of wrongdoing hurled by State counsel at PFS's witness without a shred of evidence to back them up.

(1) Economic Interest and Bias

In Louisiana Power & Light Company (Waterford Steam Electric Station, Unit 3), ALAB-732, 17 NRC 1076 (1983), the Appeal Board set forth the Commission's well-established approach toward a witness' economic interest in a case:

> The fact that a witness is employed by a party, or paid by a party, does not disqualify the witness from testifying or render the testimony valueless. In order for expert testimony, such as we have here . . ., to be admissible, it need only (1) assist the trier of fact, and (2) be rendered by a properly qualified witness. See Fed. R. Evid. 702; Duke Power Co. (William B. McGuire Nuclear Station, Units 1 and 2), ALAB-669, 15 NRC 453, 475 (1982). It should come as no surprise that most expert witnesses do receive compensation from the parties on whose behalf they testify. But their compensation is for their time and expertise, not for their testimony as such. There is nothing wrong or inherently suspect about that. To be sure . . . the opposing party can elicit the fact that a witness has been paid for his or her appearance, or is employed by a party. But that line of attack goes only to the persuasiveness or weight that should be accorded the expert's testimony, not to its admissibility. See 11 J. Moore & H. Bendix, Moore's Federal Practice ¶702.30[1] (2d ed. 1982).

17 NRC at 1091.

The State implies that the financial interest of Drs. Singh and Soler goes beyond being paid to testify, since Holtec may make money selling thousands of storage casks if the PFSF is built, and claims that this constitutes "extreme bias and self interest" which must not be overlooked by the Board. State F. at 18 and State F. ¶¶ 257-59. In addition, the State claims the Drs. Singh and Soler have a "substantial interest" in the outcome of this proceeding because the "Licensing Board's decision concerning the propriety of Holtec's codes and methodologies . . . may have far reaching effects on Holtec's business." State F. ¶ 259. These arguments are baseless and imply an effort on the part of Holtec to deceive the Board into "the affirmation . . . of the Holtec analyses, including those conducted with the DYNAMO code, also owned, in part, by Dr. Singh and Dr.

Singh and Dr. Soler." Id. Such serious allegations, unaccompanied by even a shred of evidence, are irresponsible if not reprehensible.

Reactor and other equipment vendors have routinely testified over the years at hearings for nuclear power plant licenses concerning the technical capability of their equipment to perform prerequisite health and safety functions. Obviously, a negative decision by a licensing board on the technical adequacy of a vendor's equipment or the supporting technical analyses could have significant adverse financial consequences for the vendor. A positive decision has a similar possibility of positive financial consequences. Yet the State points no case – and PFS is are aware of none – in which such potential financial impacts were found to constitute or raise an inference of bias, so that the testimony of the vendor's representatives was discredited or given less weight as a result. Indeed, vendors, as discussed below, are obliged to provide truthful, complete and accurate information to the Commission. Providing biased testimony in a proceeding, apart from violating their legal obligations, could ultimately endanger the vendor's commercial viability as a provider to at NRC-licensed facilities.

Mere allegations of witness bias are not enough to attribute bias to a witness, or to create a dispute of fact regarding the testimony of those witnesses. See, e.g., Advanced Medical Systems, CLI-94-06, 39 NRC at 306-07. In the case of technical presentations by experts, allegations of bias have been ignored in the absence of "evidence of deliberate intent to bias the results." Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), LBP-85-12, 21 NRC 644, 665 (1985). In the few cases where the particular bias of a witness has been noted in discounting the testimony of a witness, the bias has been evidenced by the witness testifying beyond his or her expertise. See, e.g., Texas Utilities Electric Company (Comanche Peak Steam Electric Station, Units 1 and 2), LBP-84-55, 20 NRC 1646, 1656-57 (1985). To the extent that testimony beyond a witnesses'

expertise is involved in this proceeding, it is the State's witnesses that violate this principle, not PFS's witnesses. See, e.g., PFS F. ¶¶ 222-26 (Khan), 524-29 (Resnikoff).

The cases cited by the State are not to the contrary. The only relevant case that the State cites underscores the fact that "key to evaluating expert testimony is its logic and persuasiveness." Power Authority of the State of New York (James A. Fitzpatrick Nuclear Power Plant; Indian Point, Unit 3), CLI-01-14, 53 NRC 488, 519 n.41 (2001). While the Commission stated that it "may accord less relative weight to a witness who is an employee of a party than to a witness with no such financial ties", id. (emphasis added), the decision does not stand for the proposition that it must accord that testimony less weight. And in that Commission decision, there is no indication that such reduced weight was given to the testimony by the witnesses in question. This principle applies equally to employees who have a direct financial interest in the success of a company.[29]

In short, there is no instance of which we are aware in which a licensing board has ignored, or given less weight to, the testimony and supporting technical analyses of vendor witnesses on the grounds of economic bias, as the State proposes should be done here. To the contrary, licensing boards have typically and appropriately looked to equipment vendors, including Holtec, as knowledgeable sources of technical information concerning the capability of their equipment. See e.g., Florida Power & Light Company (St. Lucie Nuclear Power Plant Unit 1), ALAB-921, 30 NRC 177 (1989) (Appeal Board reliance on Dr. Singh's testimony of tests underlying design of spent fuel racks).

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[29] The State also cites Houston Lighting and Power Co. (South Texas Project, Units 1 and 2), LBP-79-30, 10 NRC 594 (1979) for the proposition that "a witness' bias may reduce the weight of the witness' testimony." State F. at 19. However, that case neither discusses that issue either in its holding or in dicta. The case involved a dispute over the dicoverability of draft testimony. The board merely held that the contents of the draft testimony may be a factor in determining whether the filed testimony of a witness is credible.

(2) Applicants' and Vendors' Obligations to Provide Complete and Accurate Information to the NRC

Regulatory requirements that apply to PFS as a license applicant and Holtec as an NRC-certified storage cask vendor require that any information submitted to the Commission "must be complete and accurate." 10 C.F.R. § 72.11 (a) and (b). See also 18 USC § 1001(a), (providing fine or prison for knowingly and willfully making a material false statement in a matter before a U.S. government agency). Thus, license applicants and their witnesses must make truthful statements to the NRC. See Virginia Electric and Power Co. (North Anna Power Station, Units 1 and 2), CLI-76-22, 4 NRC 480, 486, 491 (1976), aff'd sub nom., Virginia Electric and Power Co. v. NRC, 571 F.2d 1289 (4th Cir. 1978). The Commission has emphasized that in submissions to the Commission, "Nothing less than candor is sufficient." Id. at 491 (emphasis in original).

Notwithstanding these requirements, the State is in essence suggesting (again without a shred of evidence) that PFS has provided inaccurate information to the Commission through its License Application and testimony before this Licensing Board, in violation of Commission regulations. The State is also suggesting that Drs. Singh and Soler have deliberately provided inaccurate information to the Commission in this proceeding. The State's allegations of bias are so broad and unspecified in this regard, that they apparently encompass all the analyses Holtec has provided in support of this proceeding, the information submitted in support of its application for a certificate of compliance ("CoC") for its HI-STORM 100 Storage Cask System as well as its representations regarding the capabilities of the DYNAMO computer program. Thus, in arguing that the testimony and analysis presented here by Holtec is tainted by economic interest, the State is also suggesting -- without a scintilla of evidential support -- that Holtec has submitted false, misleading, and/or incomplete information to the NRC in over forty li-

censing proceedings where the DYNAMO computer code was used as an analytical tool. See Singh/Soler Dir. at A28.

The implication that Holtec, and Drs. Singh and Soler personally, would intentionally violate the manifold regulatory provisions governing providing information to the NRC and risk civil and criminal penalties, plus the loss of Holtec's ability to do business in the nuclear arena on which its economic livelihood depends, is both baseless and illogical. Unlike the State's witnesses whose only connection to the NRC is their involvement in this proceeding, Dr. Singh and Dr. Soler, as representatives of Holtec, are under a continuing obligation to the NRC to abide by the requirements of truthfulness, accuracy and completeness in their technical presentations. Their status as NRC-approved vendors should increase, not diminish, the Board's confidence in the reliability of their testimony.

In that regard, Commission case law is clear that a party under the NRC's jurisdiction is presumed to comply with Commission regulations. "[T]he NRC does not presume that a licensee will violate agency regulations wherever the opportunity arises." Private Fuel Storage, L.L.C. (Independent Spent Fuel Storage Installation), CLI-01-09, 53 NRC 232, 235 (2001) (citation omitted). This presumption should in itself be enough to reject the State's unsupported charges.

(3) Technical Nature of Determinations

Economic interest and bias issues are of little relevance to the kinds of technical determinations that must be made in proceedings like the instant one. "Many issues, . . . particularly those involving competing technical or expert presentations, frequently are amenable to resolution by a licensing board based on its evaluation of the thoroughness, sophistication, accuracy, and persuasiveness of the parties' submissions." Carolina Power & Light Co. (Shearon Harris Nuclear Power Plant), CLI-01-11, 53 NRC 370, 386 (2001).

As the Commission pointed out in Harris, credibility determinations are necessary only in a limited range of factual disputes before a licensing board. The Commission noted, for example, that if the color indicated on a gauge were critical, and one witness said the color was red and another said it was green, the witnesses' demeanor and biases would be important in resolving this dispute. The Commission went on to observe that:

> Most technical issues before NRC licensing boards fall outside this "red light/green light" category of factual disputes, which hinge on credibility of witnesses. They are more closely akin to evaluating whether the gauge was properly designed or was functioning correctly at the critical time -- issues which, depending on the caliber and completeness of written submissions, may or may not necessitate hearing testimony from live witnesses.

53 NRC at 386 n.6. The Commission in other contexts has similarly said that "the key to evaluating expert testimonies is its logic and persuasiveness." Indian Point, CLI-01-14, 53 NRC 488, 519 n.41 (2001).

Given the technical nature of the issues involved in the seismic contention, witness credibility is less important than competence and persuasiveness. Indeed, here most of the testimony by the Holtec witnesses is based on computer-aided analyses whose results are set forth in technical reports. See, e.g., State Exh. 173; PFS Exh. 86C. Further, the design basis cask stability analyses, cask tipover analysis and other design calculations were submitted to the NRC Staff as part of the licensing process. Indeed, PFS and Holtec demonstrated their candor in this proceeding by Holtec's self-identification of an error in one of their analyses which came to light during Holtec's routine review of its calculations, and PFS' prompt notification of the error to the Board and the parties. Tr. 9560-68 (Soler).

(4) Conclusion

The State is seeking to make bias a leading issue in determining the merits of this case. Baseless attacks against the character of opposing witnesses, however, do not amount to evidence. For the reasons stated above, the charges of bias against Holtec in the State's proposed findings must be summarily rejected.

7. NRC Guidance as Licensing Requirements

The State asks the Board to treat NRC guidance documents inconsistently in order to benefit its position. Where the State believes that guidance documents suits their purposes, they argue that such documents are entitled to "special weight." See, e.g., State F. ¶ 10 (NUREG 0800 factor of safety against foundation failure of 1.1); State F. ¶¶ 23-24 (spacing and density of boreholes under Section 1.132 of NUREG 0800). By contrast, where the guidance document is inconsistent with the State's position. The State treats the guidance cavalierly at best. See, e.g., State F. ¶¶ 560-561 (rejecting NUREG 1567's use of a thirty day accident duration). In either case, NRC guidance documents, such as standard review plans, are not binding. They serve to help applicants and licensees comply with regulations, but "nonconformance with such guides does not equate to noncompliance with the regulations." Curators of the University of Missouri, CLI-95-1, 41 NRC 71, 98 (1995). In a proceeding, they are regarded as the views of one party. Consumers Power Co. (Big Rock Point Nuclear Plant), ALAB-725, 17 NRC 562, 568 & n.10 (1983); Long Island Lighting Co. (Shoreham Nuclear Power Station, Unit 1), LBP-83-22, 17 NRC 608, 616 (1983), citing Metropolitan Edison Co. (Three Mile Island Nuclear Station, Unit 1), ALAB-698, 16 NRC 1290, 1299 (1982), rev'd in part on other grounds, CLI-83-22, 18 NRC 299 (1983).

Blake, need to add footnote at end of section on State's reference to hearsay evidence on about page 13 of their findings. Look at what we said in Utah K and write a brief footnote.]

III. WITNESS CREDENTIALS

1. State Witnesses

a) Section C Witnesses

(1) Stephen F. Bartlett

R1. The State claims that Dr. Bartlett has greater experience and judgment than the PFS or Staff witnesses in "ascertaining the behavior of the upper Bonneville clays under seismic conditions, and correlation of the CPT data." State F. ¶ 5. The State bases this claim on the premise that Dr. Bartlett has 15 years of experience in assessing the seismic behavior and stability of soils, including his work on the Interstate 15 reconstruction that involved soil investigations of the upper Lake Bonneville sediments. State F. ¶ 4. However, there is no record support for the State's implicit premise that upper Lake Bonneville sediments are unique. Likewise, there is no support on the record for affording any special significance to Dr. Bartlett's work experience at "the DOE Savannah River" correlating cone penetrometer test ("CPT") data with laboratory shear strength testing. Id.

(2) James K. Mitchell

R2. The State asserts that the Board should give "particular deference" to Dr. Mitchell's opinions on the topic of soil cement. State F. ¶ 73. There is no dispute as to Dr. Mitchell's expertise on soil cement issues. The State, however, proposed no findings regarding the qualifications of Dr. Wissa. As discussed in Section IV.B.1, below, Dr. Wissa is as qualified as Dr. Mitchell in matters regarding soil cement.

b) Section D Witnesses

(1) Stephen F. Bartlett

R3. The State asserts that Dr. Bartlett is an expert in soil behavior under seismic loading, having performed "seismic analyses" for the Department of Energy High Level Waste Facilities at Savannah River. State F. ¶ 137. In fact, his work at Savannah River, as he acknowledged in his testimony, involved *underground* storage tanks of high level waste. Tr. 7818-19 (Bartlett). His work at Savannah River consisted of being "principal geotechnical investigator reviewing the Safety Analysis Report (SAR) for the seismic qualification and start-up" of the facility and being a member of a multi-disciplinary team engaged in " extensive subsurface investigations, strong ground motion modeling, probabilistic liquefaction hazard evaluations, dynamic settlement and slope stability calculations, and risk assessment." State Exh. 92. While Dr. Bartlett's expertise on soils is not in doubt, there is no evidence that Dr. Bartlett has performed seismic stability analyses in any way analogous to those involved in Section D of Contention L/QQ, or that he is qualified to perform them.

R4. On several occasions, Dr. Bartlett's testified beyond his acknowledged area of expertise, such as "cold bonding" between materials. Tr. 7707-12 (Bartlett). There is no evidence that he had experience or other qualifications that entitled him to play the role of an expert on those matters. Dr. Bartlett's testimony in those areas is entitled to no particular weight.

(2) Farhang Ostadan

R5. Dr. Ostadan's relevant background and experience is primarily in soil-structure interaction issues. Tr. 7736, 7774 (Ostadan). His qualifications as a soil-structure interaction specialist are not in question. However, he has not performed any soil-structure interaction analysis, nor any other type of analysis, for the PFSF. Tr. 7327-28, 7807 (Ostadan).

R6. There are two problems with Dr. Ostadan's qualifications as a witness. First, despite the narrowness of his expertise, he has given testimony on behalf of the State on a broad range of issues on which his expertise has not been established. Second, his overall credibility is questionable. At the hearing he often offered unqualified, sweeping testimony which was demonstrably wrong, beyond his area of expertise, and not based on a thoughtful review of the issues. Some examples: (1) Dr. Ostadan testified about the potential effects of having a fault in the vicinity of the PFSF site (State of Utah Testimony of Dr. Steven F. Bartlett and Dr. Farhang Ostadan on Unified Contention Utah L/QQ (Dynamic Analyses), inserted into the record after Tr. 7268 ("Bartlett/Ostadan Dir.") at A42 (Bartlett/Ostadan Dir.) yet he was unable to answer simple questions about seismology in general, or in particular about the seismology of the PFSF site, see Tr. 7741-43 (Ostadan). (2) Dr. Ostadan testified repeatedly and emphatically about the seriousness of having two inches of settlement in a nuclear facility's foundation and stated categorically that he knew of no nuclear facility for which two inches or more of long term settlement was allowed, and that settlements of that magnitude were considered unacceptable by structural engineers. Tr. 7382, 7501, 7729, 7749-50, 10396-97 (Ostadan). However, he was unaware that a U.S. Army Corps of Engineers manual allowed foundation settlements greatly in excess of two inches, nor was he aware of the settlement standards for nuclear facilities, Tr. 7742-50 (Ostadan), nor was he able to satisfactorily explain the mechanism through which a pad deflects as it settles, Tr. 7767-72 (Ostadan), and had not reviewed the Stone & Webster calculation for the storage pads at the PFSF, Tr. 7772 (Ostadan). Subsequent testimony presented by Applicant at the hearing established that several nuclear power plants have safely operated with estimated long-term static settlements of the foundations of safety-related structures in excess of 2 inches. PFS Exh. 232;

Trudeau Section D Reb. at A8; Tr. 11283-85 (Trudeau); Tr. 11327 (Bartlett). (3) Dr. Ostadan asserted in his direct testimony that a number of figures in the Sandia Report demonstrated that the pad response accelerations are several times larger than the peak ground acceleration used by Stone & Webster in its pad stability analysis. Bartlett/Ostadan Dir. at A37. He repeated and amplified this opinion at the hearing several times. Tr. 7535-37, 7540-44, 7604-05, 7633-37 (Ostadan). However, on cross-examination it became evident that he was not aware that the figures in the Sandia Report could not be read at face value and ultimately he admitted that he had not reviewed the Sandia report "carefully." Tr. 7781, 7797 (Ostadan). (4) In his direct testimony, Dr. Ostadan criticized PFS's decision to delay completing its soil cement testing program until after licensing of the facility, as well as the Staff's acceptance of that decision (Bartlett/Ostadan Dir. at A9). Yet at the hearing, he acknowledged that he had never been involved with the testing program at a nuclear facility and was not aware how such tests were conducted or whether such testing was conducted prior to or after licensing (Tr. 10270-74 (Ostadan)). (5) Dr. Ostadan presented direct testimony and oral testimony at the hearing on the "cold bonding" mechanism (see Bartlett/Ostadan Dir. at A46) but he and Dr. Bartlett described their understanding of the physical mechanism differently and he acknowledged that he had never sought to quantify its effects and did not know how significant they would be. Tr. 7713-14, 7723 (Ostadan).

R7. These are only examples of the inconsistencies in Dr. Ostadan's testimony. Because of these inconsistencies, Dr. Ostadan's testimony, outside the soil-structure interaction area, should not be given credibility.

(3) Moshin R. Khan

R8. The State offered no findings of fact regarding the qualifications, experience, expertise or background of Dr. Moshin R. Khan. Dr. Khan's lack of qualifications has been discussed in PFS's proposed findings and will not be repeated here. See PFS F. ¶ 222-28.

c) Section E Witnesses

(1) Stephen F. Bartlett

R9. Dr. Bartlett stated that the opinions he rendered in his Section E testimony were "to conservatisms for foundations" and in "the foundation design." Tr. 12785-86 (Bartlett). However, Dr. Bartlett testified on areas beyond his acknowledged area of expertise, such as whether a tipping cask would have a zero initial angular velocity. Tr. 12870-71 (Bartlett). To the extent that Dr. Bartlett sought to opine in areas beyond soils, his testimony is that of a layman, not an expert.

(2) Walter J. Arabasz

R10. The State characterizes Dr. Arabasz as a highly qualified seismologist. State F. ¶ 449. We agree.

(3) Marvin Resnikoff

R11. The State characterizes Dr. Marvin Resnikoff as "a qualified expert in the computation of radiation doses." State F. ¶ 550. However, Dr. Resnikoff demonstrated an inability to properly calculate his dose calculations in this proceeding by committing numerous, repeated errors both before and during his oral testimony at the hearing. See Section IV.H.1 below and PFS F. ¶¶ 544-548. In light of those repeated errors, Dr. Resnikoff's alleged expertise in the area of radiation dose computation is highly questionable.

R12. The State tacitly admits -- by describing him only as an expert in the computation of radiation doses --, that Dr. Resnikoff has no qualifications, experience or expertise in a vast array of other subjects upon which he offered testimony. Those areas are identified in PFS F. ¶¶ 524-528 and in Section IV.H below and need not be repeated here. Dr. Resnikoff's testimony in those areas should be given no weight.

2. PFS Witnesses

a) Section C Witnesses

(1) Paul Trudeau

R13. The State asserts that Mr. Trudeau has no geotechnical experience working in the Basin and Range Province (where the PFSF site is located), with the Lake Bonneville sediments, or at sites with "strong ground motions," other than the present project. State F. ¶ 2. Beyond pointing out these issues, the State neither tries to define or explain what significance each of these facts would have if true.

R14. With respect of having previously worked in the physical location of the PFSF site, Mr. Trudeau has twenty-nine years of experience as Lead Geotechnical Engineer and Geotechnical Engineer for projects throughout the United States. There is no evidence in the record that shows that the Basin and Range Province is so unique from the geotechnical standpoint that geotechnical investigations in that location require unique expertise. The same observations apply to the Upper Lake Bonneville soils present at the PFSF site.

R15. With respect to the reference to "strong ground motions," the State does not define the term in State F. ¶ 2 other than by comparison to the PFS site, and the term is not used in the portion of Mr. Trudeau's testimony referenced by the State (Tr.

6161). In any event, Mr. Trudeau explained that he received his analysis characterizing the seismic accelerations from other organizations (ICEC and Holtec). See, e.g., Tr. 6247-48 (Trudeau). His soil investigations and the stability analyses he performed did not compute the ground motions and his methodology, as described in PFS Exh. UU and VV, is not dependent on how those motions are obtained. Therefore, whether he had in the past worked on sites "with strong ground motions" is immaterial to his expertise on geotechnical issues.

R16. In short, the limitations to Mr. Trudeau's expertise that the State seeks to draw are immaterial.[30] The record demonstrates Mr. Trudeau's expertise in dealing with geotechnical issues. He has three decades of experience in geotechnical engineering, including the performance of subsurface soil investigations; the performance and supervision of the analysis of foundations in support of the design of structures; the performance of laboratory tests of soils, including index property tests, consolidation tests, static and dynamic triaxial tests, as well as other tests; the performance of analyses of the performance of soils and structures under static and dynamic conditions; and the development of geotechnical design criteria for other engineering disciplines. See Mr. Trudeau's resume, attached to Testimony of Paul J. Trudeau on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 6135) ("Trudeau Section D Dir.").

(2) Anwar E. Z. Wissa

R17. The State appears not to challenge the qualifications of Dr. Wissa. See State F. ¶ 80.

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[30] Those alleged limitations are part of the State's general attempt to impeach the qualifications of the PFS and Staff witnesses by asserting that they lack prior experience with a project that is identical to the PFSF. As discussed in Section II.6.b above, such attempts are contrary to common sense and applicable law.

b) Section D Witnesses

(1) Krishna P. Singh and Alan I. Soler

R18. The State ignores the overall technical qualifications of Dr. Singh and Dr. Soler almost entirely, although they ask the Board to give limited weight to their testimony. The State tries to draw superficial distinctions between the PFSF facility and the vast and substantial experience that Holtec has in cask stability analyses in order to improperly diminish the weight of the testimony of Dr. Singh and Dr. Soler. State F. ¶¶ 261-267. The State asserts that Dr. Singh and Dr. Soler have no relevant experience in analyzing cask stability at the PFSF site because the PFSF site has higher ground motions than the other three ISFSI sites where Holtec has conducted analyses examining the behavior of freestanding storage casks. State F. ¶ 262. Likewise, the State tries to argue that the failure of Drs. Singh and Soler to analyze cask stability at a facility designed exactly like the PFSF (no soil cement, differences in soil types, ground motions, etc.) results in Holtec "hav[ing] limited experience in performing nonlinear cask stability analysis at sites similar to the proposed PFS facility. State F. ¶ 267. Those are, as discussed in Section II.6.b above, invalid attacks on the qualifications of expert witnesses, particularly those with the impressive credentials of Drs. Singh and Soler. See Singh/Soler Dir. at A3-A5, A10-A13, A27-A28 and the *curricula vitae* attached thereto.

R19. The State also attacks the testimony of Dr. Singh and Dr. Soler on what it describes as their "extreme economic bias and self-interest in the outcome of this proceeding." State F. ¶ 139. As discussed in Section II.6.c, above, there is no basis for the State's "bias" allegations against these witnesses, nor for discounting their testimony in any manner.

(2) Drs. Wen Shou Tseng and Robert Y. Youngs

R20. The State ignores the qualifications of Drs. Tseng and Youngs. Dr. Tseng is described as "primarily responsible for the design of the storage pad" and Dr. Youngs is not addressed at all. State F. ¶ 141. The State asserts, however, that Dr. Tseng "relies on reports prepared by Holtec for significant portions of his testimony," and that Dr. Youngs also relies on the data from Holtec, and that these witnesses' reliance on "Holtec's reports affects these witnesses' opinions to the extent that the same biases, errors or unconservative assumptions are found in the Holtec documents." Id.

R21. Since the State does not challenge the professional qualifications of Drs. Tseng and Youngs, those need not be restated here. See, e.g., Joint Testimony of Robert Youngs and Wen Tseng on Unified Contention Utah L/QQ (inserted into the record after Tr. 5529) ("Youngs/Tseng Dir.") at A3, A8-A9, and the resumes of Drs. Tseng and Youngs attached to their joint testimony. With respect to the theory that their testimony has been "infected" by the alleged bias of the Holtec witnesses, the State has not pointed to any Holtec report whose results are incorrect due to bias, thus the State's unfounded attack on the testimony of these witnesses is unpersuasive.[31] Of course, Drs. Tseng and Youngs, as well as the other PFS witnesses, were entitled to base their opinions on the information supplied by Holtec. See Section II.6.a above.

(3) Paul Trudeau

[31] In the case of Dr. Youngs, the subject of his alleged reliance on biased Holtec data Tr. 10483-84 (Youngs) is non-vertically propagating waves, a claim that has apparently been abandoned by the State by proposing no findings on it.

R22. In addition to its challenge to Mr. Trudeau's qualifications with respect to his Section C testimony (discussed above), the State challenges his credentials to testify as to the sliding, overturning and bearing capacity failure of the CTB and the storage pads because "Mr. Trudeau no experience at all in soil structure interaction analysis." State F. ¶ 142. However, the State simply ignores the uncontradicted evidence that his stability analyses for the pads and the CTB neither used nor required soil-structure interaction analysis. Stone & Webster included soil-structure interaction effects into the storage pad stability analysis by using the dynamic loads on the casks obtained from ICEC's design calculation, which in turn used the results of Holtec's analysis. Tr. 6183, 6235-37, 6340 (Trudeau). Hence his lack of expertise on soil-structure interaction is immaterial.

(4) Bruce Ebbeson

R23. The State does not challenge Mr. Ebbeson's qualifications, choosing instead to alleged that his testimony relies on "biased" data from Holtec. State F. ¶ 141.[32] In addition to the reasons described above with respect to Drs. Tseng and Youngs why such a derivative challenge is invalid, in the particular case of Mr. Ebbeson the attack could not be more wrong. Mr. Ebbeson did not rely on any Holtec data for his analysis, which is not surprising since Mr. Ebbeson led the structural design of the CTB and Holtec is the cask vendor. Specifically, of the two transcript citations offered by the State in support of its claim, the first one (Tr. 6376) does not mention Holtec at all and the second (Tr. 6380) is part of a description by Mr. Ebbeson of his understanding of how the casks behave in a 10,000-year earth-

[32] Mr. Ebbeson's qualifications and experience are summarized in Testimony of Bruce E. Ebbeson on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 6357) ("Ebbeson Dir.") at A3 and the *curriculum vitae* attached thereto.

quake. Thus, the State's challenge to Mr. Ebbeson's expert qualifications is totally lacking in merit.

c) Section E Witnesses

(1) Donald Wayne Lewis

R24. The State refers to Mr. Lewis only in passing (State F. ¶¶ 165-168) and does not address Mr. Lewis' qualifications, which include 10 years of experience with the design, licensing, construction, and operation of independent spent fuel storage installations. See Testimony of Donald Wayne Lewis on Section E of Unified Contention Utah L/QQ (inserted into the record after Tr. 8968) ("Lewis Dir.") at A3-A4 and the *curriculum vitae* attached thereto.

(2) C. Allin Cornell

R25. The State does not address Dr. Cornell's qualifications. As the record shows, Dr. Cornell is eminently qualified as an expert on methodologies and standards for probabilistic seismic hazard analysis, engineering safety assessments, natural hazards analyses, and earthquake engineering. See Testimony of C. Allin Cornell (inserted into the record after Tr. 7856) ("Cornell Dir."). at A2-A7 and the *curriculum vitae* attached thereto.

(3) Krishna P. Singh and Alan I. Soler

R26. The State does not address separately the qualifications of Dr. Singh and Dr. Soler with respect to their Section E testimony.

(4) Everett L. Redmond II

R27. The State also ignores the qualifications of Dr. Redmond, who performed the radiological dose consequence analyses for PFS. Dr. Redmond's credentials are described in the Testimony of Krishna P. Singh and Alan I. Soler, and Everett L.

Redmond II on Radiological Dose Consequence Aspects of Basis 2 of Section E of Unified Contention Utah L/QQ (inserted into the record after Tr. 12044) ("Singh/Soler/Redmond Dir.") at A7 and in the *curriculum vitae* attached thereto.

3. Staff Witnesses

a) Section C Witnesses

(1) Goodluck Ofoegbu

R28. The State describes Dr. Ofoegbu as having "no direct experience with the Bonneville clays and apparently has not personally correlated CPT data with other test data." State F. ¶ 3. As was the case with Mr. Trudeau, the State cites to no evidence of any unique features of the Upper Lake Bonneville soils that would be beyond the expertise of a competently trained geotechnical engineer. Likewise, the reference to Dr. Ofoegbu's "apparent" lack of experience correlating CPT data is offered without explanation of its significance, if any. State F. ¶ 3. Dr. Ofoegbu specializes in the mechanical analyses of geological processes, finite element modeling, and the constitutive modeling of geological materials. Ofoegbu Qualifications at 1. His experience includes mechanical analysis of underground excavations, foundations, earthworks, and natural geological processes such as faulting and volcanism. Id.; Ofoegbu Post Tr. 11001, at 1.

R29. The State further describes Dr. Ofoegbu as not being a registered engineer in the United States, State F. ¶ 3, without explanation of what, if any significance, should be drawn from that fact and ignoring the fact that he is a registered professional engineer in Canada. Dr. Ofoegbu's qualifications and experience are set forth in the statement of professional qualifications attached to NRC Staff Testimony of Goodluck I. Ofoegbu Concerning Unified Contention Utah L/QQ, Part C (inserted into the record after Tr. 11001) ("Ofoegbu Dir.").

b) Section D Witnesses

(1) Goodluck Ofoegbu

R30. The State does not address Dr. Ofoegbu's qualifications applicable to Section D separately from its discussion of his qualifications in Section C. State F. ¶ 143.

(2) Daniel Pomerening

R31. The State gives similarly short shrift to the qualifications of Mr. Pomerening who is described merely as a "non-NRC employee witness[]". State F. ¶ 143. The qualifications and experience of Mr. Pomerening are described in the NRC Staff Testimony of Daniel J. Pomerening and Goodluck I. Ofoegbu Concerning Unified Contention Utah L/QQ, Part D (Seismic Design and Foundation Stability) (inserted into the record after Tr. 6496) ("Pomerening/ Ofoegbu Dir.") at A2(b) and the statement of professional qualifications attached thereto.

(3) Jack Guttman

R32. The State does not directly address the qualifications of Mr. Guttman. Mr. Guttman's qualifications are described in NRC Staff Testimony of Vincent K. Luk and Jack Guttman Concerning Unified Contention Utah L/QQ (Geotechnical Issues) (inserted into the record after Tr. 6760) ("Luk/Guttman Dir.") at A2(a) and the statement of professional qualifications attached thereto.

(4) Vincent K. Luk

R33. The State attacks Dr. Luk's testimony in a variety of ways, but does not directly discuss his substantial professional qualifications, which are set forth in Luk/Guttman Dir. at A2(b) and the statement of professional qualifications attached thereto.

R34. As discussed in Section IV.F.10.c) below, the State attempts to distinguish away Dr. Luk's extensive experience by making artificial distinctions between his work on the PFSF and other generic and site-specific cask stability analyses he has performed and based on differences in characteristics of those sites. See, e.g., State F. ¶¶ 377, 385-392. Suffice it to say that the State's attacks on Dr. Luk's credentials are unavailing, both on legal grounds and on the facts, since his experience and expertise are unmatched and directly applicable to the PFSF.

c) Section E Witnesses

(1) John A. Stamatakos, Rui Chen, and Martin W. McCann, Jr.

R35. The State fails to address the qualifications of the Staff witnesses regarding the evaluation of the PFS exemption request. The qualifications of these Staff witnesses are presented in NRC Staff Testimony of John A. Stamatakos, Rui Chen and Martin W. McCann, Jr., Concerning Unified Contention Utah L/QQ, Part E (Seismic Exemption) (inserted into the record after Tr. 8051) ("Stamatakos/Chen/McCann Dir.") at A1(a), A1(b) and A1(c) and the respective statements of professional qualifications attached thereto.

(2) Michael D. Waters

R36. The State merely describes Mr. Waters as a "health physicist," Staff F. ¶ 545, ignoring his substantial expertise on radiological dose assessment matters. NRC Staff Testimony of Michael D. Waters Concerning Unified Contention Utah L/QQ, Part E (inserted into the record after Tr. 12215) ("Waters Dir.") at A2 and the statement of professional qualifications attached thereto.

IV. PROPOSED FINDINGS OF FACT

A. Section C of Contention L/QQ: Characterization of Subsurface Soils

1. Background and Purpose of Characterizing Subsurface Soils[33]

R37. The State prefaces its findings on the characterization of the subsurface soils at the PFSF site with the assertion that, in order to show that the cask storage pads and the Canister Transfer Building will be adequately supported on a stable foundation during a seismic event, PFS's subsurface soils characterization must show that the site soils have "adequate margins against potential failure during a seismic event." State F. ¶ 8. The State seeks to equate adequate margins against potential failure to rigid adherence to certain "factors of safety" of the soils beneath the foundations of the CTB and the pads, expressed as the capacity of the soils to resist failure divided by the demand placed on the soils by the seismic event and other foundation loads. State F. ¶ 9.

R38. The State contends that a factor of safety of at least 1.1 against the various soils failure modes in an earthquake is "inviolable." State F. ¶ 10.[34] However, the NRC Staff testified that it is not necessary to meet a factor of safety of 1.1 against soils failure to satisfy NRC regulatory requirements in 10 CFR Part 72. Tr. 6594-96 (Ofoegbu). All that Part 72 requires is that the structures, systems and compo-

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[33] The discussion of the proposed findings of fact follows the same organization and section headings as the State uses in its proposed findings. Use of the State's headings does not imply agreement with the characterizations contained therein.

[34] State F. ¶ 10 cites Tr. (Bartlett) at 11845-48 for the proposition that a factor of safety of 1.1 is "inviolable". There is no such testimony by Dr. Bartlett on the cited pages of the hearing transcript, or anywhere else in his oral or written testimony. What Dr. Bartlett said in his written direct testimony is that "the use" of factors of safety below 1.1 for extreme environmental events is "usually not allowed by the engineering profession." State of Utah Testimony of Dr. Steven F. Bartlett on Unified Contention Utah L/QQ (Soils Characterization), inserted into the record after Tr. 11822 ("Bartlett Soils Dir.") at A9.

nents important to safety be shown to perform their safety functions when subjected to seismic loadings. Id. The foundation stability analyses performed by PFS demonstrate that this condition will be met, whether or not the factor of safety guidelines are satisfied. Id.

R39. Not only does the State seek to impose an "inviolable" requirement to meet a factor of safety of 1.1, but it goes on to contend that the minimum factors of safety computed by PFS against sliding and bearing capacity failure of the soils under the pads, and against sliding failure of the CTB soils, have "only a 6 to 15 percent margin in PFS's assumed capacity of the soils used in its design calculations before it would reach unacceptable performance." State F. ¶11.[35] Based on that allegation, the State asserts that the soundness of the PFS soils characterization program "is critical" to showing that the soils are adequate for the "proposed foundation loadings." Id.

R40. The State's proposed finding would require unduly piling of conservatism upon conservatism. PFS's foundation stability analyses show that there are large margins against the onset of soil failure. The minimum factors of safety calculated by PFS against sliding and bearing capacity failure of the pads are 1.27 and 1.17 (or 27 percent and 17 percent) respectively. Rebuttal Testimony of Paul J. Trudeau to Testimony of State of Utah Witness Dr. Stephen F. Bartlett on Section C of Unified Contention Utah L/QQ (Soils Characterization) (inserted into the record after Tr. 11724) ("Trudeau Soils Reb.") at A3. A reduction in one of these calculated minimum factors of safety to 1.1 would still leave a 10 percent margin of

[35] This "6 to 15%" is obtained by the State by dividing the minimum factors of safety computed by PFS, computing the difference between those factors and 1.1, dividing that difference by 1.1 and expressing the result a percentage. Tr. 11845-46 (Bartlett). Thus, the minimum factor of safety against pad sliding, 1.27, is 15.5 % above the 1.1 standard, or as the State would put it, has a 15.5% margin above the recommended margin of safety. Id.

safety against the failure mechanism in question, nowhere near reaching "potentially unsafe condition." Id. at A2. Further, the PFS foundation stability analyses were performed utilizing extremely conservative assumptions. If those assumptions were replaced with more realistic ones, the analyses would show even larger margins of safety. Id. at A3. For that reason, soils characterization inaccuracies would have no effect on soil performance during a seismic event. Id.[36]

2. Shear Strength of the Soils

R41. The State would have the Board find that "an accurate and adequate characterization of the upper Bonneville clays is essential to PFS's demonstration that the pads and CTB will be supported on a stable foundation during a seismic event." State F. ¶ 13. The parties agree that the soils in the Upper Lake Bonneville clay layer are the ones of interest for establishing the minimum value of soil strength; however, the parties disagree as to whether the extent to which an "accurate" computation of the strength of those soils is necessary.

R42. It is undisputed that PFS focused its soils investigations – borings, samplings, and laboratory tests – on that layer. However, because of the exceptionally conservative approach used by PFS in establishing the minimum strength and other characteristic of the PFSF site soils, even if there were some inaccuracies in the determination of the strength of the Upper Lake Bonneville clays (which the record

[36] Dr. Bartlett testified that, apart from sliding failure, the conservatisms in the foundation design led him not to expect overturning of a pad foundation even for a 10,000-year return period earthquake, and that PFS's "bearing capacity analysis" for the pads for the 2,000-year return period "seems to be adequately conservative." Tr. 12845-46 (Bartlett). Dr. Bartlett also has no concerns with respect to "catastrophic potential failures of the foundations" for the CTB other than potential sliding of the building. Tr. 12849 (Bartlett). Thus, the primary concern of the State is with respect to potential sliding of the foundations for the storage pads and the CTB. As further discussed below, sliding of the pads and the CTB, if occurring, would pose no safety concerns.

shows not to be the case), the conservatisms built into PFS's methodology for determining the soils properties and the factors of safety against soil failure are more than sufficient to assure that the soils conditions are adequate to meet the anticipated foundation loadings. Trudeau Soils Reb. at A11.

3. Soil Variability and Upper Bonneville Clays

R43. The State indicates that "from the soils laboratory data PFS has not determined what percentage of the upper Bonneville clays are a plastic soil using the soil classifications (i.e., a CH or MH material)."[37] From that assertion, the State audaciously asks the Board to conclude that "because PFS has failed to classify the plasticity of the upper Bonneville clays, it cannot claim that there is uniformity across the site." State F. ¶ 20. There is, however, absolutely no testimony on the record, either by State witnesses or anyone else, which correlates the uniformity of soils with their plasticity.[38] Thus, this proposed State finding must be rejected.

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[37] The State cites as the basis for this assertion "Tr. (Trudeau) at 11751." However, Mr. Trudeau was asked whether PFS had determined "what percentage of the upper Bonneville clays is a plastic soil, a CH or MH material that we talked about in soil cement?" and his response was "I don't recall ever trying to break it down by the Hs versus the Ls." Tr. 11751 (Trudeau). (The terms "Hs" and "Ls" refer to an industry classification under which "Hs" are "high plasticity" and "Ls" are "low plasticity" soils. Tr. 11214 (Mitchell). Mr. Trudeau did not say that PFS had not sought to classify the Upper Bonneville Layer soils as "high" or "low" plasticity, and in any event the shear strength of the tested soil samples was the critical parameter, independent of whether those samples exhibited "high" or "low" plasticity.

[38] The discussion of soil plasticity at the hearing was in terms of the varying degree of plasticity of the eolian soils that are to be removed and used to manufacture soil cement. See Tr. 10872-10881 (Trudeau). Although Mr. Trudeau acknowledged that there might be some variability in the eolian soils because of varying plasticity, he maintained (and the record shows) that the Upper Bonneville clays are uniform across the site. See, e.g., Joint Testimony of Paul J. Trudeau and Anwar E. Z. Wissa on Section C of Unified Contention Utah L/QQ (inserted into the record after Tr. 10834 and/or Tr. 11724) ("Trudeau/Wissa Dir.") A11-12, A20; Tr. 11772 (Trudeau); see also Tr. 11816 (Ofoegbu); PFS Exh 233, 233a.

4. Density of Borings

R44. While admitting that Reg. Guide 1.132 by its terms applies to nuclear power plants and not to ISFSIs, the State would have the Board find that "it [is] appropriate guidance at the PFS site unless PFS has devised a more conservative sampling plan." State F. ¶ 24. The State offers no basis for arguing that Reg. Guide 1.132 provides "appropriate guidance at the PFS site." To the contrary, the evidence shows that Reg. Guide 1.132 is inappropriate for application to ISFSIs because nuclear power plants have larger and more heavily loaded foundations than ISFSIs and include, unlike ISFSIs, several categories of interconnected safety-related system and components. Trudeau/Wissa Dir. at A20; Trudeau Soils Reb. at A4. Nor is there any support for the State's position that PFS should have devised "a more conservative sampling plan" than that set forth in Reg. Guide 1.132. The same reasons that dictate that the guidance in Reg. Guide 1.132 not apply suggest that a sampling plan by PFS does not need to be more conservative than the guidance in Reg. Guide 1.132.

R45. In addition, Reg. Guide 1.132 points out that its recommendations "should be tempered with professional judgment" and that "[a]lternative ... procedures that have been derived in a professional manner should be considered equally applicable for conducting foundation investigations." Reg. Guide 1.132, PFS Exh. 234, at 1.1321. PFS exercised professional judgment and developed a subsurface investigation program that combined the drilling of boreholes with other activities to the extent warranted by site conditions and the size, loading, and isolation of the storage pads. Trudeau Soils Reb. at A4.[39]

[39] Dr. Bartlett acknowledged that the 100 foot spacing called for in Reg. Guide 1.132 was not a hard and fast rule, and that it was appropriate to exercise judgment in deciding how many borings should be conducted. Surrebuttal of Dr. Steven Bartlett to PFS Witness Paul Trudeau's

R46. The State goes on to argue that its position on Reg. Guide 1.132 "is reinforced by the fact that PFS makes analogies to nuclear power plant ("NPP") guidance in arguing for the grant on its seismic exemption. See Contention Part E: Seismic Exemption Request." State F. ¶ 24. However, the State's attempted application of the analogy is faulty here. The rationale for number of borings for NPP do not apply with respect to the pad area wholly apart from issues of conservatisms in design acceptance criteria. Any comparison must be drawn it will lead to an analogous result in both situations: just as it is not appropriate to apply the Reg. Guide 1.132 guidance to soils investigations at ISFSIs, the more conservative earthquake definition standards used for NPPs are not applicable to ISFSIs. See, e.g., Tr. 9122-24 (Arabasz).

R47. The State also argues that PFS has significantly undersampled the pad emplacement area when compared with both the Canister Transfer Building sampling density. State F. ¶ 27. For the CTB, PFS elected to provide a density of borings that matches the recommendations in Reg. Guide 1.132 because the CTB has a large, heavily loaded foundation, analogous to those of nuclear power plant structures. Trudeau Soils Reb. at A4. As discussed above, cask storage pads are not like nuclear power plant structures.

5. No Continuous Sampling at Depth to Establish Engineering Properties of the Upper Bonneville Clay

R48. The State agrees with PFS that the purpose of continuous soil sampling is to ascertain whether there are any zones of weak or unstable soils in the area of interest, in this case the Upper Lake Bonneville clays. State F. ¶ 28; see also Trudeau Soils Reb. at A8. The State acknowledges that the cone penetration ("CPT") test

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Rebuttal Testimony on Section C of Unified Contention L/QQ (inserted into the record after Tr. 11982) [hereinafter "Bartlett Soils Surrebuttal"] at R4; Tr. 11854-55 (Bartlett).

data provide continuous sampling of the soil properties. State F. ¶ 31. The State, however, asks the Board to disallow reliance on CPT testing because PFS did not "conduct any statistical analysis of the CPT data to determine the variability of the upper Bonneville clays" nor did it "analyze the range or standard deviation of the tip resistance across the site." State F. ¶ 32. However, the only possible use of the statistical analyses sought by the State would be to determine the margin of error in the values of soil strength that might be inferred from the resistance measured at the tip of the cone penetrometer.[40] Such quantitative information does not go to determining whether there are any thin zones of weak or unstable soils within the Upper Lake Bonneville clays layer. Should such thin zones exist, they would be easily identifiable by the CPT tests as areas of low tip resistance. No such zones were found in the PFS investigations, confirming that the Upper Lake Bonneville clays layer is reasonably uniform. Tr. 11749-50 (Trudeau). Nor has the State identified any such zones on its own.

R49. Another reason the State claims the CPT tests cannot be cited as "continuous sampling" is that the PFS program for taking soil samples for laboratory testing was completed before PFS conducted cone penetrometer testing. State F. ¶ 30. Therefore, the State argues, "the CPT data could not have been used to select the weakest zone for the laboratory shear strength test program." State F. ¶ 36. But PFS does not claim that it used the CPT data to select the weakest soil zone; the CPT test results merely confirmed that the sample selected had the lowest strength of the soils in the pad emplacement area. PFS Exh. 238; Tr. 11960-62 (Trudeau).

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[40] PFS testified that such statistical analyses are unnecessary because the plots of cone penetration tip resistance demonstrate that the soils in the Upper Lake Bonneville clays layer are essentially uniform in the horizontal direction. Tr. 11771-72 (Trudeau).

R50. Thus, while Reg. Guide 1.132 is not applicable to ISFSIs such as the PFSF, performance of the CPT test program was consistent with the continuous sampling recommendations in the Guide. Trudeau Soils Reb. at A7; NRC Staff Testimony of Goodluck I. Ofoegbu Concerning Unified Contention Utah L/QQ, Part C (inserted into the record after Tr. 11001) ("Ofoegbu Dir.") at A12.

6. Extreme Undersampling to Measure Undrained Shear Strength of the Upper Bonneville Clays

R51. The State notes that PFS based its foundation stability analyses for the pad emplacement area on a minimum value for undrained shear strength determined from a single sample that it collected from a borehole in the pad emplacement area. State F. ¶ 41. The State terms this "gross undersampling" and asserts that "there is no apparent reason PFS could not have performed additional direct shear testing on other undisturbed samples from some or all of the other five borings in the pad area." State F. ¶ 44. Whether PFS could have performed additional tests is not the issue, however. The question is whether the testing conducted by PFS is sufficient to determine the minimum shear strength of the soils in the pad emplacement area. PFS has shown that the testing was sufficient.

R52. The State describes PFS's explanation as to why it used a single sample as follows: "the direct shear test sample came from one borehole in the northeast quadrant of the site; of all the soils specimens tested in the pad area, the northeast quadrant had the highest void ratio; a high void ratio results in low soil density; and low soil density is evidence of weaker soil. Tr. (Trudeau) at 11774-76; Trudeau Rebuttal (Soils), Post Tr. 11954 at 9." State F. ¶ 44. The State cites no evidence that controverts PFS's rationale for relying on the single sample it selected for testing. Rather, the State would have the Board find the testing inadequate be-

cause "PFS has an insufficient density of borings in the pad area", and "has not continuously sampled the upper Bonneville clays". Id.

R53. The State's arguments are again non-sequiturs. The number of borings made by PFS or whether those borings were sampled continuously has nothing to do with how many samples are tested for shear strength. In addition, the State's challenge to the number of borings and the argument that PFS did not conduct continuous sampling are invalid for the reasons discussed above. The fact remains that the rationale employed by PFS in its sample selection process was sound and that PFS did select the soil samples for testing based on the standard penetration tests performed in the borings, which indicated that these would be the weakest soils underlying the proposed foundations. The results of the laboratory testing and the cone penetration testing that were subsequently performed corroborated the fact that the weakest soils were tested for shear strength. See Tr. 11767-71 (Trudeau).

R54. PFS witness Mr. Trudeau also testified that the measurements of tip resistance obtained in the CPT testing program confirm that the sample selected had the lowest strength of the soils at the site. Tr. 11772-73, 11955-62 (Trudeau). The State contests this position. It argues, based on tracings made by Dr. Bartlett with a marker of enlarged photocopies of tip resistance plots such as those shown in PFS Exh. 233A, that there can be a factor of two variability in the shear strength of the soils in the Upper Lake Bonneville clays layer. State F. ¶ 45. As demonstrated at the hearing, such tracings are too crude to have any evidentiary value. See Tr. 11893-99.

R55. The State cites Dr. Bartlett's explanation at the hearing that the reason he prepared his crude tracings is that "he had been unable to obtain the electronic CPT data from PFS so that he could refine his plots. Tr. (Bartlett) 11898-99". State F.

¶ 48.[41] From there, the State goes on to argue that "Dr. Bartlett testified that this issue could easily be put to rest if such plots were developed electronically either by him or by PFS" and then to represent that "[n]o such evidence is in the record." State F. ¶ 51. Dr. Bartlett's explanation is inexplicable and the State's representation wholly inaccurate, since numerical tabulations associated with the cone penetration tip resistance plots have been available to the State since 1999 and, indeed, a sample of the 4-inch binder of numerical tabulations was introduced into evidence as PFS Exh. 238. Tr. 11955-62 (Trudeau).[42]

R56. Moreover, the numerical tabulations of CPT tip resistance show that the measured cone penetration tip resistance varies as one moves downward in the soil profile but is remarkably uniform for the Upper Lake Bonneville clays layer as one moves from one location to another and takes measurements at comparable depths in the profile. See PFS Exhs. 238, 233A; Trudeau Soils Reb. at A11. Thus, the numerical data that the State claims would have resolved the issue were available, exist in the record, and resolve the issue conclusively.

R57. In fact, the numerical tabulations of CPT test data confirm that the soil strength obtained by PFS at the chosen location in the Upper Lake Bonneville clays layer is the lowest shear strength in the pad emplacement area. Tr. 11960 (Trudeau). The undrained strength of the soil tested in the laboratory without taking into account the weight of the pads is approximately 1,400 pounds for square foot ("1.4

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[41] It is unclear what Dr. Bartlett meant by "electronic" CPT data. If he means numerical values corresponding to the cone penetration resistance plots, such numerical values were available to the State since 1999, something he admitted. Tr. 11941-42 (Bartlett). If, on the other hand, he was seeking an electronic file containing the data, the State never requested such a file, and could have constructed such a file from the numerical data tabulations provided by PFS.

[42] It is particularly puzzling that the State would allege that such numerical data do not exist, since the State devotes two findings to trying to demonstrate that their use by PFS was inappropriate. See State F. ¶¶ 46, 47.

ksf") whereas the value obtained in the CPT tests, as derived from the values in PFS Exh. 238, is 1.34 ksf. Tr. 11962 (Trudeau). That is an excellent match, as Mr. Trudeau testified: "It doesn't get any better than that in geotechnical engineering." Id.

R58. The State challenges the derivation of undrained soil shear strength from CPT test data on the grounds that the formula used to correlate cone tip resistance and soil shear strength uses an empirical "cone bearing factor" N_k derived from a test that measures shear strength in a sub-vertical direction, whereas "the mode of failure for sliding and [sic] the PFS site is horizontal, *i.e.*, direct shear." State F. ¶¶ 46-47. However, the soil failure mechanism is a composite of failures along horizontal and vertical surfaces and is adequately represented by either the horizontal or vertical shear strengths determined by laboratory test results and field measurements. Staff Exh. ZZ; Tr. 12017-21 (Ofoegbu). Therefore, the value of N_k used by PFS's contractor is appropriate, as the almost exact match between the laboratory test results and the CPT readings demonstrates.

R59. The State invokes Dr. Bartlett's opinion that there can be a variability factor of 2 in the undrained shear strength of the Upper Lake Bonneville clays to argue that the minimum shear strength values in the pad area could range from 1.4 ksf[43] to 2.8 ksf, and any value of undrained shear strength of 1.82 ksf or less would decrease the minimum factor of safety against pad sliding from 1.27 to a value below 1.1. State F. ¶ 49. As demonstrated above, there is no credible evidence that

[43] This minimum value of 1.4 ksf for the undrained shear strength in the pad area quoted by the State should not be confused with the 1.4 ksf measured in the laboratory, which is the value of the undrained shear strength of the soil without the weight of the pad. The latter, if adjusted for the weight of the pad, would produce the 2.1 ksf utilized by PFS as the minimum undrained shear strength of the soil under as-constructed conditions. See Tr. 11956-62 (Trudeau) for a description of how to translate measured undrained shear strengths into estimated soil strengths with the pad on the soil.

such variability exists; however, even if there were such variability, it would be accommodated by the following conservatisms incorporated into the calculation of the minimum factor of safety against sliding:

- The factor of safety against sliding was computed using the strength of the weakest section of the Upper Lake Bonneville clay layer even though soils directly under the cement-treated soil will in most cases be much stronger than those below them. The use of the weaker strength of the soil at the lower section of the layer is quite conservative because there is a stronger crust, approximately 2 to 3 ft thick, at the top of the Upper Lake Bonneville clay layer, upon which most of the pads and cement-treated soil will be founded. Taking the actual strength of the soils directly beneath the cement-treated soil and pads into consideration, the factor of safety against sliding will be at least twice the minimum value used by PFS, or on the order of 2.5.

- The minimum factor of safety against sliding of the pads was computed without taking into account the increase in strength of clayey soils under cyclic dynamic loadings. Taking credit for this well-known phenomenon would increase shear strength by at least 50%, thus increasing the minimum factor of safety against sliding to 1.9 (or a margin of or 90%).

- The minimum factor of safety was computed without taking into account the passive resistance of the soil cement around the pads. Taking credit for that passive resistance would increase the minimum factor of safety for the design base case from 1.27 to 3.3.

- These increases in the minimum factor of safety are independent of each other and, thus, their effects are cumulative. Combining their effect would lead to a minimum factor of safety against sliding of the pads of at least 5.

Trudeau Soils Reb. at A3. Removing any or a combination of these conservative assumptions would more than offset the alleged effect of soil strength variability.

R60. The State also would cast doubt on the validity of PFS's minimum shear strength measurements for the soils in the CTB area, alleging that "the shear strength testing of the upper Bonneville clays under the CTB from samples taken from only

two boreholes outside the footprint of the building is insufficient to characterize the engineering properties of those soils." State F. ¶ 50. This finding is not supported by any testimony, and none is cited by the State. In fact, the finding is inconsistent with the testimony of Dr. Bartlett, who agreed that the processes for CTB sample selection and bearing capacity determination used by PFS were appropriate. Trudeau Soils Reb. at A14; Surrebuttal of Dr. Steven Bartlett to PFS Witness Paul Trudeau's Rebuttal Testimony on Section C of Unified Contention L/QQ (inserted into the record after Tr. 11982) [hereinafter "Bartlett Soils Surrebuttal"] at R14.

7. Other Tests to Determine Engineering Soil Properties

a) Cyclic Triaxial Tests

R61. With respect to the allegation that PFS should have conducted strain-controlled cyclic triaxial tests to determine the stress-strain relationship for the Upper Lake Bonneville clays layer, the State proposes that the Board find that "the extrapolation from resonance column tests are no substitute for actual strain-controlled cyclic triaxial testing." State F. ¶ 61. Not only is this argument unsupported by the evidence, it is also in stark contrast to the testimony of the State's own witness Dr. Bartlett, who testified that if one can be assured that there is no marked decrease in shear strength at high levels of strain, the concern about characterizing the dynamic properties of the soil at high strain levels is of no consequence. Tr. 11992 (Bartlett). There is uncontested testimony that stress-controlled cyclic triaxial tests conducted by PFS did not show any degradation of the shear strength of the samples throughout 500 cycles of loading at extremely high cyclic stress ratios. Trudeau Soils Reb. at A12. Therefore, the condition set by Dr. Bartlett is satisfied and, since there is no decrease in shear strength under cyclic earthquake

loadings, performance of strain-controlled cyclic triaxial tests is unnecessary. Id.; Tr. 11791-93 (Ofoegbu).

R62. The State would also have the Board find that PFS has not demonstrated "an acceptable level of conservatism in its seismic stability calculations for the storage pads and CTB because PFS has not conducted strain-controlled cyclic triaxial testing or, alternatively, reduced the shear strength it estimated from monotonic shear strength testing for use in those sliding stability calculations." State F. ¶ 61. Again, this proposed finding is inconsistent with Dr. Bartlett's views. When pressed by State counsel to declare the failure to conduct strain-controlled cyclic triaxial tests a "fundamental flaw in PFS' analysis" Dr. Bartlett would not agree. Tr. 11992 (Bartlett). In reality, the resonant column tests performed by PFS encompassed the range of strains applicable for the one-dimensional site response analyses for the lower of the two specimens tested and nearly encompassed the full range of strains for the upper specimen. The trends in these two sets of test results were very similar; therefore, extrapolation of the results from the upper specimen along the same curve as measured for the lower specimen was reasonable, obviating the need to perform strain-controlled cyclic triaxial tests. Trudeau/Wissa Dir. at A26; Tr. 11736-39, 11759-62 (Trudeau).[44]

b) Anisotropy

R63. The State claims that, in conducting triaxial compression tests to calculate the soil's resistance to bearing capacity failure, PFS "has given no consideration to performing triaxial extension tests to determine the degree of anisotropy of the foundation soils." State F. ¶ 65. According to the State, anisotropy (that is, the

[44] Dr. Bartlett himself agreed that making such an extrapolation is a valid technical approach. Tr. 11991-92 (Bartlett).

dependence of shear strength on the direction of shear) is a concern because "[t]he upper Lake Bonneville sediments are strongest in triaxial compression and weakest in triaxial extension." State F. ¶ 63. The State claims that if significant anisotropy exists and is not taken into consideration, the use of triaxial compression tests "overestimates the average shear resistance along the potential failure plane." State F. ¶ 65. The State asserts that this issue "has the greatest significance in analyzing the bearing capacity of the storage pads, due to their relatively narrow width (30 feet) and the small margin (i.e., 5 percent) against seismic bearing capacity failure estimated by the Applicant." Id.

R64. The minimum vertical shear strength obtained by PFS in its triaxial compression tests for the pad emplacement area is 2.2 ksf, and the horizontal shear strength as obtained in the direct shear tests is 2.1 ksf, so the degree of anisotropy exhibited by the PFSF site soils is slight, if any. Tr. 11973 (Trudeau); Tr. 12021 (Ofoegbu). In addition, the soil failure mechanism is a composite of failures along horizontal and vertical surfaces and is adequately represented by either the horizontal or vertical shear strengths determined by laboratory test results and field measurements. Staff Exh. ZZ; Tr. 12017-21 (Ofoegbu). Therefore, the effects of anisotropy are insignificant. Tr. 11973 (Trudeau); Tr. 12021 (Ofoegbu).

R65. The proposed State finding goes on to assert that "[p]revious studies performed on Lake Bonneville sediments have shown that the undrained shear strength in triaxial extension is approximately 60 percent of the undrained shear strength in triaxial compression." Id. State F. ¶ 63. However, the studies to which the State refers were conducted for soils in the I-15 corridor in Salt Lake City. See State Exh. 104; Bartlett Soils Dir. at n. 12. Those soils are softer and more saturated than the soils at the PFSF site, so no conclusions regarding the properties of the PFSF

soils, including the degree of anisotropy, can be drawn from the properties of the Salt Lake City soils. Tr. 6278 (Trudeau); Tr. 12033 (Ofoegbu).

R66. At any rate, the minimum factor of safety against bearing capacity failure of the storage pads was computed by PFS using many conservative assumptions, including among others using the minimum measured value of shear strength in the bearing capacity stability calculation, instead of following customary practice and using the average shear strength of the soil through a depth of 30 ft. below the base of the pads to determine the bearing capacity. Ofoegbu Dir. at A8. If this and other conservatisms in the analysis were removed, the calculated minimum factor of safety against bearing capacity failure of the storage pads would be well in excess of 3. Trudeau Soils Reb. at A9. Dr. Bartlett agrees that PFS's bearing capacity analysis for the pads is appropriately conservative. Bartlett Soils Surrebuttal at R3; Tr. 12845-46 (Bartlett). Therefore, the concerns about soil anisotropy even if well founded (which they are not) are inconsequential.

B. Section C of Contention L/QQ: PFS's Proposed Use of Soil Cement

1. Background

R67. In its background discussion of the proposed use of soil cement and cement-treated soil at the PFSF, the State asks that the Board give "particular deference" to the opinions of State expert Dr. James K. Mitchell on the topic of soil cement. State F. ¶ 73. PFS agrees that Dr. Mitchell's opinions should generally be given considerable weight; in particular, the Board should give deference to Dr. Mitchell's overall assessment that many of the issues he raised with the soil cement program at the PFSF are matters that he would like to see confirmed through testing, but which are technically achievable. PFS Exh. 228 at 186. Dr.

Mitchell's overall assessment means that the only disagreement between the parties' experts is as to when the testing is to be performed.

R68. The document that embodies the soil cement testing program developed by PFS is the "Engineering Services Scope of Work for Laboratory Testing of Soil-Cement Mixes" ("ESSOW"), PFS Exh. GGG. Dr. Mitchell agrees that the tests enumerated in the ESSOW are the appropriate tests to conduct to qualify soil cement for use; that the industry standards that the ESSOW specifies must be followed in performing the tests are the right ones; and that the test methodology described in the ESSOW is consistent with the current state of practice in the industry. PFS Exh. 228 at 68-70.

R69. There are only a few aspects of the proposed use of soil cement at the PFSF with which Dr. Mitchell disagrees. As to those, Dr. Anwar E. Z. Wissa, PFS's soil cement expert, has credentials just as impressive as Dr. Mitchell's, being among other things co-author of the standard industry work on soil cement, the "State of the Art Report on Soil Cement" published by the American Concrete Institute. See PFS Exh. HHH. Therefore, although Drs. Mitchell and Wissa are in remarkable agreement on most issues, where their opinions differ the Board should examine the arguments presented and the evidence cited by them and the other witnesses to determine which is more persuasive.

2. PFS's Soil Cement Testing Program to Date

R70. The State would have the Board find that "the quality and success of PFS's demonstration that it can prove and successfully implement its soil cement design concept depends in significant part on the credentials and experience of the person or entity chosen to conduct and supervise PFS's testing program." State F. ¶ 82. There is no evidence to support that conclusion, and the State cites none. The

success of the PFS testing program depends on having the testing program conducted in accordance with a suitable test program. Such a program is embodied in the ESSOW, PFS Exh. GGG. Trudeau/Wissa Dir. at A38-44; Tr. 11089-93, 11103-04 (Mitchell). All parties, including Dr. Mitchell, agree that the program is based on appropriate industry standards, including the American Concrete Institute "State-of-the-Art Report" on Soil Cement (PFS Exh HHH), and that it includes the proper tests and suitable test methodology. Trudeau/Wissa Dir. at A44; Ofoegbu Dir. at A22; Tr. 11061 (Mitchell); PFS Exh 228 at 47-50 (Mitchell). All parties, including Dr. Mitchell, also agree that the program will be effective in establishing whether the properties of the soil cement specified in the design have been achieved. Tr. 11266 (Mitchell).

3. PFS's Testing Program

R71. After describing the steps in the PFS soil cement testing program, the State refers to Dr. Wissa's testimony that he expects the bond testing program would take about 2 to 3 months and that it would take somewhere between six to nine months to complete the whole testing program. Tr. (Wissa) at 10865-66. The State then offers the following proposed finding: "Only then will PFS have proven the design. Mitchell/Bartlett Tstmy, Post Tr. 11033 at 13 (citing Trudeau deposition, Tr. at 81)." State F. ¶ 87. This assertion is incorrect and is based on an erroneous premise. PFS has already established the adequacy of its soil cement design. Tr. 11021-22 (Ofoegbu). Indeed, as the State's soil cement expert testified, the soil cement design does not need to be "proved" because there is no fatal flaw in it that would prevent it from being implemented. Tr. 11211 (Mitchell).[45]

[45] At his deposition, Dr. Mitchell stated: "I don't see anything wrong with the basic concept that is being proposed here." PFS Exh. 228 at 43. He also testified that he had no reason to be-

R72. Thus, the soil cement design concept does not need to be proven through testing. Tr. 11021-22 (Ofoegbu). The design is what it is, and what testing will prove is compliance of the selected construction mixes and installation techniques with the design requirements. Tr. 11087-88 (Mitchell).[46] What the NRC regulations and licensing practice do provide for is for testing to be conducted after licensing to verify that the material properties of the as-constructed structures satisfy the design. Tr. 11017 (Ofoegbu). PFS has defined a testing program that all parties agree is adequate. Implementation of this program will assure that the installed cement will meet design requirements.

4. PFS SAR Commitment to Shear Strength Testing

R73. With respect to PFS's commitment to demonstrate through laboratory testing that the cohesive bond between the concrete pad and the cement-treated soil and between the cement-treated soil and the underlying native soil will be strong enough to resist seismic loadings, the State argues that the adequacy of the shear strength of the cement-treated soil should be demonstrated "to the Board" (i.e., prior to licensing.) State F. ¶ 88. The State cites in support of its contention the shear strength testing PFS conducted on the Upper Lake Bonneville clay layer to establish the minimum shear strength of those soils. State F. ¶ 89. This confused ar-

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lieve that the soil cement design approach developed by PFS would not be successful. Id. at 45.

[46] The State refers to Mr. Trudeau's deposition as asserting that only when the testing program is completed will the design be "proved". The State's attempt to draw that concession from Mr. Trudeau's deposition deserves no credit, since what Mr. Trudeau was asked was: "Q: Do you consider this proving your design through all these testing?" His answer was: "A. It will -- it will prove the design." State Exh. 106 at 81. Clearly, Mr. Trudeau did not testify that completion of the testing program was required to "prove" the design, but the converse, i.e., that if the test program was successfully completed, this would show that the design could be implemented in the field. The State did not question Mr. Trudeau at the hearing about whether the designed needed to be "proved" prior to licensing.

gument misses the distinction between establishing the minimum soil strength for analysis and design, on the one hand, and the demonstration that the strength of the bond between the cement-treated soil and the soil exceeds the strength of the soil. Trudeau/Wissa Dir. at A39, A53. The former was an unknown quantity, and one that needed to be established before the design could proceed. The latter is a known requirement, and one that can be demonstrated at any time using the methodology and procedures to which PFS is committed and with which the State's expert, Dr. Mitchell, agrees. PFS Exh. JJJ; Tr. 10910-13, 10970-71 (Wissa); PFS Exh. 228 at 54-55.

5. Construction of Soil Cement and Field Testing

R74. In a series of proposed findings (State F. ¶¶ 90 through 97), the State would have the Board identify a number of "uncertainties" in the soil cement construction process. These include the "actual construction details" (State F. ¶ 91),[47] the "effect construction and exposure of the subsurface layer will have on the upper Bonneville clays" (State F. ¶ 92),[48] "how much of the upper Bonneville clays will be removed along with the eolian silts during excavation of the site" (State F. ¶ 93);[49] the impact of replacing eolian silts with native clays in those areas where it

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[47] Although the State contends that the construction details would be left to the discretion of the contractor, the same testimony by Dr. Wissa cited by the State made clear that the owner would impose constraints on what the contractor could do, while still allowing some flexibility as to the implementation details. Tr. 10888-89 (Wissa).

[48] The State would have the Board find that "the samples of the upper Bonneville clays that PFS has used for testing may not be representative of actual field conditions." State F. ¶ 92. There is absolutely no record support for this factual assertion, and the State cites none.

[49] The State alleges in State F. ¶ 93 that there is uncertainty as to the depth of the eolian soils in the pad emplacement area. No such uncertainty exists. The soil profiles shown in SAR Fig. 2.6-5, sheets 1 through 14 (see, e.g., PFS Exh. 233A), show that for most of the pad emplacement area, the eolian silt layer extends less than two feet below the pad. Only the far southeastern corner of the pad emplacement area has a section where the eolian silt layer to be removed may extend more than 2 ft. below the bottom of the pads. Rebuttal Testimony of Paul J. Trudeau and Anwar E.Z. Wissa to Direct Testimony of State of Utah Witnesses Dr. Steven

is necessary to excavate more than three feet of silt (Id.);[50] whether contractors employed by PFS to make soil cement will be able to tell plastic and non-plastic soils apart during excavation (State F. ¶ 94);[51] and the quality assurance/quality control measures that need to be instituted in order for the application of cement-treated soil to attain the qualities in the field that PFS aspires to demonstrate in the lab (State F. ¶ 96),[52] all leading to a proposed conclusion by the Board that "unless elaborate and detailed specifications are spelled out for contractors to fol-

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F. Bartlett and James K. Mitchell on Section C of Unified Contention Utah L/QQ (inserted into the record after Tr. 11232) ("Trudeau/Wissa Reb.") at A10.

[50] The State decries the absence of an analysis on whether the remolded upper Bonneville clays, consisting of compacted clay fill, will have the same shear strength as the undisturbed upper Bonneville clays that form the basis of PFS's pad sliding analysis. (State F. ¶ 93) This proposed finding is puzzling because the State witness who raised the concern about the potential need to remold the native clays if they are used to replace removed eolian soil testified that such analyses would be unnecessary since the strength of remolded, recompacted clay can be determined through a simple laboratory test. Tr. 11164 (Bartlett).

[51] Again, this is a surprising proposed finding, since the State itself notes that "Dr. Wissa testified that a trained person could identify non-plastic soils from plastic soil visually and by touch. Tr. (Wissa) at 10883-84." State F. ¶ 94. There is no testimony disputing Dr. Wissa's assertion, and the State cites none. The State goes on to propose a finding in which the Board would speculate that "if any of the various soil-cement contractors who work on the PFS project fail to correctly identify plastic from non-plastic soils, this failure could lead to a higher Young's modulus in the constructed cement-treated soil than analyzed in the Holtec cask tip over analysis." State F. ¶ 95. Of course, there is no evidence that there will be several soil-cement construction contractors working at the PFSF, nor that – contrary to Dr. Wissa's testimony that one can tell by inspection whether a soil is plastic or non-plastic – some contractor will fail to identify the soil material correctly, nor the effect (assuming the mistake is not caught) that such an erroneous identification will have on the properties of the constructed soil cement.

[52] The State proposes that the Board find that "[a]ttaining the target cement-treated soil properties in the field will be affected by the quantity and timing of cement-treated soil production and placement as well as by the competency of the contractors in ascertaining what measures they will take to ensure adequate adhesion between interface layers." State F. ¶ 96. The State cites no evidence in support of this broad proposition; this is not surprising, since there is no factual evidence on the record that supports it.

low, there is no assurance that laboratory test results can be achieved in the field." State F. ¶ 97.[53]

R75. The answer to these alleged "uncertainties" is that they can be easily managed through the selection of a competent contractor and the normal oversight of the contractor's work by the owner and the NRC. Tr. 10883-86 (Wissa). Dr. Wissa put it best at the hearing in response to a question by State counsel:

> Q. . . . Given the uncertainty and the construction period for now, how you would insure consistency and quality over such an extended construction period?
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> A. I don't see the relevance. . . . You prepare a set of specifications. You qualify contractors. Then you supervise the construction. I assume you do this for each phase. The fact that you may not have the same contractor for all phases should not impair the quality of a product as long as you have a quality assurance process or program which is enforced.
>
> I think if anything what you will find is the first phase you are going to be debugging your problems and by the time it goes around you will have learned from it. By the third time I think it will go very smoothly. I think you gain experience as you go through it and make some

[53] The State reads the SAR section on soil cement construction, PFS Exh. JJJ, as indicating that "[i]f the soil cement production cannot keep pace with the efficient placement of cement-treated soil lifts, this will negatively effect [sic] interface bonding, thereby decreasing bond strength. Id. at 2.6-116. Further, the record illustrates that based on research by DeGroot there are many factors that can decrease bond strength. Id. at 2.6-116 (items 1 through 7)." State F. ¶ 97. However, what that page says is that "increasing the time delay between placement of subsequent lifts decreases the bond strength." There is nothing in that SAR section that suggests that bonding will be decreased if soil cement production does not keep pace with placement of soil cement, and nothing was said at the hearing to even suggest that soil cement production would not be able to keep up with installation. With respect to the factors noted by DeGroot, the SAR acknowledges these factors and indicates that "DeGroot has demonstrated that techniques are available that will enhance the bond between lifts of soil cement. These techniques should be equally effective when applied to the soils at the PFSF site. PFS has committed to perform direct shear tests of the interface strengths during the design phase of the soil cement to demonstrate that the required interface strength can be achieved, as well as during construction, to demonstrate that they are achieved." PFS Exh. JJJ at 2.6-117.

> improvements and modifications as you proceed. I don't see the fact that it's done in three or four phases that you would jeopardize the quality of product.

Tr. 10893-94 (Wissa). Indeed, the State's soil cement expert agreed that the construction program set forth in the PFSF SAR is reasonable and appropriate. Tr. 11088-89 (Mitchell); PFS Exh. 228 at 56-57.

R76. In addition, rather than requiring "elaborate and detailed specifications" in order to succeed (as argued in State F. ¶ 97) the soil cement construction program at the PFSF will more appropriately be given significant flexibility, which can be applied to address the range of field conditions and material and finished product properties that may be encountered. Tr. 10944-47 (Wissa). Dr. Mitchell agreed. Tr. 11179-80. Soil cement placement is not rocket science, and the uncertainties alleged by the State to exist are no more complicated or mysterious than those encountered in other large construction projects. Also, as a matter of law, details such as those raised by the State in this area are not appropriate for adjudication in a Commission licensing proceeding. See Section II, supra.

6. Young's Modulus

R77. The State proposes a finding that "[o]ne of the most difficult tasks confronting PFS's [sic] is to find a mix using PFS surficial site soils that will attain a Young's modulus (i.e., a vertical stress to strain ratio) of less than 75,000 psi for 40 psi compressive strength cement-treated soil." State F. ¶ 98. This is, however, not such a "difficult task" as the State would have the Board believe. All parties agree that seeking to limit the Young's modulus to less than 75,000 psi for cement-treated soil having an unconfined compressive strength of 40 psi is achievable, because having relatively low modulus is consistent with the relatively low strength required. Tr. 10915 (Wissa); Tr. 11023-24 (Ofoegbu); Tr. 11159-60

(Mitchell). This is also demonstrated to be achievable based on data reported in the literature. Tr. 11023-26 (Ofoegbu).

R78. Dr. Ofoegbu provided citations to several papers in the literature that demonstrate that a Young's modulus of no more than 75,000 psi is achievable at a compressive strength of 40 psi. Tr. 11025-26 (Ofoegbu). The State attempts to dismiss this testimony by asserting that "[t]ests reported in the literature are based on site specific soils." State F. ¶ 99. However, there is no testimony that supports this proposition. Dr. Ofoegbu certainly did not state that limitation when describing the literature, and in fact referred to a paper that provided charts of ranges of values of Young's moduli for use in soils analysis. Tr. 11026 (Ofoegbu).[54]

R79. Another issue raised by the State's proposed findings is that the soil cement and the cement-treated soil continue to cure with time. The State cites Dr. Mitchell's testimony for the proposition that in order to achieve a Young's modulus of no more than 75,000 psi, one may need to start with a modulus perhaps as low as 40,000 psi. State F. ¶ 100, citing Tr. 11222 (Mitchell). Dr. Mitchell testified that he could not specify a starting value of modulus to aim for without test data, and that his only point was that it would not be prudent to start at the 75,000 psi value. Tr. 11222 (Mitchell). However, it is undisputed that the greatest increase in Young's modulus occurs during the first 28 days of curing. Tr. 11226-27, 11229-30 (Mitchell); Tr. 11251-52 (Wissa). For that reason, the Young's modulus value

[54] The State cites Dr. Wissa's testimony for the proposition that "testing to establish a Young's modulus is a function of the site soils." Tr. (Wissa) at 10985. State F. ¶ 99. Actually, Dr. Wissa said, in response to a question by State counsel as to how much cement would need to be added to the soils to achieve the required combination of compressive strength and modulus, that in order to answer that question he would need to perform a testing program because the appropriate mix would be a function of the soil properties. Tr. 10985 (Wissa). He neither said nor implied that there were doubts as to the feasibility of achieving a proper mix; he just did not know, without testing, what the mix would be.

used in Holtec's cask drop and tipover analysis is benchmarked at a curing age of 28 days. Tr. 11253 (Trudeau). In other words, the 75,000 psi maximum Young's modulus value is determined as of the 28-day curing point. Id. Dr. Mitchell was not aware of what benchmark PFS intended to apply, but confirmed that 28-day strength was a commonly used value. Tr. 11227-28 (Mitchell). Because he was unaware of the benchmark used by PFS, Dr. Mitchell incorrectly assumed that the 75,000 psi limit applied throughout the life of the facility. See, e.g., Tr. 11216-17 (Mitchell). While the strength of the cement-treated soil increases slowly with time after 28 days as it continues to cure, this process is immaterial because the important data point for which the cask drop and tipover analyses are performed is after 28 days of curing.

R80. Despite the clarifications offered at the hearing, the State continues to insist that the Young's modulus should be measured under dynamic, not static loads. State F. ¶¶ 101-102. However, State witness Dr. Ostadan agreed that the Holtec design intent could be satisfied by formulating a test program that established that the modulus of elasticity of the cement-treated soil did not exceed 75,000 psi at the strain level occurring in the vicinity of cask impact (i.e., 1.93 percent in the soil directly beneath the cement-treated soil) based on Holtec's analysis. Tr. 7426-27 (Ostadan). Thus, the distinction between dynamic and static loadings is immaterial; the important issue is that the proper strain level be achieved in the test. Testimony of Krishna P. Singh and Alan I. Soler on Unified Contention Utah L/QQ (inserted into the record after Tr. 5750) ("Singh/Soler Dir.") at A55. PFS's approach to determining the Young's modulus is precisely to use soil strain level as the reference parameter for its Young's modulus testing. Moreover, the Sandia National Laboratories paper that provided experimental data forming the bases for

the cask drop analyses uses static moduli of elasticity for the soils underlying the pad and it demonstrated good agreement between analytical results and experimental results, indicating that large-strain moduli are appropriate for such analyses. Tr. 10927-28 (Trudeau); Tr. 10988 (Wissa).

R81. The State proposes a conclusory finding with respect to Young's modulus of the cement-treated soil that states: "Part of the Board's concern is that as PFS's modulus testing is intended to be done at some time in the future, it will likely require an exercise of discretion on the part of the Staff to determine whether PFS has, in fact, met a 75,000 psi over time and under dynamic loading conditions. This process would grant Staff post-licensing decision making authority that is much more than ministerial in nature." State F. ¶ 103. This proposed finding is wrong both as a matter of fact and in the law. As discussed above, the determination whether the Young's modulus limit of 75,000 psi is satisfied will be made with respect to the modulus after 28 days of curing, which is the benchmark (i.e., criterion) used in the cask drop and tipover analysis, and it will be determined based on measurements made at the appropriate strain levels. Thus, there will be a single value against which to determine compliance with the design requirements and hence no need for the Staff to exercise "decision making authority," as the State contends.[55]

[55] Also, for the reasons discussed above, it is totally wrong to assert that it will be necessary to "determine whether PFS has, in fact, met a 75,000 psi . . . under dynamic loading conditions. (State F. ¶ 103). As Dr. Soler testified, dynamic loading conditions result in less strain on the soil than the required 1.93 percent strain rate. Such a strain is more likely to be achieved under static loading. Singh/Soler Dir. at A55; Tr. 6003-04 (Soler).

7. Precedent for the Use of Soil Cement to Resist Sliding from Strong Ground Motions

R82. The State devotes several proposed findings (State F. ¶¶ 104-115) to seeking to demonstrate that the proposed use of soil cement is "precedent setting" and that "PFS has made many assumptions about the properties and behavior of soil cement but has not demonstrated them in this proceeding." State F. ¶ 115.

R83. There are three relevant points to be made with respect to the existence of precedent for the use of soil cement at the PFSF: (1) the existence or absence of precedent is of no regulatory significance; (2) there are perhaps thousands of precedents for the use of the properties of soil cement to stabilize soils, which is the general application that PFS intends to give to the material; and (3) there are direct precedents in which soil cement has been used in exactly the same way as PFS intends.

R84. On the first point, the State does not contend that there is any licensing significance to the absence of precedent for the soil cement applications proposed for the PFSF.[56] It is uncontested that there is no regulatory requirement that the suitability of soil cement for its intended use be demonstrated by case history precedent. Ofoegbu Dir. at A20. And, as the State's soil cement expert acknowledged, there is no significance to an application being new; new applications for soil cement are being developed all the time, and there is nothing inherently wrong with the application that PFS proposes to make of soil cement at the PFSF. Tr. 11054, 11187 (Mitchell). Therefore, the State's precedent argument is irrelevant.

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[56] The State acknowledges that "there must always be a first new application of a concept." State F. ¶ 113. It goes on, however, to declare that "in such instances the Board expects that there will be sufficient testing prior to project approval to prove the concept." There is no factual or legal basis for such "expectation" and the State offers none.

R85. The second point may be one of semantics rather than substance. As the State notes (State F. ¶ 105), PFS considers as precedent those uses of soil cement that draw upon the same mechanical properties of the soil cement. Trudeau/Wissa Reb. at A1. The use of soil cement and cement-treated soil at the PFSF relies on the shear and compressive strengths of those materials to resist founding loadings, as do many other well known applications dating as far back as the early 1900s. Id. Dr. Mitchell agrees "that the properties, the mechanical properties that you're concerned about are the strength, the compressibility, the stiffness or modulus, and the permeability of the material. Every project involving soil cement that was constructed since that first road in, was it Sarasota, Florida in 1906 or 1908, draws on one or more of those properties." Tr. 11255-56 (Mitchell).

R86. Dr. Mitchell chooses to define "precedent" in a much, much more narrow fashion. According to him, even going from using soil cement in the foundations of 50 to 60 story buildings is no precedent for using soil cement in the same manner in buildings over 100 stories tall. Tr. 11256 (Mitchell). In his view, "every project is different." Tr. 11263 (Mitchell).

R87. There is no need to attempt to resolve this semantic dispute. The use of soil cement in a manner that utilizes the same properties of the material in essentially the same manner as prior applications gives confidence that the intended use makes sense from an engineering standpoint. Dr. Mitchell has agreed that the uses PFS proposes to make of soil cement and cement-treated soil are reasonable. Tr. 11187 (Mitchell). Thus, looking at how close an analogy exists between the proposed application and previous ones is unnecessary.

R88. In any case, there are close analogies between the PFSF application and other recent uses of soil cement at major construction projects. As testified by both PFS

and the Staff, and as indicated in the paper by Lambrechts, Roy, and Wishart (1998) cited to by Dr. Ofoegbu, the shear and compressive strength of soil cement were used extensively to create soil-cement buttresses to resist lateral forces during construction of the five highway tunnels for I-90 and I-93 that converge at the Fort Point Channel crossing of Boston's Central Artery/Tunnel Project. Trudeau/Wissa Reb. at A1; Ofoegbu Dir. at A22; Tr. 10846-47 (Wissa).[57] This resistance to lateral loads is provided by the shear and compressive strength of the deep soil-cement buttresses. This is essentially the same use of soil cement that PFSF has proposed for the Canister Transfer Building.

R89. Another similar application of soil cement to that at the PFSF is the use of soil cement to provide foundation strength and uniform support at Koeberg, South Africa, where an 18-foot thick layer of saturated sand under two 900-MW nuclear power plants was replaced with soil cement. Like the use of cement-treated soil beneath the storage pads at the PFSF, the Koeberg site uses soil cement to provide foundation stabilization through increased shear strength, so as to resist earthquake loadings. Trudeau/Wissa Dir. at A36; PFS Exh. JJJ at 2.6-113; Tr. 10972, 10974 (Trudeau).[58]

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[57] The State would have the Board reject the Boston Central Artery Tunnel project as a precedent for the PFSF because of differences in the type of soil with which the cement is mixed, the higher water content of the soil in the Boston project, and the Boston project's use of a deep soil mix. State F. ¶ 109. These are differences without distinction and even though they may affect the type and proportions of the soil/cement mix, they do not take away from the fact that the purpose of the application is essentially the same in both instances, i.e., to help resist lateral loads. Tr. 11192, 11257, 11266-67 (Mitchell); Trudeau/Wissa Reb. at A1; Tr. 10846-47 (Wissa).

[58] The State would also have the Board reject the Koeberg project as a precedent because the soils at Koeberg were prone to liquefaction and because the mix used was sand-cement rather than silt-cement. State F. ¶ 110. However, Dr. Mitchell acknowledged that both at the PFSF and in Koeberg the purpose of soil cement is to increase the cohesive strength of the soils. Tr. 11267 (Mitchell)

R90. Still another analogous application of soil cement is its use in retaining walls to resist lateral loadings. In those applications, the passive resistance provided by the soil cement at the toe of the wall provides stability against sliding, as it will do for the CTB and the soil cement "frame" around the cask storage pads at the PFSF. Tr. 10847-48 (Trudeau).[59]

R91. In short, the use of soil cement at the PFSF is amply justified by precedent. As Dr. Mitchell testified, confidence in the effectiveness of soil cement to provide soil stabilization is "growing all the time." Tr. 11194 (Mitchell). There should be no doubt as to the appropriateness of its use at the PFSF.[60]

8. Degradation and Environmental Effects

R92. The State proposes several findings on alleged "unresolved problems with PFS's use of soil cement." State F. ¶¶ 116 – 120. Mentioned (although not addressed in any detail) are: (1) construction problems, such as remolding of the Upper Lake Bonneville clays (State F. ¶ 116); (2) cracking of the soil cement material (State F. ¶¶ 116-117); (3) adverse effects of moisture infiltration (State F. ¶¶ 116, 118); (4) debonding at interface layers (State F. ¶ 116); (5) cracking of the concrete slab due to "[u]nknown reasons", "from a cask tip over or seismic event" or through degradation "by windblown sulfates and salts that attack and corrode the steel re-

[59] The State would have the Board disregard the application of soil cement to lateral walls as a precedent for the PFSF because "the dynamics are different." State F. ¶ 111. However, Dr. Mitchell agreed that both at the PFSF and in some other applications the soil cement is used to provide resistance against lateral loads. Tr. 11193, 11255-59 (Mitchell); see also Ofoegbu Dir. at A22.

[60] The State also broadly alleges that "[e]very new application of soil cement is subject to significant failure in the early stages of its use." State F. ¶ 112. Id. The only specific example the State provides in support of this assertion is the failure of a cement lateral wall in the Bird Island Flats project in Boston. However, Dr. Mitchell testified that in that instance the failure was due to not using the right strength of the soil being retained behind the wall, not a failure of the soil cement itself. Tr. 11220 (Mitchell). Thus, there are no examples on the record to support the State's claim.

inforcing bar via shrinkage cracks in the concrete and cause the concrete to spall" (State F. ¶ 119); (6) the existence of "a 30 foot wide gravel trench" which, "if there is no rapid drainage of water from the aggregate, will "create a bathtub effect" (State F. ¶¶ 118, 120); and even (7) "whether weakened soil cement from water infiltration will be capable of supporting the cask transporter used to move the 175 ton storage casks." State F. ¶ 120.[61] Because the State itself gives short shrift to its claims of "degradation and environmental effects," they need not be addressed at length.

R93. (1) Construction concerns, such as remolding of the Upper Lake Bonneville clays, are easily addressed by use of appropriate techniques for the installation of soil cement and cement-treated soil. Trudeau/Wissa Dir. at A55. The main area of concern with respect to remolding of the native soils is with respect to the cask storage pads, for which the cohesive strength of the clay under the cement-treated soil is required to provide sliding resistance.[62] However, there is construction equipment that can be located on either side of the pads at the placement locations and reach out to make a cut to the final subgrade surface, if necessary. All other construction equipment can be kept off of the exposed subgrade. Through these means, the subgrade can be sufficiently protected during the soil cement installa-

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[61] This last allegation, which the State itself labels an "operational" concern, is both trivial and outside the scope of the seismic contention. In any event, uncontested testimony shows that the soil cement in the frame around the pads has a compressive strength that is three to four times greater than the loading that is applied at the surface of the soil cement by a moving, fully-loaded cask transporter. Trudeau/Wissa Dir. at A61; Tr. 11237-38 (Trudeau). Thus, even assuming that the soil cement in the frame was "weakened" by water infiltration, it would need to be weakened by more than 75 percent before it risked not meeting the transporter loads.

[62] The Upper Lake Bonneville clays are in fact not prone to deformation due to compaction because they are stiff, partially saturated clays lying more than 100 feet above the water table. Tr. 10899 (Trudeau).

tion. Id. Dr. Mitchell agreed that the measures proposed by PFS can effectively protect the soils from any adverse effects from disturbance due to construction activities. Tr. 11162 (Mitchell). He also agreed that the construction techniques proposed by PFS to avoid remolding of the clay soils are within the state of the art. PFS Exh. 228 at 114-15.

R94. (2) With respect to soil cement and cement-treated soil cracking, the State asserts that the mechanisms identified by its witnesses[63] raise concerns about "loss of tensile strength in those materials." State F. ¶ 117.[64] However, any such loss would only occur in the cracked area, and would not constitute a total loss of tensile strength unless the crack went through the entire cross-section of the soil cement. Tr. 11300-01 (Trudeau). This is unlikely to occur. Tr. 11110-11 (Mitchell). In any event, PFS does not rely on the tensile strength of the soil cement, so the effect, if any, of such cracking is inconsequential. Trudeau/Wissa Dir. at A60; Tr. 10933, 11296-97 (Trudeau).

R95. (3) With respect to water infiltration, the State summarily asserts that "water infiltration into the soil cement or cement treated soil layers will potentially degrade those materials" with infiltration potentially occurring due to "cracks in the concrete slab, shrinkage cracks between the soil cement and the structure (pads or CTB), and standing water in the rows between the pads." Those three specific

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[63] See PFS F. ¶¶97-113 for a detailed discussion of the potential soil cement cracking mechanisms postulated by the State witnesses.

[64] The State cites Dr. Mitchell (Tr. 11111) for the proposition that "[b]ecause there are no cases to draw upon that use soil cement of the depths that PFS intends to use, it is difficult to predict the size and extent of such cracks." State F. ¶ 117. Contrary to the State's assertion, Dr. Mitchell did predict the size and extent of soil cement crack, indicating that such cracks would be thin, narrow, and close to vertical. Tr. 11108 (Mitchell). At his deposition, Dr. Mitchell was even more specific, describing the cracks as less than one millimeter wide and more or less vertical across the slab. Exh. 228 at 133-34. In so opining, Dr. Mitchell agreed with all other witnesses who testified on the issue.

mechanisms are addressed below; see, more generally, PFS F. ¶¶91-95 for a general discussion of potential water infiltration claims raised by the State witnesses.

R96. (4) The concern about debonding along a soil cement lift interface or an interface with the concrete pad or the native soil during a seismic event is very unlikely to develop because PFS has identified, described, and intends to use methods for achieving proper bonding between the different soil cement lifts and between the soil cement and the concrete pad and the native soil. PFS Exh. JJJ at 2.6-114 – 2.6-117. Cement surface treatments, which consist of placing small amounts of cement on the interface between lifts as each lift is applied, are extremely effective in creating a bond along the interface that exceeds the shear strength of the soil cement itself. If the results of the interface strength tests that PFS is committed to performing demonstrate that such surface treatments are warranted, PFS will institute them as part of its construction procedures. Trudeau/Wissa Reb. at A6; Trudeau/Wissa Dir. at A53; PFS Exh. JJJ at 2.6-114- 117; Tr. 10910-13 (Wissa). Dr. Mitchell agreed that the approach proposed by PFS to deal with potential debonding was correct. Tr. 11129 (Mitchell).

R97. (5) The State witnesses postulated the possibility of water infiltration into the cement-treated soil layer due to cracking of the cask storage pad from "[u]nknown reasons", "from a cask tip over or seismic event" or through degradation "by windblown sulfates and salts that attack and corrode the steel reinforcing bar via shrinkage cracks in the concrete and cause the concrete to spall" (State F. ¶ 119). With respect to how cracking of the pad could occur, Dr. Mitchell stated: "I don't know, if it were overloaded of course it could crack. Sometimes concrete slabs crack, witness my garage floor, for reasons that we don't understand, perhaps." Tr. 11130 (Mitchell). There is, of course, no evidence that the cask storage pads

would ever become "overloaded", and cracking of a three-foot thick reinforced concrete slab "for reasons that we don't understand" is a rather unscientific explanation that, with due respect to Dr. Mitchell, deserves little weight.[65]

R98. The State witnesses identified two potential mechanisms that could cause a cask to drop on the pad and potentially cause it to crack, leading to the subsequent infiltration of water through the crack: A drop of a cask from the cask transporter, and a cask tip-over in a seismic event. Tr. 11133 (Mitchell, Bartlett). Regarding the potential dropping of a cask off a transporter, Dr. Mitchell acknowledged that in such an event it was likely that the pad would be repaired. Tr. 11134 (Mitchell). If, on the other hand, a cask were to tip over during a seismic event and cause the pad to crack, the potential water infiltration through the crack would be immaterial since it would occur (assuming no pad repairs) after the seismic event of concern in Contention Utah L/QQ.[66] Thus, water infiltration through cracks in the pad caused by a cask drop or tipover is not a matter of concern.

R99. The third mechanism postulated by the State, degradation of the pad due to chemical attack by windborne sulfates and salts, was posited by Dr. Bartlett through extrapolation of his experience with one-foot thick bridge slabs in Utah, which over time may cause the reinforcing steel bars to rust and the concrete to ultimately spall and crack. Tr. 11135 (Bartlett). Dr. Bartlett, however, did not know whether such a mechanism would be applicable to the far more massive three-foot storage cask pads at the PFSF, and did not know whether it was reason-

[65] This is particularly true because in his deposition Dr. Mitchell testified that he did not envision that the concrete slab itself would crack. PFS Exh. 228 at 142.

[66] When asked why should one care if the pad cracked upon a cask tip-over during a seismic event, Dr. Bartlett testified that he was "just reminding that there is another mechanism" for the potential cracking of the pad. Tr. 11134 (Bartlett).

able to anticipate that it could occur for the pads. Tr. 11136-37 (Bartlett). Thus, Dr. Bartlett's testimony in this regard does not rise above mere speculation.

R100. (6) The State also cites as a potential mechanism for the infiltration of moisture into the soil the existence of "a 30 foot wide gravel trench" which, "if there is no rapid drainage of water from the aggregate," will "create a bathtub effect" in that standing water will collect in the aggregate and migrate through "[s]hrinkage cracks between the soil cement and the storage pads or debonding of the laminar planes" resulting "in the ingress of standing water as well as snow melt" into the native soil beneath the soil cement. State F. ¶ 120. The alleged risk of such a "bathtub effect" is debunked since PFS will install berms around the pad emplacement area to direct any surface water away from the pad emplacement area. Tr. 11233-34 (Trudeau). In addition, within the pad emplacement area, the site is generally sloped from south to north and from the center of the site to the edges where there are concrete-lined drainage ditches to transport the surface water to the detention pond at the north. Id. For these reasons, there is no potential for significant presence of standing water in the pad emplacement area following snow melt, run-off, thunderstorms, or any other mechanism. Tr. 11234 (Trudeau).

R101. Dr. Mitchell agreed that if there are provisions in the design for the rapid drainage of water from the aggregate, "then the problem doesn't exist." Tr. 11139 (Mitchell). Since those provisions do exist, the "bathtub effect" will never materialize.

R102. Even assuming that somehow moisture accumulated in the soil beneath or around the pads or around the CTB, such an accumulation and any potential reduction in the shear strength of the soil due to the presence of the moisture would only be a

localized phenomenon, which would not have a significant effect on the strength or bearing capacity of the soils underlying the storage pads or the CTB. Ofoegbu Dir. at A22; Tr. 11152-53 (Mitchell); Tr. 11157-58 (Bartlett).

9. Pad-to-Pad Interaction

R103. The State proposes several findings (State F. ¶¶ 121-124) on the potential interaction between the pads, the soil cement and the cement-treated soil, and the underlying native soils. These findings will be addressed in Section D below, where the topic of pad-to-pad interaction is mainly raised.

R104. Two of the State's proposed findings in this section, however, merit discussion at this point. The State would have the Board rule that "[t]he storage pad has been analyzed to determine its structural suitability for dynamic loading conditions but no similar calculation exists for the underlying cement-treated soil or soil cement" (State F. ¶ 123) and that "PFS is relying on the shear strength of both the upper Bonneville clays and the cement-treated soils to meet a minimum factor of safety of 1.1 in the pad sliding analysis. While PFS has attempted to demonstrate the shear strength of the upper Bonneville clays, no such demonstration has been attempted for the shear strength of the cement-treated soil." State F. ¶ 124. Both proposed findings are erroneous.[67] The required strength of the soil cement and the cement-treated soil under dynamic conditions has been analyzed by PFS and is included in the stability calculation for the storage pads. PFS determined that a minimum cement-treated soil compressive strength of 40 psi would provide an acceptable factor of safety against sliding between the concrete at the base of the pad and the surface of the soil cement. See, e.g., PFS Exh. UU at 28. Likewise,

[67] State F. ¶ 124 refers to the "shear strength" of the cement-treated soil. The shear strength of the cement-treated soil is half of its unconfined compressive strength. PFS Exh. UU at 28.

PFS determined that a compressive strength of 50 psi was needed for the soil cement around the pads in order to provide an adequate subbase for support of the cask transporter, where a strength of at least 250 psi has been specified. See id. at 29.

C. Section D of Contention L/QQ: Seismic Design and Foundation Stability: Background

R105. In an extended background discussion of the seismic design and foundation stability section (Section D) of its proposed findings on Contention L/QQ, the State raises a number of general issues with respect to the PFSF design, some of them articulated for the very first time in these findings. Before addressing the State's position on the allegations actually raised in the contention, we shall respond to these general issues.

1. Background

R106. In the background discussion of its proposed Section D findings, the State would have the Board keep in mind "the meagerness of PFSF's design." State F. ¶ 144.[68] That alleged "meagerness" is a fabrication by State counsel. The State

[68] The State would have the Board find that "[t]he State goes so far as to claim that it is difficult to contemplate a design that is so cheap and unsafe as the one PFS proposes." State F. ¶ 144. This proposed finding is offered without citation. This should come as no surprise, since there is no testimony by any *witness*, even the State's own, that calls the PFSF seismic design "cheap" or "meager". Indeed, after State counsel suggested that PFS had cut corners in its seismic design to save money, PFS witness Mr. Trudeau rejected that suggestion as follows:

> Q. Judge Farrar asked you a question about cost considerations and he was prompted by a question in which Ms. Chancellor characterized the decision to use soil cement as cheap. Could you tell the Board and the parties whether, in fact, cost was a consideration in your decision to use soil cement?
>
> A. No. I mean, we were not instructed to go find a cheap way to make this work. But it is a very cost effective way to use a good product to make the stability of these foundations work.

witnesses speculated about the possibility of introducing what they called "redundancy" into the design by essentially varying the design concept. Tr. 7377-86 (Ostadan, Bartlett). While the State witnesses spoke generally about anchoring the casks to the pads, they acknowledged that such a design alternative also had drawbacks, such as increasing the possibility of overturning because, being anchored, the cask would no longer able to slide on the pad. Tr. 7384-86 (Bartlett).[69] Even in those discussions, the State witnesses spoke of alternate ways of increasing the "redundancy" in the design, at no point did they suggest that the existing design was "cheap" or that it had been reached by cost considerations.

R107. The State also refers to the "unprecedented" nature of the PFSF design and lists several "unproven" design features including

> unanchored cylindrical casks; acceptance of cask sliding on the pad as a basic design philosophy and taking full credit from cask sliding to reduce the seismic load to the storage pads and their foundations; shallowly embedded storage pads founded on a compressible clay with the potential for several inches of settlement; untested and precedent-setting use of cement-treated soil and soil cement as a structural

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> Q. But what I'm trying to understand is your thought process. Was your thought process first to find something that worked and then if it was cost effective it was a good thing, like the cherry on top of the sundae?
>
> A. I guess that's a fair statement, yes.

Tr. 6320-21 (Trudeau).

[69] The State witnesses talked in general terms about other design alternatives that could be considered for the PFSF. Dr. Ostadan referred to a "base isolation system," but acknowledged that such a system had never been used in a nuclear facility. Tr. 7380 (Ostadan). Dr. Bartlett referred to deep piling of foundations, but such an approach would raise licensing concerns with the NRC. Tr. 6280-81 (Trudeau). Dr. Bartlett also mentioned in passing concepts such as building underground silos to store the waste canisters there, and to recess the pad so that the waste container would be partially buried. Tr. 7384-86 (Bartlett). He was not aware, however, of the details of such designs and offered no opinions on the feasibility of their use at the PFSF or on whether they would have net advantages over the design concepts developed by PFS.

> foundation element to resist lateral earthquake forces and to add strength and stiffness to soils."

State F. ¶ 148. However, the State witnesses acknowledged at the hearing that none of these features was "unprecedented". See Tr. 7305-06 (Ostadan) (re use of unanchored casks); Tr. 7306-07 (Ostadan) (re possibility of cask foundation sliding); Tr. 7362 (Ostadan) (re use of shallow pads); Tr. 11327 (Bartlett) (re instances of foundation settlement at nuclear facilities); Tr. 11192-93, 11257-58 (Mitchell) (re use of soil cement to provide resistance against lateral loads); Tr. 11267 (Mitchell) (re use of soil cement to increase cohesive strength of soils).

R108. The State also alleges that "there is relatively little margin for error in PFS's design." State F. ¶ 148. It claims that if Applicant has under-predicted loads or over-predicted capacity by twenty-percent, "it is questionable whether PFS's design will perform during an earthquake." Id.[70] In reality, the design margins calculated by PFS for the "base case" include factors of safety of 27% and 26% against sliding, respectively, of the cask storage pads and the CTB. Trudeau Soils Reb. at A2. Those factors of safety incorporate a number of conservatisms which, if removed, would result in vastly larger factors of safety. Id. at A3. Likewise, the ratio between the angle of rotation at tipover to the calculated angle of rotation during a DBE is 28.6. Singh/Soler Dir. at A36. Thus, there is more than adequate margin in the PFS design and the State's claims to the contrary are unfounded.

R109. The State also advances several proposed findings (State F. ¶¶ 150-55) on the possibility of performing shake table tests of the seismic performance of the HI-STORM 100 casks, leading to a finding that PFS "could have conducted shake ta-

[70] The testimony by Dr. Ostadan cited by the State is not specific to any calculation, but is merely illustrative of his concerns about the need to provide large margins of safety in the design. Tr. 7342-43 (Ostadan).

ble tests on a scaled model cask or, in the United States by next spring, may acquire such data by conducting shake table tests on a full size cask" but has chosen not to do so. State F. ¶ 156. Such a proposed finding is contradicted by the testimony of State witness Dr. Ostadan, who agreed that it would not be feasible to model the soil column and the pad and the casks. Tr. 7407-09 (Ostadan). At most, testified Dr. Ostadan, it might be possible to conduct scale model tests to investigate certain aspects of the seismic behavior of casks, such as the contact stiffness. Id.[71] There is no evidence in the record that such tests are feasible[72] or that, if conducted, they would give meaningful results. See Section IV.F.9 infra.

R110. The State goes on to argue that what one is left with, in the absence of shake table test data, is "Holtec's design calculation and engineering judgment." State F. ¶ 157.[73] With respect to the design calculation, the State proposes that where an expert's conclusion "rests upon a performed analysis, the witness must make available sufficient information pertaining to the details of the analysis to permit the correctness of the conclusion to be evaluated." Id. As discussed in Section II above, there is no requirement that an expert submit "the details" of his analysis so it can be evaluated by the fact-finder.

R111. The State refers to the non-linear nature of the analysis performed by Holtec and indicates that such analyses are "well known for being sensitive to the selection of

[71] Dr. Ostadan admitted he would not be qualified to conduct such tests. Tr. 7410 (Ostadan).

[72] The State proposes a finding that "shake table tests are routinely conducted in earthquake engineering practice." State F. ¶ 151. However, there is no evidence that a shake table test has ever been conducted for all or any meaningful portion of a complex physical configuration such as that of soil/soil cement/pad/cask found at the PFSF. Tr. 7407-08 (Ostadan).

[73] The State proposes a finding that "an assertion of 'engineering judgment,' without any explanation or reasons for the judgment, is insufficient to support the conclusions of the expert engineering witness." State F. ¶ 157. This proposed finding is a red herring, since the State does not actually charge that any aspect of the PFS design or analysis is based on unexplained or unsupported engineering judgment.

input parameters and have been referred to as obtaining solutions from a 'black box.'" State F. ¶ 158. Furthermore, the State asserts, "small changes in an input parameter, such as contact stiffness or damping, could dramatically change the result of nonlinear analyses. Tr. (Ostadan) at 7336, 7352; Khan/Ostadan Tstmy, Post Tr. 7123 at 11-12." Id. The testimony by Drs. Singh and Soler demonstrated that the cask stability is relatively insensitive to the choice of input parameters in the analysis, as long as the values of the parameters selected are consistent with physical reality. See discussion of Holtec's cask stability analysis, infra.

2. The PFS Facility

R112. The State's proposed findings on the operations of the PFSF include several discussing the cask transfer operations. State F. ¶¶ 165-68. The gist of the proposed findings is that the testimony of Mr. D. Wayne Lewis presented by PFS provides a potentially inaccurate estimate of the duration of the cask transfer operations in the CTB. The State presented no testimony on cask transfer issues.

R113. Mr. Lewis testified that the process of transferring a multi-purpose canister ("MPC") containing spent fuel from the shipping cask in which it is brought to the PFSF site to a storage cask located on its pad takes approximately 20 hours. Testimony of Donald Wayne Lewis on Section E of Unified Contention Utah L/QQ (inserted into the record after Tr. 8968) ("Lewis Dir.") at A8; Tr. 9074-75 (Lewis). He also testified that, within that period, the total time that the MPC is not completely sealed within either a shipping cask or storage cask is nine hours per operation (from initiation of the removal of the HI-STAR cask closure plate bolts to completion of the installation of the HI-STORM cask lid and bolts). Lewis Dir. at A9; Tr. 9040-42 (Lewis). Finally, he testified that the total time the canister is being lifted directly or in the transfer cask and held by the crane in the

transfer cell while being transferred from the shipping cask to the storage cask is approximately 3 hours per transfer operation. Lewis Dir. at A10; Tr. 9029 (Lewis).

R114. Counsel for the State sought to cast doubts on these and other estimated operation durations, and Mr. Lewis was asked to explain in detail how each estimate was obtained, the basis for the estimated length of the operations involved, and the manner in which the various lengths were computed. See, e.g., Tr. 8984-86, 8997-99, 9008-10, 9020-22, 9039-41, 9043-44, 9075-76. Despite intense probing by counsel, the State was unable to elicit any retraction or modification of the estimate.[74]

R115. The State seeks to discredit the 20 hour estimate by questioning whether it and other estimated durations are based on actual Holtec cask transfer operations. State F. ¶ 165. Mr. Lewis testified that many of the activities encompassed by the estimate routinely take place at operating nuclear plants such as Hatch and Dresden. Tr. 9046 (Lewis). He also stated that the estimates are based on operational or pre-operational activities at those plants. Tr. 9059, 9078-80 (Lewis). Mr. Lewis also worked with personnel from utilities that have been actually involved in loading similar casks at the Point Beach and Palisades nuclear power plants to develop his estimates. Tr. 8982 (Lewis).

R116. The State also tries to undercut the 20-hour total estimate by noting that it may take place over a three-day duration. State F. ¶ 166. Mr. Lewis explained that the

74 As Judge Farrar remarked: "Ms. Chancellor, let me ask a question here. I don't want to limit your cross-examination, but so far it seems we're just kind of discussing with the witness what all these things are, which if that's important to you we'll let you do it, but so far I haven't heard -- I haven't heard anything yet that would indicate that the 20-hour estimate is dramatically off. And I take it that's where you want to go." Tr. 9022-23 (Farrar).

entire transfer operation described in PFS SAR Table 5.1-1 (PFS Exh. ZZ) could extend for up to three days, but 20 hours would be the duration of the actual operation. Tr. 9040, 9074-76 (Lewis).

R117. The State attacks the 9-hour estimate of the time that it will take to transfer the MPC from the transportation to the storage cask by pointing out that there are no licensing commitments or regulatory requirements that require PFS to complete the operation within a working day. State F. ¶ 167. However, Mr. Lewis made it clear that there was no condition under which the MPC would be allowed to remain, overnight, outside the protection of a shipping or a storage cask. Tr. 9073-74, 9077 (Lewis).

R118. Finally, the State tries to undercut Mr. Lewis's testimony that it will take 2.8 hours from the time the MPC is placed in a transfer cask to the time it is placed in a storage cask. The State makes reference to the deposition testimony by Holtec's Dr. Singh that it should be possible to complete the transfer "during the course of the day," with a day meaning a working day, which can be eight to twelve hours. State F. ¶ 167; State Exh. 193 at 30-31. However, Mr. Lewis interpreted this testimony to mean that the transfer should be completed within a day, but not necessarily take the whole day, which was consistent with his testimony. Tr. 9031 (Lewis).[75]

R119. Mr. Lewis repeatedly testified that the estimated durations of the various activities involved in the transfer of the MPC from the transportation cask to the storage

[75] Mr. Lewis pointed to testimony from Dr. Singh in the same deposition to the effect that "[a] typical transfer operation of the MPC from a HI-TRAC to an overpack, the actual time it takes to transfer should be no more than 1 to 2 hours." Tr. 9031 (Lewis); State Exh. 193 at 29. Mr. Lewis testified that the 2.8 hours estimate he offered was conservative, and that as Dr. Singh testified the transfer should take no more than 1 to 2 hours. Tr. 9032-33 (Lewis).

cask were conservatively high and that some of the steps could be accomplished concurrently, thus further saving time from the overall duration. Tr. 8974, 8975, 9011, 9033, 9041, 9044, 9066 (Lewis). Therefore, even if there was some imprecision in the estimated durations of some of the activities, the estimates would still remain conservative and would represent upper limits to the portion of the time during which the safety-related equipment in the CTB would be required to operate, or during which the MPC would be without the protection of a transportation or storage cask.

3. PFS's Seismic Design

R120. In one of its proposed general findings on PFS's seismic design, the State would have the Board find that "[t]he State maintains that the many disparate pieces of PFS's seismic design have evolved, often in response to cost cutting measures, and have not been fully thought out and integrated into a cohesive and rigorous design. See, e.g., PFS Exh. 210 [sic];[76] Tr. (Soler) at 10609 . . . ."[77] State F. ¶

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[76] PFS Exh. 210 does not relate to Contention L/QQ. If the intended reference is to State Exh. 210 (an early, April 1997 memorandum discussing potential geotechnical design approaches), that memorandum does not evidence "cost cutting measures" and has nothing to do with design integration. State Exh. 210 and its companion State Exh. 211 are historical documents, admitted only to show the extent to which foundation design issues were considered early on in the project. Tr. 10336-37 (Farrar). Thus, it is highly improper (in addition to being erroneous) for the State to attempt to use it in its findings to attempt to demonstrate a non-existent "cost-cutting" basis for the design.

Substantively, State Exh. 210 discusses, inter alia, the possibility of protecting the *in situ* soils from disturbance to avoid having to excavate the soils and replace the material underneath and adjacent to the pads with structural fill, an approach which, if feasible, could yield "considerable savings." Of course, the idea of using structural fill has been abandoned and soil cement is being proposed instead. In that (and many other respects) the design of the PFSF foundations has changed drastically since the early discussions in 1997. The State witnesses acknowledge that such is the case. Tr. 10292-96, 11343-46 (Bartlett).

[77] In support of its claim of lack of design integration, the State quotes from Dr. Soler's testimony at the hearing in which he stated that "we were tasked ... to get forces from the casks on the pad and transmit them to ICEC. We were not party to the calculations being done by ICEC, nor were we party to the calculations being done by Stone & Webster in Boston. We wrote the reports... but we were not part to what use he [Wen Tseng] was going to make of

171. However, both the allegation that the seismic design of the PFSF has evolved "in response to cost cutting measures" and the assertion that the "pieces" of the PFS seismic design "have not been fully thought out and integrated" are new claims by the State, not advanced in prior filings and not supported by any testimony at the hearing. Thus, such proposed findings must be rejected as contrary to the evidence and an attempt to advance, literally at the eleventh hour in this proceeding, yet another set of new claims. See Section II, supra.

R121. In the same proposed finding, the State declares that "[e]mblematic of this [lack of design integration] is the lack of independent verification or checks and balances of the input parameters to the various design calculations; Tr. (Trudeau) at 6247-49; Tr. (Soler) at 10610; Tr. (Ostadan) at 7350." This is again a novel claim and an absurd one – the State would apparently have, for example, Mr. Trudeau independently "validate the assumption of sliding at .8 times the normal stress at the base of the casks," see Tr. 6247, "evaluate the potential for cold bonding of the cask with the pad and how that may impact sliding of casks," see Tr. 6248, and review ICEC's calculation to determine whether it included "any deflections resulting from short or long term settlement of the pad," see Tr. 6248-49. State F. ¶ 171.[78] There is no testimony to indicate that such cross-discipline checking is

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those forces." Tr. 10609 (Soler). In fact, Dr. Soler was responding to an expression of surprise by Dr. Ostadan that nobody had asked Dr. Soler for the seismic response forces developed in Holtec's analysis. Dr. Soler's response was that the information was available and was provided to whoever asked for it. That the information was not requested does not prove that there was a lack of design integration as the State now claims, but that other members of the design team did not have a need for it.

[78] The citation to Dr. Soler's testimony (Tr. 10610) is erroneous, because on that page of the transcript Dr. Soler merely stated that even though pad accelerations were available from the DYNAMO computer runs, Holtec did not choose to plot them or make them available because acceleration data were subject to the problems discussed by Dr. Luk in his testimony, that is, the unfiltered acceleration data would be meaningless. Tr. 10610 (Soler). He said nothing that would denote lack of design integration.

either required by NRC regulations, is the practice of the industry, or makes any sense from the technical standpoint. Thus, this proposed finding must be rejected as both out of scope and unsupported by the evidence.[79]

R122. State F. ¶ 172 would have the Board conclude that "PFS's design has evolved from contemplation of anchored casks, excavation and replacement of foundation soils with structural fill, to unanchored casks and removal of the eolian silts to save costs. PFS Exh. 210 [sic], internal memo Trudeau to Macie, April 3, 1997; Tr. (Bartlett) at 10293-94." As discussed above, the claim that the PFS design is driven by cost-cutting considerations is out of the scope of the contention and unsupported, and the use the State wants to make of State Exh. 210 is impermissible. Here, however, the State has ratcheted up the rhetoric by charging that the use of unanchored casks and the removal of the eolian soils are also the result of attempts to save costs. There is absolutely NO evidence to support such a finding, which is one of fantasy rather than of fact.[80]

With respect to Dr. Ostadan's cited testimony, he decried the fact that the entire design depended (in his view) on the Holtec cask stability calculation, and indicated that if he were designing the facility he "would look at some other backup calculations and other ways of confirming the design." Tr. 7350 (Ostadan). Dr. Ostadan did not elaborate further on this observation; it is clear, however, that he was criticizing Holtec for allegedly failing to verify the results of the calculation, as opposed to chiding other design organizations for failing to do so.

[79] State F. ¶ 171 also states that "[m]any of the input parameters for the design calculations are derived from Holtec – the cask manufacturer who stands to gain millions of dollars from the PFS project and who is providing technical assistance from its president and vice-president to PFS for the hearings as part of its sales package." Such ad hominem attacks are unseemly as well as irrelevant. There is no evidence that the input parameters provided by Holtec were colored by its financial interest in the success of the project. State witnesses may have disagreed with the methodology employed by Holtec, but there are no words by anyone – except the intemperate charges by State counsel – to indicate that the "input parameters" supplied by Holtec were deliberately distorted in any manner. See Section III, supra

[80] It is regrettable that the State has attempted to enlist its expert Dr. Bartlett in support of its baseless charge that the design decisions were made in an effort to save money. What Dr. Bartlett did in the cited testimony was to provide a historical recounting of how the PFSF foundation design evolved. See Tr. 10292-96. In his lengthy discussion of the subject, Dr.

R123. The State incorrectly asserts that in order for the clay soils underlying the CTB to resist seismic loads, "there must be some lateral movement of the building to mobilize the peak shear strength of the soil cement [sic]. Tr. (Ostadan) at 7316." State F. ¶ 175. What Dr. Ostadan actually testified in the cited testimony was that, in the absence of a soil cement buttress, the *clay* needs to "sustain some amount of movement . . . to mobilize the peak shear strength. And that mobilization requires lateral movement of the building." Tr. 7316 (Ostadan). However, in the presence of a soil cement buttress, the building will not slide; the factor of safety against sliding of the CTB, assuming a soil cement buttress around it, is 1.26. Trudeau Soils Reb. at A2.

R124. At the conclusion of this introductory section, the State proposes a finding that "there is a hesitancy to model the nonlinear behavior of a soil beneath a foundation system based on an untested design or reliance on a nonlinear analysis, such as the one performed by Holtec. Id. at 10301-02." State F. ¶ 177, emphasis added. That is not what Dr. Bartlett said. Rather, he testified: "I would be very hesitant to model the nonlinear behavior of a soil underneath a foundation system using these [codes used by structural engineers] because of our uncertainties that are involved in the natural soils and their very complex behavior." Tr. 10302 (Bartlett), emphasis added. Dr. Bartlett was clearly referring to geotechnical analyses and calculations, such as those he and Mr. Trudeau would perform, not stability analyses of structures and components, like the ones performed by Holtec. However, in performing geotechnical stability calculations, it is not necessary to us nonlinear analyses or complex computer codes. See, e.g., PFS Exh.

Bartlett did not utter a single word to suggest that the design changes were driven by cost considerations.

UU and VV. At any rate, whatever the accuracy of Dr. Bartlett's assessment of the tools used in geotechnical analyses, he was not passing on the methods used by Holtec, and was not competent to do so.[81]

D. Section D of Contention L/QQ: Seismic Design and Foundation Stability: Stability Analyses for Cask Storage Pads

1. PFS's Seismic Design Calculations

R125. The State would have a finding of fact that refers to the earthquake time histories developed by Geomatrix and used by Holtec for its analysis, and notes that those time histories are in the free field and thus "the 0.7g peak vertical and horizontal ground acceleration estimated by Geomatrix does not include any effects on ground motion from the underlying soils or overlying structures. Those effects must be analyzed through soil structure interaction." State F. ¶ 179. However, soil structure interaction effects need not be analyzed separately. Tr. 5538 (Tseng); Tr. 11280 (Trudeau). Holtec included soil-structure interaction effects by incorporating soil spring and damper parameters into its analytical model. Tr. 5993 (Soler); Tr. 5997-98 (Singh). Stone & Webster included soil-structure interaction effects into the storage pad stability analysis by using the dynamic loads on the casks obtained from ICEC's design calculation, which in turn used the results of Holtec's analysis. Tr. 6183, 6235-37, 6340 (Trudeau).

2. Sliding as a Design Concept and Base Isolation Systems

R126. The State proposes a finding that "PFS relies entirely on cask sliding as a mechanism to reduce seismic loads. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 5." State F. ¶ 183. However, Dr. Ostadan acknowledged at the hearing that the Holtec cask

[81] Indeed, the State itself describes Dr. Bartlett's expertise as being limited to soils. See State F. ¶4.

stability calculation does not rely on cask sliding as a mechanism to reduce seismic forces; rather, that is just a result of the physical phenomena involved, not a design feature. Tr. 7354 (Ostadan); see also Tr. 5659-61 (Tseng); Tr. 6633-35 (Pomerening).

R127. The State repeatedly makes the point that Holtec does not include in its cask stability analyses a computation of the seismic forces on the pad that does not include cask sliding. State F. ¶¶ 180, 183.[82] It is not clear what purpose such a computation would serve. Dr. Bartlett opined that if it was assumed in the calculation that the casks are restrained from sliding (i.e., anchored), then the loadings to the foundation would be increased and could lead to potentially overturning the cask. Tr. 10292 (Bartlett). Therefore, to perform the computation that the State seeks would produce unrealistic and meaningless results.

R128. The State references an alleged requirement of the Uniform Building Code ("UBC") with respect to the use of base isolation systems, pursuant to which only a maximum 20% credit is allowed to be taken for reduction in seismic loads on account of the use of base isolation systems. State F. ¶¶ 184-185. However, the UBC is not applicable to the PFSF. Also, base isolation systems are different from the arrangement at the PFSF: base isolation systems are engineered mecha-

[82] State F. ¶ 180 asserts that "there is no record in Holtec's calculation of computation of seismic load without cask sliding. Tr. (Ostadan) at 10291-92." This finding, and the reference to Dr. Ostadan's testimony, are correct but misleading. Dr. Ostadan was being asked questions with respect to "base isolation systems" in which a mechanism is provided to allow foundations to slide. For those systems, according to Dr. Ostadan, the designer is required by the building codes to compare the loads on the structure with and without the isolation system being in place. It was in that context that Dr. Ostadan indicated that PFS had not performed a similar comparison between loadings with and without sliding. Tr. 10290 – 91 (Ostadan). However, Dr. Ostadan did not state that it was technically incorrect, in calculating the seismic loads on unanchored casks, to allow them to slide.

nisms whereas at the PFSF the cask simply sits on the pad. State F. ¶ 186; Tr. 10291 (Ostadan). Therefore, the analogy that the State tries to draw is improper.

R129. State F. ¶ 186 calls "a bold gesture" for PFS (and the NRC Staff) to rely on the Holtec cask stability analysis to predict cask performance "with no experimental or reliable performance data." This assertion is mere rhetoric and just restates previous proposed findings. Likewise, State F. ¶ 187 would have the Board rule that "PFS has not proposed a conventional engineered base isolated system; instead it is willing to accept happenstance during an earthquake as to the movement of the casks." There is, however, no happenstance involved in the PFS design. Holtec has analyzed a wide variety of loading conditions, both for the 2,000-year design basis earthquake and a more severe, beyond-design-basis 10,000-year seismic event. Under none of them did the casks come anywhere near exhibiting unacceptable behavior.

3. Pad Flexibility/Rigidity

R130. The State alleges that in its design concept for the storage pads, "PFS has conflicting requirements." State F. ¶ 188. As the State puts it, "[t]he storage pads need to be rigid enough to allow smooth sliding of the storage casks but somewhat flexible for cask drop or tipover." Id. The State further claims that "the stiffness of the cement-treated soil directly under the pads cannot be too stiff because of Holtec's cask drop and tipover condition but must be stiff enough to provide resistance to pad sliding during an earthquake." Id.[83] The latter claim was discussed with respect to Section C above. As demonstrated there, a Young's modulus for cement-treated soil of no more than 75,000 psi (to satisfy the cask ti-

[83] The same claim is made in State F. ¶ 194, where the State asserts that "PFS is asking that the cement-treated soil be strong enough to carry the horizontal loads and meet the pad sliding requirements but soft enough to satisfy Holtec's cask drop tip over conditions."

pover requirements) is achievable at a compressive strength of 40 psi (more than enough to provide the cohesive force required to prevent sliding). Tr. 10915 (Wissa); Tr. 11023-26 (Ofoegbu); Tr. 11159-60 (Mitchell).

R131. With respect to the alleged conflict between sufficient pad rigidity to ensure smooth sliding of the storage cask but some flexibility for cask drop or tipover, the requirements are incorrectly stated and do not conflict. There is no requirement that the pad be rigid to assure smooth sliding of the cask; in fact, the effects of pad flexibility are only second-order in nature, as Holtec demonstrated in analyses performed for Tennessee Valley Authority's Sequoyah Nuclear Power plant. Singh/Soler Dir. at A59 – A60; Tr. 6014 (Singh). In any case, Holtec used both an upper bound (0.8) and a lower bound (0.2) coefficient of friction between the cask and the pad to account for local irregularities at the interface between the two bodies; in some analyses, Holtec used a random coefficient of friction from 0 to 1 between the cask and the pad. Singh/Soler Dir. at A66; Tr. 6018-20 (Soler). These variations in the coefficient of friction would account for the potential effects of pad flexibility on cask sliding. Singh/Soler Dir. at A66.

R132. The independent computer analyses performed by Sandia National Laboratory ("Sandia") for the NRC Staff confirm the lack of significance of pad flexibility on cask sliding. Sandia incorporated pad flexibility into its detailed computer model and its analyses yielded very small cask displacements under seismic loadings. Tr. 6789 (Luk). These results further show that the effects of potential pad flexibility on the sliding of the casks are insignificant.[84]

[84] State F. ¶¶ 179 and 189 allege that Holtec assumed in its cask stability analyses that the pad was rigid based on recommendations from Stone & Webster. The State charges that Mr. Trudeau "admitted that he did not make this recommendation to Holtec." State F. ¶ 189. That is a strange turn of the phrase, given that Mr. Trudeau actually denied that he made such a recommendation and stated that he did not know who at Stone & Webster could have made it.

R133. The State further alleges that the assumption of pad rigidity "also guided Holtec's selection of soil springs and damping values." State F. ¶ 189. Again, this is incorrect. The soil springs and dampers were defined by Holtec using the applicable formulas in the applicable industry code ASCE 4-86, which assume that the pad acts like a rigid body. Singh/Soler Dir. at A63. Thus, the treatment of the pad as rigid for purposes of defining the soil parameters was not only a correct design choice of Holtec's, but was also the result of applying industry standards which indicate that the assumption of pad rigidity is appropriate.

R134. The State asserts that PFS "takes full credit for radiation damping" associated with a rigid pad, yet it has not shown that the pads are rigid. State F. ¶ 190. However, as will be discussed below, PFS has amply demonstrated that the pads are rigid. Thus, it is appropriate to take full credit for radiation damping. At any rate, the effect of pad flexibility on radiation damping is not an all or nothing proposition, but a matter of degree. As Dr. Ostadan admitted, a slightly flexible pad may still produce a significant amount of radiation damping. Tr. 7459-60 (Ostadan). In fact, PFS performed an evaluation of the effects of pad flexibility on the properties of the foundation, based on the methodology described in a recognized technical paper (Iguchi and Luco (1981)) and demonstrated that the effect of flexibility on the foundation damping properties of the pad is insignificant in the frequency range of importance to the cask response. PFS Exh. MM; Joint Testimony of Robert Youngs and Wen Tseng on Unified Contention Utah L/QQ (inserted into the record after Tr. 5529) ("Youngs/Tseng Dir.") at A65-67; Rebuttal Testimony of Wen S. Tseng on Section D of Unified Contention Utah L/QQ

Tr. 6187 (Trudeau). Whether that was the case or not is immaterial, since the assumption of pad rigidity was a sound one and was consistent with Holtec's design approach for other facilities. Singh/Soler Dir. at A61.

(inserted into the record after Tr. 10727) ("Tseng Reb.") at A2; Tr. 5683-85, 10751-52 (Tseng).

R135. The State also argues that "ICEC was never asked to determine the appropriate damping under rigid or flexible conditions," and that "the relative flexibility or rigidity of the pad could have been easily ascertained by using the industry standard computer program for soil structure interaction, SASSI." State F. ¶ 192.[85] However, there is nothing in the record to suggest that ICEC needed to determine the magnitude of the available radiation damping in order to design the pad, so there was no reason for ICEC to perform such an analysis. On the other hand, radiation damping was calculated in connection with the pad stability analyses. See PFS Exh. 231; Tr. 11279-81, 11289 (Trudeau).[86]

R136. The State also refers to "flexibility or deformation of the pad from physical cask impact" resulting from a cask tipover or drop. State F. ¶ 193. The State asserts that "[t]he pad, cement-treated soil, and soil all contribute to the stiffness or flexibility that would engage in this drop/tipover condition." Id. The State further asserts that "[t]he contact condition in Holtec's analytical calculation for cask tip over and drop requires that the pad and underlying cement-treated soil be somewhat flexible to be able to absorb energy from cask impact." State F. ¶ 194.

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[85] Dr. Tseng testified that ICEC used SASSI to confirm that the code used by ICEC for its design of the pad, CECSAP, gave appropriate results. Youngs/Tseng Dir. at A69; Tr. 5631 (Tseng).

[86] The State goes on to argue that ICEC could have conducted "a half day analysis, first by assuming the pad was rigid and then assuming it has concrete properties," and that by "calculating the amount of damping for these two scenarios, the Applicant would have quantified the appropriate amount of damping for the PFS site." State F. ¶ 192. The amount of radiation damping available, however, can be calculated without conducting the soil-structure analyses that the State claims are necessary. PFS conducted such a calculation. Testimony of Paul J. Trudeau on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 6135) ("Trudeau Section D Dir.") at A28; Tr. 6199-6200 (Trudeau); Rebuttal Testimony of Paul J. Trudeau on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 11275 ("Trudeau Section D Reb.") at A3; PFS Exh. 231; Tr. 11279-81 (Trudeau).

However, the State does not claim in Contention L/QQ, nor have any of its witnesses ever alleged, that the design of the pad does not accommodate a cask drop. In fact, that subject was addressed in the Holtec cask tipover analysis, which has not been challenged by the State. See State Exh. 173.[87] Therefore, these two proposed findings are outside the scope of the contention and amount to no more than insubstantial rhetorical flourishes.

R137. Of more substance, but equally misguided, is the State's attempt to refute the overwhelming evidence presented by PFS that the pads are rigid for purposes of dynamic analysis. (See PFS F. 266-270 for a discussion of that evidence.) The sole basis for the State's pad flexibility contention is Dr. Ostadan's claim that table D-1(d) of the ICEC design calculation (PFS Exh. 85) "evidenced pad flexibility because it showed vertical deformation or displacement occurring." State F. ¶ 195; Bartlett/Ostadan Dir. at A28. However, it was established in Dr. Ostadan's deposition, and he confirmed at the hearing, that the vertical displacements he read off that table were maximum pad deformations at various locations. These deformations were not simultaneous and could have occurred at different points in time, thus they were not inconsistent with rigid motions of the pad. State Exh. 112 at 107-108; Youngs/Tseng Dir. at A70.

R138. The maximum displacements shown in Table D-1(d) are on the order of 3/8th of an inch. Id.; PFS Exh. 85 at 234. These are "very small" displacements. State Exh. 112 at 105. Moreover, Dr. Tseng testified that the maximum displacements in that table include rigid displacements, that is, vertical motions of the entire pad

[87] The testimony of Drs. Bartlett and Ostadan refers to the Holtec cask drop calculation but does not assert that there are any deficiencies in it. State of Utah Testimony of Dr. Steven F. Bartlett and Dr. Farhang Ostadan on Unified Contention Utah L/QQ (Dynamic Analyses) (inserted into the record after Tr. 7268) ("Bartlett/Ostadan Dir.") at A24.

as a rigid body. Id. at A71. When the rigid displacements are removed, the maximum deviation of local displacements from rigid body motion for the pad is on the order of approximately ⅛ of an inch. Id. at A72; Tr. 10733-39, 10754-55 (Tseng). Such a small local displacement would produce only secondary effects on the global dynamic response of the pad/cask system, and would not affect the stability of the casks. Youngs/Tseng Dir. at A73; Tseng Reb. at A1; Tr. 5662 (Tseng); Singh/Soler Dir. at A78.[88]

R139. The State cites the testimony by Dr. Ostadan to the effect that the magnitude of the local displacement from rigid body motion is not as important as "the movement of the different points on the pad with respect to each other." State F. ¶ 195. The State indicates that "[o]ne needs to look at the entire pad and determine whether it is moving intact together and engaging with the soil (highest damping) or flip flopping (less damping). Where the maximum deformation is repeating in nearby adjacent points, the pad is flexible." Id. However, Dr. Tseng addressed this precise allegation in his rebuttal testimony and showed, by means of PFS Exh. 227, that there is no "flip-flopping" of the pad as alleged by Dr. Ostadan (see Tr. 7466, 7469-70 (Ostadan)). As shown in PFS Exh. 227, the vertical displacement of the pad is virtually zero for most of the length of the pad and there is one single, gradual, small vertical displacement at the point of application of the seis-

[88] The State charges that Dr. Tseng's testimony that the maximum deviation of local displacement from a rigid body is 1/8 of an inch is offered "without any basis for his conclusion." State Exh. 195. However, Dr. Tseng gave in his rebuttal testimony an extensive discussion of the deviations of local displacement from rigid body motions, and even provided detailed plots of those deviations. Tseng Reb. at A1 – A5; PFS Exh. 227. Dr. Tseng testified twice at the hearing and was subjected to lengthy cross-examination by the State on his assessment of the extent of pad deflections during a seismic event. Tr. 10754-59 (Tseng). The State could have cross-examined him on the basis for his expert opinion that the maximum local displacements from rigid body motions was 1/8 of an inch. It chose not to do so. The fact that the State failed to probe into the basis for Dr. Tseng's opinion does not render it any less persuasive.

mic loading, which slowly decreases as one moves away from the point of application of the seismic force. PFS Exh. 227; Tseng Reb. at A3–A5; Tr. 10733, 10737-39, 10755-60 (Tseng). These results show the absence of "ripples" of the type of concern to Dr. Ostadan, and demonstrate the rigid behavior of the pad under dynamic seismic loadings. Id.

R140. The State would frame, as the question for the Board to decide, "whether the pad is flexible enough for the cask drop and tip over constraint [sic] and rigid enough to produce significant radiation damping and provide a smooth (i.e., undeformed) surface for cask sliding." State F. ¶ 196. Whatever that sentence means, it is not the question for the Board to decide, but rather whether, as alleged in Section D.1.b of Contention L/QQ, " [t]he Applicant's calculations incorrectly assume that the pads will behave rigidly during the design basis earthquake." PFS Exh. 237 at 4.

R141. The State goes on to propose the following ultimate finding: "The Board finds that PFS . . . could have conducted a half day analysis with SASSI and determined the appropriate dynamic properties of the pad for the PFS site compared to a rigid pad. Instead, we have this tortured post-hoc justification of why the pad can be somewhat flexible under dynamic cask drop and tip over yet still retain its rigid properties when it comes to cask sliding and computation of soil springs and radiation damping. PFS is asking the Board to accept that the same pad-foundation system is flexible enough for the cask drop and tip over constraint and, given that condition, allow Holtec and ICEC to claim full credit for radiation damping and assume a smooth surface for cask sliding." State F. ¶ 197. There is of course no post-hoc justification. The testimony and evidence offered by Dr. Tseng and the other PFS witnesses are in response to the State's allegations, and the reason the

substance of this response was not developed during the course of design is because – as the evidence demonstrates – there was no need to do so.

R142. The State's proposed finding goes on to state that "PFS is asking too much of this Board to agree to these potentially conflicting requirements, especially when its entire design concept is not based on any experimental, test or performance data but relies entirely on a nonlinear analysis with assumed inputs. The Board finds that PFS had the ability to satisfy the claims advanced by the State. It has not, however, credibly or consistently demonstrated the dynamic properties and behavior of the storage pad." State F. ¶ 197. Again, this is just empty rhetoric. What PFS is asking the Board to find is that, contrary to the claim in Contention L/QQ, it was correct for the PFS seismic analysis calculations to treat the storage pad as a rigid body. There is overwhelming evidence to support such a finding, and no credible evidence to contradict it. Thus, the State's proposed finding must be rejected.

4. Storage Pad Foundation System and Soil Structure Interaction Effects

R143. The next section of the State's proposed findings – State F. ¶¶ 198 through 211 – addresses two topics raised for the first time in the testimony of the State witnesses at the hearing, and absent from Contention L/QQ: the alleged need for a soil structure interaction analysis and the allegedly incorrect use by PFS in its pad stability calculation G(B)-04 of peak ground acceleration to calculate the inertial forces acting on the pad. Being new, late claims outside the scope of Contention L/QQ, they should be rejected. See CLI-02-20, supra.

R144. On the first topic, the State would have the Board make a number of findings to the effect that: (1) The soil column analysis conducted by Geomatrix "cannot in

any way be considered a soil structure interaction analysis" (State F. ¶ 198); (2) Holtec's cask stability analysis "does not quantify any soil structure interaction effects" (State F. ¶ 200); and (3) "At best, ICEC's analysis constitutes about ten to twenty percent of what is needed for a complete soil structure interaction analysis." (State F. ¶ 204). Such findings, even if accurate, are irrelevant. There is no regulatory requirement that the design of cask storage pads include a formal soil-structure interaction analysis, and the State points to none. In addition, there is no claim in this proceeding that that the design inputs provided by Geomatrix were inadequate.[89] Nor is there a claim that Holtec's analyses were deficient for failing to expressly quantify soil-structure interaction effects.[90] There is also no claim

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[89] Dr. Ostadan testified: "I have no objection with the way the SHAKE was handled in this project. It was done by Geomatrix and they did what is typically done in the industry to obtain the soil properties." Tr. 7574 (Ostadan).

[90] The State claims that there was insufficient consideration by Holtec of the frequency dependence of the soil parameters used by Holtec in its analysis (this claim is discussed below), but not that the failure to expressly present soil-structure interaction information was a deficiency. In fact, the testimony by Dr. Ostadan cited by the State (State F. ¶ 200) refers to a number of things he would have liked to review and could not find in the report, but does not say anything about the appropriateness of the Holtec analysis:

> Unfortunately, the Holtec report, as complex as it is, is not -- is very brief. It does not discuss or present results for one to evaluate, quantify the soil-structure interaction effects, the frequency response, what -- how does it change; when they change the soil property from lower bound to best estimate to upper bound, is there any rocking, is there any torsional response on the pad. This is focused only on the displacement of the cask, and that's really all the results they show.

Tr. 7517 (Ostadan). But, of course, the Holtec's cask stability analysis was intended to present just the "displacement of the cask," so the absence of the other information that Dr. Ostadan would have liked to review cannot in itself be viewed as a deficiency. It is also worthy of note that the State witness Dr. Khan did not include consideration of soil-structure interaction effects in his computer analyses. Tr. 7737 (Khan).

In State F. ¶ 200 the State also writes "Holtec's focus was on 'what casks do.' Tr. (Soler) at 10610." This reference to Dr. Soler's testimony is inexplicable, since nowhere on that page of the transcript does Dr. Soler address the focus of Holtec's analysis. He merely indicates that his simulations did not provide as express outputs the value of the pad accelerations because

that the pad is incorrectly designed, except in that long term pad settlement was not considered in the pad's design, [91] a claim that -- as is discussed below -- is belated, inconsequential and does not relate to soil-structure interaction.

R145. With respect to the pad stability analyses performed by Stone & Webster, the State alleges that determining the inertial loadings on the pad requires knowledge of the acceleration of the pad. State F. ¶ 205. The State then charges that, instead of obtaining the acceleration of the pad from Holtec in the cask stability design calculations, PFS "assumed a number — peak ground acceleration (0.7g) – for a design input into the pad sliding analysis." State F. ¶ 206. The State asserts that "[p]eak ground acceleration ('pga') is the ground motion in the free field and does not account for soil structure interaction effects. Use of pga for the seismic loads for the pads has nothing to do with the response of the pad." State F. ¶ 206. The State concludes that "[u]sing peak ground acceleration as the input motion to estimate the seismic loads for the pad is only appropriate for rock sites and that is not the case at the PFS site." Id.

R146. At the hearing, PFS presented alternative analyses that demonstrated that the use of peak ground acceleration as a proxy for the response acceleration of the pad results in acceptable estimates of the inertial loadings on the pad. First, PFS showed that the radiation damping applicable to the soil/pad/cask system is so high (50 percent for the "best estimate" soil properties case) that the effects of soil-structure interaction in terms of amplifying the accelerations imparted on the pad are limited. Therefore, the response acceleration of the pad is essentially

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those values were unreliable since they included unfiltered high frequency effects. Tr. 10610 (Soler).

[91] Bartlett/Ostadan Dir. at A28.

equivalent to the free field ground acceleration. Trudeau Section D Dir. at A28; PFS Exh 231; Tr. 11280 (Trudeau).

R147. Indeed, PFS confirmed the appropriateness of using peak ground acceleration in its cask stability analysis by comparing the factor of safety against sliding of the pads for its base case, 1.27, against the factor of safety that obtains using the time history of forces developed by Holtec in its cask stability analysis. The use of this time history of forces at the base of the pad and casks yielded a factor of safety against sliding of 1.25, demonstrating that there is only a very slight reduction in the minimum factor of safety against sliding when these loads are used to compute the inertial forces of the pad instead of using the peak ground acceleration for that purpose. Trudeau Section D Dir. at A28 – A29.

R148. As an additional check, PFS computed the actual response acceleration for the pad and how much error was introduced by using, as PFS did, the peak ground acceleration as a proxy for the response acceleration. The horizontal response acceleration computed based on Holtec analysis would be .79g instead of the .711g used by PFS in its analyses. Trudeau Section D Reb. at A1, A4; Tr. 11278-79 (Trudeau). Use of the .79g acceleration instead of the peak ground acceleration employed by PFS would result in a slight decrease in the "base case" factor of safety against sliding of the pads from 1.27 to 1.22, which still provides a margin against of 22 percent against the potential onset of sliding. Trudeau Section D Reb. at A4.

R149. The State and its witness Dr. Ostadan seek to cast doubts on the validity of the explanation provided by Mr. Trudeau for his results. As noted in State F. ¶ 207, the State's expert Dr. Ostadan expressed skepticism about the value of radiation damping testified to by Mr. Trudeau. Tr. at 7623 (Ostadan). Dr. Ostadan indi-

cated that he had not seen a calculation that demonstrated the existence of the 50 percent value of radiation damping estimated by PFS and expressed concern that such a damping level might be unrealistic. Tr. 7623 (Ostadan). He agreed, however, that if such a level of damping could be established, his concern about the difference between peak ground acceleration and the response acceleration of the pads would diminish. Tr. 7624 (Ostadan). PFS subsequently produced a calculation that substantiated the radiation damping values it used and which was not challenged by the State. See PFS Exh. 231; Tr. 11279-81, 11289 (Trudeau).[92]

R150. The State seeks to dismiss Mr. Trudeau's testimony by claiming that he "has no expertise whatsoever in soil structure interaction." State F. ¶ 207. However, as explained above, a formal soil-structure interaction analysis is unnecessary to the geotechnical stability analysis calculations, and Mr. Trudeau did not use such an analysis. Tr. 6163 (Trudeau). The effect of soil-structure interaction is included in the loads that Stone & Webster received from ICEC, which in turn derived them from Holtec's analysis. Tr. 6235-36, 6305-06, 6339-40 (Trudeau).

R151. The State seeks to draw an analogy between the response acceleration of the CTB mat, which it characterizes as "in excess of 1 g" and the response of the pad, which it describes as "0.7g". State F. ¶ 208. Comparisons between the seismic responses of the foundations of the CTB and the pads are however not meaningful. The CTB is a five-story building that sits high above the ground. The pad is

[92] In its proposed findings, the State attempts to brush off Mr. Trudeau's calculation (PFS Exh. 231) by noting that the methodology used in that calculation is different than the one employed to calculate damping for the CTB, and by calling it "simple." State F. ¶ 207. The methodology for analyzing the CTB is entirely different than that used for the stability analysis of the pads because the two structures are radically different. Tr. 6390 (Ebbeson). With respect to the "simplicity" of Mr. Trudeau's calculation, there is nothing wrong with a calculation being simple. And whether "simple" or not, Mr. Trudeau's calculation has neither been challenged nor refuted by any State witness.

three feet thick and buried. So it is to be expected that the amplification due to soil structure interaction would be different for those two distinctly different structures. Tr. 6192, 6355-56 (Trudeau).

R152. In its proposed findings, the State continues the misguided effort on which it embarked during the hearings to read the raw node acceleration values in Figures 17 and 20b of the Sandia Report (Staff Exh. P) as suggesting that the pads experience accelerations on the order of 2 to 3g. State F. ¶ 209. [93] Such an interpretation of the figures is not only contrary to the testimony of the author of the report and other witnesses,[94] but is inexplicable, given that the Sandia National report predicts only very small pad and cask displacements, which is inconsistent with the high accelerations that Dr. Ostadan and the State would read off the report's figures. See Tr. 10427-28 (Ostadan).[95] In short, the use of the Sandia report's Fig-

[93] In his prefiled direct testimony, Dr. Ostadan had challenged the use of .711g as the horizontal acceleration of the pads by referring to these figures in the Sandia report as "clearly show[ing] that the pad response accelerations are several times larger than the peak ground acceleration used by Stone & Webster in its stability analysis." Bartlett/Ostadan Section D Dir. at A37; Tr. 7627-30 (Bartlett, Ostadan). Dr. Ostadan, however, acknowledged that at the time he provided the testimony in A37 he had not reviewed the Sandia report in any detail. Tr. 7781, 7786, 7793, 7798 (Ostadan), so he was not aware that the figures from the report on which he relied were obtained by omitting the stiffness proportional damping and were only for a single node, and thus could not be relied upon to be a correct representation of the pad accelerations. Tr. 7788 (Bartlett, Ostadan); Staff Exh. HH; Tr. 7794-98, 7801-02, 7806 (Ostadan).

[94] Staff witness Dr. Luk testified that the plots in Fig. 17 of his report could not be used to predict pad accelerations. Tr. 6805 (Luk). The structural responses that produced the accelerations shown in those plots were computed by Sandia by omitting one of the terms of the damping equation, which would have the effect of reducing the damping that occurs at high frequencies. Tr. 6793-95, 6805-08 (Luk). (The reason the term was explicitly omitted from the calculation was that it impacts only the high frequency components of the seismic response, which are not relevant to the analysis. Tr. 6805-06 (Luk)). In addition, Dr. Luk emphatically warned that those reviewing the results of Sandia's analysis "should not use the analysis results on a single node point" but instead should average the results over a four point square. Tr. 6804 (Luk). Other witnesses agreed that the Sandia report's acceleration plots could not be used to predict pad accelerations. Tr. 10610, 10659-61 (Soler); Tr. 10729-33, 10740-41 (Tseng).

[95] While for the reasons discussed above it is not appropriate to draw comparisons between the accelerations of the pad and those of the CTB mat, the pad accelerations of 2 to 3g that the

ures 17 and 20b "as an indicator of pad acceleration" as the State wishes the Board to do (State F. ¶ 209), is just plain wrong.[96]

R153. The State provides the following explanation why the dispute over the value of the pad acceleration is important: "Applicant has only a 1.27 factor of safety against sliding of the storage pads. In that calculation, Mr. Trudeau did not take into consideration the potential amplification of the acceleration of the pads in the horizontal direction. Tr. at 6201 (Trudeau). Foundation sliding is a major concern to the State - expecting the foundation to remain stable under the large accelerations predicted for the PFS site is 'very optimistic expectation, to say the least.' Tr. (FO) at 10340." State F. ¶ 210. The State's explanation actually helps put the dispute in perspective. First, the calculation of the minimum factor of safety against sliding of the pads incorporates a number of conservative assumptions such that the actual minimum factor of safety against sliding is probably about 5. Trudeau Soils Reb. at A3. Thus, the effect of some underestimation of the seismic loadings should have no adverse effect on the pad's stability to withstand them. Second, it is uncontested that sliding of the pads has no adverse safety consequences and, to the contrary, has the beneficial effect of reducing seismic load-

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State and Dr. Ostadan would read off the figures in the Sandia report are two or three times larger than the calculated horizontal acceleration of the CTB mat. Given the much larger size and height of the CTB, there is no physical mechanism that can account for such a gross discrepancy.

[96] The State grudgingly acknowledges that Dr. Luk's analysis deliberately omitted one term of damping from its structural response computation and that this "tends to over-predict high frequency response." State F. ¶ 209. The State insists, however, that "accelerations at low end frequencies in the range of 5 to 7 hertz are still large and indicate high accelerations of the pad." Id. However, the State chooses to ignore Dr. Luk's admonition that single-node responses, such as those plotted in Figs. 17 and 20b of the report, must not be relied upon. To get meaningful results, one must both restore the two terms of damping to the equation and average the response results over four physical locations. Tr. 6798-6800, 6804-08 (Luk). Reading any results directly off those figures, as the State attempts to do, makes no sense.

ings on the cask. Tr. 6151-52, 6155-57, 6278-79 (Trudeau); Tr. 6596-97 (Ofoegbu); Tr. 6633-35 (Pomerening); Tr. 10653, 10663-64 (Soler); Tr. 7348-49, 7354, 10408 (Ostadan); Tr. 10375-77 (Bartlett). For these reasons, the controversy over the proper value of pad acceleration is, at most, much ado about nothing.

5. Pad-to-pad Interaction

R154. In its proposed findings on pad-to-pad interaction, the State starts by making reference to the claim in the prefiled direct testimony of Drs. Bartlett and Ostadan that, in the portion of the Stone & Webster pad stability calculation that analyzes the potential sliding by a column of ten storage pads, PFS assumed that "the soil and cement-treated soil under the pads and soil cement around the pads would move in unison with the pads. In other words, Stone & Webster assumed that during an earthquake the different masses of the entire system would be in-phase." State F. ¶ 213. No doubt exists in the record, however, that the PFS design is founded on the concept that neither a single pad nor a row of pads will slide in the event of an earthquake. See, e.g., Trudeau Section D Dir. at A13, A18. Thus, the analysis that the State criticizes does not represent the anticipated performance of the pads and their foundations during an earthquake.

R155. The pad stability analyses, however, consider "what if" scenarios, beyond the base case. Id. at A19. These scenarios include one that considers the behavior of a column of ten pads in the north-south direction. This analysis demonstrates that the resistance to sliding of the entire column exceeds that of each individual pad because there is more area available to engage more shearing resistance from the underlying soils than just the area directly beneath the individual pads. Id. This analysis, which conservatively ignores the passive resistance acting on the end of

the column of pads and cement-treated soil and assumes that the soil cement east and west of the long column of pads provides no resistance to sliding, results in a calculated factor of safety against sliding of 1.50 for the entire column of 10 pads. Id. Thus, for that conservative case, the pads in the column do not slide relative to each other or to the underlying soil, but move together with the soil and the soil cement that surrounds them. Id.

R156. The State questions how it is possible that, in this "what if" scenario, the storage pads and the surrounding soil cement will move together, since they are not structurally connected. State F. ¶ 214. The State, however, ignores Mr. Trudeau's explanation that the soil cement "frame" between adjacent pads is bonded to the underlying cement-treated soil just as the pad is, so the pads and the surrounding frames, as well as the underlying soils, will move together as a single unit ("in phase") because they adhere to the same underlying base. Tr. 6235 (Trudeau).

R157. The State cites the deposition testimony of Dr. Tseng for the abstract proposition that since there is no rebar joining them, the pads and the adjacent soil cement would not act as an integrated structure. State F. ¶ 214. The State again ignores Mr. Trudeau's testimony that the pads and the soil cement do not need to have a physical connection to act as a unit, because they are bonded at their bases through the underlying cement-treated soil. Tr. 6235 (Trudeau). Therefore, the concerns raised by the State about what may happen in this hypothetical case are unfounded.

R158. According to its proposed findings, the "crux" of the State's testimony on pad-to-pad interaction is that "during the cycling of earthquake forces, there will be separation between the soil cement and the storage pads; the soil cement and pads will not act as an integrated unit; and the difference in modulus between the very stiff

soil cement and the relative soft upper Bonneville clay will create strain incompatibility and stress concentration in the soil cement as the gap between the soil cement and pads attempts to close." State F. ¶ 215. Thus, the State theorizes that the seismic forces will cause the soil cement and the pads to separate (most likely along preexisting shrinkage or settlement cracks in the soil cement) due to the effect of the seismic forces and will interact with each other. Bartlett/Ostadan Dir. at A36. However, the evidence establishes that such interaction will not occur because the soil cement and the pad will not move relative to each other, and will move in concert with the underlying soils as they deform under earthquake loadings. Trudeau Section D Reb. at A9; Youngs/Tseng Dir. at A80.

R159. The State then argues, inconsistently, that rather than becoming separated as a result of the seismic forces, the soil cement and the pad will remain together and the soil cement "will act as a strut introducing significant transfer of inertial force through pad-to-pad interaction. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 17." State F. ¶ 215. In this alternate hypothesis, the State is postulating that horizontal seismic forces from one pad will be transmitted to the adjacent pad(s) through the soil cement between them. The State asserts that the pads will "move differently from the free field motion of the soils" and this phasing of the motion of the pads "will create a push and pull action as the pads move towards and away from each other, creating a force transfer that has not been accounted for in PFS's pad sliding analysis of the pads and stability analysis of the casks." State F. ¶ 216.

R160. Mr. Trudeau explained, as described above, that there will be no out of phase motion of the pads relative to the underlying soil, so the "push and pull action" posited by the State will not take place. However, to test the State's hypothesis, Holtec performed an analysis in which it modeled two adjacent pads, five feet

apart, one pad fully loaded with eight casks, the other having only a single cask, and included a representation of the soil cement between the pads. Soler Reb. at A2; Tr. 10560 (Soler). The configuration in these cases was set so that the potential for pad-to-pad forces was maximized. No forces were allowed to be absorbed by the soil cement; no forces were allowed to be transmitted downwards to the cement-treated soil and to the soils beneath; no damping was included in the model; a maximum value of Young's modulus for the soil cement was assumed; the pads were not allowed to slide; and no credit was taken for the potential crushing of the soil cement by the forces going from one pad to the other. Tr. 10657, 10720-24 (Soler).

R161. Holtec performed two computer simulations for this model: one in which the soil cement between the pads is assumed to retain its integrity and therefore be able to transmit both tension and compression forces; and another simulation in which the soil cement is assumed to be cracked and thus able to transmit only compression forces. Soler Reb. at A2; Tr. 10560-63 (Soler). Notwithstanding the very conservative assumptions made in running these simulations, the maximum calculated force in the soil beneath the pads was less than that required to initiate pad sliding. PFS Exh. 225; Tr. 10723 (Soler). This testimony has been unchallenged by the State. Also, while both simulations predicted some interactions between the pads or between the pads and the soil cement, the forces resulting from those interactions, when added to the seismic loadings, resulted in total cask motions of the same order – inches – as had been obtained in prior simulations that had not

expressly accounted for pad-to-pad interaction forces. Soler Reb. at A6; Tr. 10697-10700 (Ostadan).[97]

R162. The State alleges that the maximum compressive force due to pad-to-pad interaction predicted in the Holtec simulations "has not been accounted for in the stability analysis of the pads." State F. ¶ 217. This assessment is incorrect. The cask stability analysis conducted by Holtec accounts for both the seismic forces acting directly on the pad and any forces due to pad-to-pad interactions. Tr. 10618-20 (Soler). Therefore, Stone & Webster's pad stability analysis, which utilizes the forces on the pad calculated by Holtec, does account for the forces due to pad-to-pad interaction.

R163. The State makes the additional argument that there can be pad-to-pad interaction without sliding, thus the PFS position that the pads do not slide does not respond to the State's concerns. State F. ¶ 218. The State cites, as "an example" of the soil-structure interaction effects, the "significant transfer of lateral forces even without initial of [sic] pad sliding." Id. However, that is exactly the issue that was addressed by the Holtec analysis just discussed. There are no other "exam-

[97] Holtec also performed an analysis in which it examined the potential effect of having a large gap between a pad and the adjacent soil cement layer. The analysis evaluated the impact forces that would be imparted on the pad as a result of its collision with the soil cement across the gap and the effect of those forces on the stability of the casks on the pad. For this analysis, a single pad fully loaded with eight casks was allowed to slide on the underlying soil and collide with a fixed, rigid soil cement frame surrounding the entire pad with a clearance gap of approximately 0.6 in. to all edges of the moving pad. Soler Reb. at A2; Tr. 10564-67 (Soler). The results of the Holtec analysis for this case indicate that, while there will be impacts between the pad and the surrounding soil cement, the forces produced by those impacts tend to offset the forces that would be imparted by the gradual application of compression of the pad against the soil cement, so that the net result is a reduction in the overall forces acting on the pad and the casks and a reduction by a factor of two in the displacement of the casks. Id. In short, the collision between the pad and the soil cement frame has no discernible adverse impact on the stability of the casks. See PFS Exh. 225.

ples" of pad-to-pad interaction that have been identified by the State in this proceeding.[98]

R164. The State also argues that pad sliding will cause more severe pad-to-pad interaction effects than calculated by Holtec in Applicant's Exh. 225. Id. Not so. First of all, the pads will not slide. See, e.g., Trudeau Section D Dir. at A18, A32; Trudeau Section D Reb. at A9; PFS Exh. UU.

R165. Second, even if the pads were to slide, the soil cement frame around them will tend to crush under the imparted loading because there is a significant difference between the compressive strength and modulus of elasticity of the storage pad (3000 psi and 3,120,000 psi), and the compressive strength and the dynamic modulus of the soil/cement (250 psi and 228,000 psi). Pomerening/Ofoegbu Dir. at A17; Tr. 11225-26 (Mitchell). The crushing of the soil cement will reduce the force that is transmitted from one pad to another. Pomerening/Ofoegbu Dir. at A25; Tr. 11225-26 (Mitchell).

R166. Finally, the State notes that "the Holtec calculation did not include the effects of multiple pad interactions." State F. ¶ 218. However, there is no evidence that multiple pad interactions will occur, so there is no basis for considering multiple pad interactions.[99]

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[98] The State makes a non-specific argument that the upper Bonneville clay underlying the pads is a relatively deformable body compared to the much stiffer soil cement plug between the pads, as a result of which there will be soil structure interaction effects from the differences in kinematic (stiffness of the soil cement relative to the deformable clay soil) and inertial (mass differences between the cask-pad system and the soil cement) properties of the system. State F. ¶ 218. All of that goes to describing the physical bases for soil-structure interaction phenomena, but does not identify any new specific problems that need to be analyzed.

[99] Dr. Ostadan theorized that there could be configurations in which interaction loads from various pads could accumulate on a single pad and result in potential sliding of the pad, but indicated that without additional analysis he could not specifically postulate any such configuration. Tr. 10685-91 (Ostadan).

6. Stability Design Calculations

R167. The State argues that the pad stability calculations "do not address the 10,000 year earthquake" and that Mr. Trudeau admitted that "he would need to do more than is presented in his testimony to support a 10,000-year DBE analysis. Tr. (Trudeau) 6348." State F. ¶ 225. PFS has never contended that it performed design calculations for a 10,000-year return period earthquake. However, with the very significant elements of conservatism incorporated into the stability analyses for the pads, the storage pads will not experience failure under the loadings from an earthquake far more severe than the design basis earthquake. Trudeau Section D Dir. at A24; see also id. at A16-24; Trudeau Soils Reb. at A2-A3.

R168. The State goes on to describe another "major" concern with the pad stability calculation as involving "uncertainties" in the pad overturning calculation. It should be noted at the outset that this issue was not part of Contention L/QQ or the testimony of the State's witnesses and should not be considered since it is untimely. See Section II, supra.[100] This "major" concern has been stitched out of whole cloth by the State counsel.

R169. This newly-minted concern with pad overturning boils down to a question whether the driving moment that PFS used for computing the factor of safety

[100] The prefiled direct testimony by Drs. Bartlett and Ostadan asserted that "[t]here are two overriding concerns with this calculation: pad-to-pad interaction, and calculation of the dynamic forces for pad stability." Bartlett/Ostadan Dir. at A35; see also Tr. 7599-7600 (Bartlett). None of the concerns identified in that testimony refer to pad overturning. In fact, at the suggestion of the State's witnesses, the first sentence in A38 of Drs. Bartlett and Ostadan's prefiled direct testimony was struck because it incorrectly referred to "factor of safety against overturning," whereas the State's concerns were only with potential sliding of the pads. See Tr. 7647-50 (Bartlett).

Nor was there any mention of pad overturning as a potential problem in the oral testimony by the State's witnesses. To the contrary, Dr. Bartlett testified that he would not expect overturning of a pad foundation even for a 10,000-year return period earthquake. Tr. 12846-47 (Bartlett).

against overturning is a "worst case" value or whether, for a case in which the cask is just below the point where it starts to slide, the driving moment is greater than the value assumed by PFS. State F. ¶ 226; see also Tr. 6241-47 (Trudeau).

R170. Mr. Trudeau acknowledged that, on first impression, there appeared to be a potentially unconservative choice of driving moment in the calculation. Tr. 6246 (Trudeau). Mr. Trudeau later testified, however, that he was hasty in his initial reaction, and that he was not prepared to answer the hypothetical questions posed to him on cross-examination but would need to look further into the analysis. Tr. 6323, 6338-39 (Trudeau). [101] Thus, there was no final assessment on the issue by Mr. Trudeau and no other witness offered testimony on the matter. Leaving some ambiguity on the issue is, however, of no consequence because even assuming it was appropriate to use a larger driving moment than was used in the calculation, the factor of safety against overturning of the pad would still exceed 1.1. Tr. 6247 (Trudeau). In addition, the cask would have to overturn before the pad does and the Holtec analyses clearly show that the cask does not overturn. Id. at 6250-51, 6285

R171. The State goes on to several additional "uncertainties" that it finds with the overturning calculation, including that Mr. Trudeau accepted without independent validation Holtec's determination that sliding would be initiated at 0.8 times the normal stress at the base of the casks; that Mr. Trudeau did not take into account the effect of long term pad settlement, or of concentration of stresses from partial cask uplift or the resistance to sliding due to cold bonding, or the possibility that

[101] On examination by NRC Staff counsel, it was brought out that unanchored casks such as those at PFS cannot transmit moment to the pad, and that the weight of the cask would counter the moment due to the horizontal inertial forces. Tr. 6339 (Trudeau). These factors would tend to negate the effect of having a longer arm from which the moment may be derived.

the pad accelerations may be greater than used in the analysis due to soil structure interaction effects. State F. ¶ 227. This recitation of "uncertainties" raises two issues, one with respect to the alleged obligation of the analyst to independently check the inputs developed by other design organization, and another on the impact of various mechanisms. Neither issue is legitimate.

R172. As noted above, NRC regulations do not require that members of different technical disciplines perform checks on the validity of the design inputs provided by the other disciplines. Therefore, the allegation by the State that such checks may not have been conducted is of no consequence.

R173. The other sources of "uncertainty" with the pad overturning calculation alleged by the State are second- and third-order effects that can be disregarded. See PFS F. 279-95 (long term pad settlement); PFS F. 296-319 (pad-to-pad interaction); PFS F. 320-28 (effects of soil-structure interaction); PFS F. 356-61 (cold bonding).[102]

R174. There is no indication that any of these factors, even if applicable, would materially affect the results of the overturning stability calculation. After all, the calculated factor of safety against overturning of the pads is 5.6. PFS Exh. UU at 13. It taxes credulity to contend that cold bonding or half an inch of pad settlement could reduce such a large margin below the point (factor of safety = 1.0) where overturning becomes a real risk.

R175. The State proposes an ultimate finding in which the Board concludes that "the overturning calculations in Cal. No. G(B) 04, Rev. 9, PFS Exh. UU, are deficient and cannot be relied upon." State F. ¶ 231. There is no basis for this finding, and

[102] The State also mentions as a source of "uncertainty" in the pad overturning calculation "concentration of stresses from partial uplift" of the casks. However, no claim on that subject has been raised in any prior State filings or in the testimony of the State's witnesses.

overturning of the pad in a seismic event is not an issue of concern with respect to the licensing of this facility, as recognized by State witness Dr. Bartlett. Tr. 12846-47 (Bartlett).

7. Pad Settlement

R176. The State asserts in its proposed findings that "[p]ad settlement was not considered in PFS's structural design of the pads or in Holtec's cask sliding stability analysis." State F. ¶ 232. At the hearing, however, this concern was described as involving not the design of the pads themselves, but the potential impact of pad settlement on the sliding of the casks on the pads due to the deformation caused by such settlement. Tr. 7382-83, 7386, 7393-94 (Ostadan). The potential impact of settlement on the design of the pads was not part of Contention L/QQ and should therefore not be an issue in this proceeding.[103]

R177. The State alleges that "PFS's estimations of pad settlement have spiraled downward from an initial five inches of settlement, to two inches to finally, in rebuttal testimony, half an inch." State F. ¶ 233. However, as the State itself admits, the "initial" settlement estimate of five inches, discussed in a 1997 memorandum, was based on a preliminary design that, among other things, included a four inch mud mat beneath the storage pads, contemplated raising the pads by the same amount as the thickness as the mud mat, and did not contemplate the use of cement-treated soil. State Exh. 211; Tr. 11344-45 (Bartlett). In fact, the foundation design at that preliminary stage was entirely different from what it is today. Id.

[103] In fact, PFS and the Staff argued unsuccessfully that the entire pad settlement issue was out of the scope of this proceeding since it not part of Contention L/QQ and was only identified for the first time in the prefiled direct testimony of Drs. Bartlett and Ostadan. See Tr. 7483-7491, 7754-60.

Therefore, any reference to the "five inches" of settlement referred to in 1997 is wrong and misleading.

R178. While acknowledging that the 1997 memorandum "is a historical document", the State would read it as "point[ing] out the long standing concerns about the settlement of the pads and its potential impact to the structural adequacy of the pads." State F. ¶ 234. However, the extrapolation that the State wishes to make from the concerns expressed in 1997 about a settlement estimate which was based on an entirely different design to today's conditions is unfounded. There is no evidence whatsoever on this record about any "long standing concerns about the settlement of the pads" or "its potential impact to the structural adequacy of the pads." Indeed, there is no evidence of concerns about the structural adequacy of the pads, whether due to settlement or otherwise.

R179. The State claims that "over the 51 acre pad emplacement area there is soil variability, and this variability will have an effect on settlement of many of the pads. See Soils supra; Tr. (Bartlett) at 7497-7500." State F. ¶ 235. This claim misconstrues Dr. Bartlett's testimony. Dr. Bartlett was asked to describe what change in the configuration of the pad could be expected as a result of settlement and he responded that, if the soil under the pad was uniform, a dish-shaped deformation would be likely. However "[i]f there's some soil variability that maybe on one part of the pad the soil properties had changed for some reason dramatically, then -- and it may not be dish-shaped, it may be more of a -- somewhat of a tilting." Tr. 7499-7500 (Bartlett). Thus, potential "soil variability" across the pad emplacement area in terms of the dynamic strength of the Upper Lake Bonneville clays – addressed in Section C of Contention L/QQ -- has nothing to do with "soil variability" under a pad. Dr. Bartlett was not testifying that local soil variability

under a single pad does exist; he only speculated that, if "for some reason" the soil properties "had changed dramatically" under "one part of the pad," this might lead to pad tilting.

R180. The State proposes a finding that "[t]he State agrees that two to three inches of settlement is a reasonable estimate of total settlement." State F. ¶ 236. In fact, Dr. Bartlett testified that he did not disagree with the 1.75 inches of total long-term pad settlement calculated by PFS and incorporated in PFS's licensing submittals to the NRC. Tr. 11347-48 (Bartlett).

R181. The State cites Dr. Ostadan's testimony as stating that "in geotechnical practice a few inches of settlement is a significant number in foundation design. Tr. (Ostadan) at 7501." State F. ¶ 236. In fact, Dr. Ostadan repeatedly testified that he knew of no nuclear facility for which two inches or more of long-term settlement was allowed, and that settlements of that magnitude were considered unacceptable by structural engineers. Tr. 7382, 7501, 7729, 7749-7750, 10396-97 (Ostadan). That opinion was, however, thoroughly discredited by evidence which showed that several nuclear power plants have operated with estimated long-term static settlements of the foundations of safety-related structures in excess of 2 inches. PFS Exh. 232; Trudeau Section D Reb. at A8; Tr. 11283-85 (Trudeau). Even Dr. Bartlett distanced himself from Dr. Ostadan's opinion. Tr. 11326-27 (Bartlett). Dr. Bartlett did not dispute PFS's evidence that nuclear power plant structures have exhibited settlements in excess of two inches. Tr. 11327 (Bartlett).

R182. Mr. Trudeau testified that, based on the conservatisms incorporated in the pad static settlement analyses, the actual long-term static settlement of the pads that can be reasonably expected to occur would be much less than the 1.75 inches that was calculated by Stone & Webster – only one fourth to one third of the calcu-

lated value, or approximately ½ inch. Trudeau Section D Reb. at A5. The State takes note of Mr. Trudeau's testimony but would have the Board reject it as an "unsupported supposition." State F. ¶ 237.

R183. There is no supposition involved in Mr. Trudeau's assessment. The PFS SAR refers to the settlement calculation as follows:

> This settlement represents an upper-bound estimate of the total compression, because it was developed assuming that the consolidation characteristics that were measured for the clayey soils at a depth of about 10 ft are applicable for the entire upper layer (~25 to 30 ft). The SPT [standard penetration test] data from the borings and the CPT [cone penetration test] results indicate that the soils become stiffer within the 10 to 20 ft depth zone. Additional consolidation tests performed on samples obtained from depths of about 25 ft in the Canister Transfer Building area, reported in Attachment 6 of Appendix 2A, indicate that the soils at that depth are less compressible than those used to estimate the settlements presented above. Further, based on the CPT program, most of the soils underlying the pad emplacement area are characterized as soils that behave as "sandy" soils, rather than as cohesive soils. Such soils are much less compressible than the clayey soils described above. Therefore, assuming that the entire upper layer at the site was comprised of soils whose compressibilities are similar to those measured at a depth of 10 to 12 ft conservatively overestimates the expected settlements.
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> State Exh. 168 at 2.6-51 (italics in original).

R184. The State cites Dr. Bartlett's opinion that one cannot estimate settlements in tenths of an inch, and that a two-inch total settlement prediction is reasonable. State F. ¶ 237. Dr. Bartlett's criticism of the ½ inch settlement figure was rooted in his perception that PFS had already removed many of the conservatisms in its settlement analysis in going from the preliminary estimate of 5 inches given in 1997 to the calculated 1.75" value submitted to the NRC, thus he concluded that PFS was perhaps "sharpening our pencils a little too finely." Tr. 11316 (Bartlett). However, as Dr. Bartlett acknowledged, the reduction in the preliminary settlement estimate may well have resulted from more refined methods and data rather

than removal of conservatisms. Id. at 11317. Indeed, as the above quoted excerpt from the SAR makes it clear, the settlement calculation whose results are presented in the SAR has significant conservatisms incorporated into it which can be reasonably removed to attain the realistic estimate provided by Mr. Trudeau.

R185. Witnesses for PFS and the State agreed that a total settlement of ½ inch would have negligible effect on the dynamic performance of the pads and the casks. Tr. 10730-31 (Tseng); Tr. 11125 (Mitchell).

R186. Witnesses for PFS and the Staff testified that, because of the great stiffness contrast between the concrete pad and the underlying clayey soils, the long-term settlement of the pads at the PFSF will be essentially uniform across the pad, thus its effect on the dynamic response of the pads and the casks supported on the pads should be negligible. Trudeau Section D Reb. at A5-A6; Tr. 6675-78 (Ofoegbu).

R187. The State claims that "[t]here is insufficient evidence in the record to show that all the pads will settle uniformly." State F. ¶ 240. However, Dr. Bartlett explained that the assumption that is made as to the distribution of the estimated maximum settlement of a foundation depends on the purpose of the analysis; it involves choosing between assuming it occurs at the center of the pads to maximize "the dishing effect," assuming it all occurs on one side of the foundation so as to produce some tilting, and distributing the total settlement over the minimum footing width, to emphasize differential settlement with adjacent structures. Tr. 11349-50 (Bartlett). In reality, the assumption of uniform pad settlement is the only one supported by physical considerations, as pointed out by Mr. Trudeau and Dr. Ofoegbu. Trudeau Section D Reb. at A5-A6; Tr. 6675-78 (Ofoegbu).

R188. With respect to the potential effects of pad settlement, the State theorizes that "[s]ettlement from differential cask loading could cause dishing or tilting of the

pads. Consequently, such an effect impacts Holtec's cask stability analysis because Holtec assumed a perfectly horizontal, planer [sic] surface in its cask sliding and stability analyses. Tr. (Bartlett) at 10332-33." State F. ¶ 232. However, such dishing – were it to occur, contrary to the views of Mr. Trudeau and Dr. Ofoegbu that the pads will settle uniformly – would result in little pad deformation. Assuming that the 0.5 inches of settlement testified to by Mr. Trudeau is concentrated on the center of the pad, there would be a 0.5 inch differential settlement in the center relative to the pad's edges. For that geometry, the average slope measured along the short end of the pad would be only 0.159 degrees. Rebuttal Testimony of Alan I. Soler on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 10557) [hereinafter "Soler Section D Reb."] at A8. Such a slight slope would have an insignificant impact on the motion of the casks. Id.

R189. Also, the cask stability analyses performed by Holtec utilized a variety of friction coefficients, including random variations in such coefficients, and in no case was a substantial amount of cask displacement observed. Therefore, it is unlikely that the long-term settlement phenomenon will induce cask motions that differ significantly from those obtained in the Holtec analyses. Soler Section D Reb. at A8; Tr. 6013 (Singh)

R190. Witnesses for both Applicant and the Staff testified that the anticipated long-term settlement of the pads does not pose a concern in terms of the dynamic stability of the foundations and constitutes, at most, a maintenance issue. Trudeau Section D Reb. at A6; Pomerening/Ofoegbu Dir. at A11(a); State Exh. 168; Tr. 6009-6010,

6013-14 (Singh).[104] Accordingly, there is no merit to the State's proposed ultimate conclusion on this issue, which would have the Board rule that "[f]ailure by PFS to support this proposition [that the pads will settle uniformly] invalidates assumptions in Holtec's pad sliding analysis which in turn has the potential to underestimate cask movement atop the pads and the inertial forces transmitted to the pads and the foundation." State F. ¶ 240. The small, uniform amounts of settlement that can be reasonably anticipated will have no effect on the results of the cask stability analyses.

E. Section D of Contention L/QQ: Seismic Design and Foundation Stability: Stability Analyses for CTB

R191. The State proposes a handful of findings (State F. ¶¶ 241-46) with respect to the stability analyses for the CTB. These findings are predicated on the State's position that equates licensability with meeting the recommended 1.1 factor of safety against sliding. See State F. ¶¶ 244, 247. As noted in Section II above, the recommended 1.1 factors of safety are not part of the NRC regulations and are not licensing requirements. In reality, there is no dispute on the record that there are no safety concerns with respect to the behavior of the CTB in an earthquake. Hence, even if meritorious (which they are not), the proposed State findings should be regarded as inconsequential.

R192. The CTB is a massive building, conservatively designed to industry codes and standards that provide wide margins of safety. Testimony of Bruce E. Ebbeson

[104] Dr. Bartlett testified that, even though it was difficult to give a precise number, the change in the amount of cask sliding due to long term pad settlement would be no more than 50 to 100 percent. Tr. 7512 (Bartlett). Given that the maximum cask displacements estimated by PFS (and those estimated by Sandia) for the design basis earthquake are only a few inches, an increase of even 50 percent or 100 percent in the sliding rate would have no adverse safety consequences.

on Section D of Unified Contention Utah L/QQ (inserted into the record after Tr. 6357) ("Ebbeson Dir.") at A6 – A15. In particular, a number of conservatisms are incorporated into the design of the CTB foundations. Id. at A16. Because of these conservatisms and its physical configuration (short, squat, bottom heavy), there is no concern about potential overturning of the CTB under beyond-design basis earthquake loadings. Id.; Trudeau Section D Dir. at A38; PFS Exh. VV; Pomerening/Ofoegbu Dir. at A31(a); Tr. 6378 (Ebbeson). Nor is there any concern about bearing capacity failure of the building, since the margin of safety provided in the design is 5.5. Trudeau Section D Dir. at A39; PFS Exh. VV; Pomerening/Ofoegbu Dir. at A31(a), Tr. 6378 (Ebbeson). The State has raised no concerns about the potential overturning or bearing capacity failure of the CTB.

R193. Thus, the only failure mechanism that the State has raised as potentially occurring with respect to the CTB is sliding. See Tr. 7655-56 (Bartlett); Tr. 7663, 7674 (Ostadan). Moreover, if sliding took place it would have no safety consequences, because there are no safety-related structures connected to the building that could be adversely affected by the sliding. Tr. 7323-25 (Bartlett, Ostadan); Trudeau Section D Dir. at A37; Ebbeson Dir. at A25; Ebbeson Reb. at A3.

R194. The State proposes a finding that PFS "cannot meet a factor of safety of at least 1.1 without the buttressing effect of soil cement around the foundation perimeter of the CTB basemat, yet not until some distant future date will PFS acquire any data that it may arguably rely upon to support its use of soil cement. Soil Cement supra; Bartlett/Ostadan Tstmy, Post Tr. 7268 at 4-6." State F. ¶ 241. This, however, is just a restatement of the State's allegations on the need to perform soil cement testing before licensing, and is invalid for the reasons discussed in Section C above.

R195. The State goes on to allege that "there are no engineering calculations or performance data to support the presumed passive resistance PFS expects to obtain from using such a mass of soil cement around the perimeter of the CTB mat foundation for the 2,000-year design basis earthquake. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 21; see also Tr. (Trudeau) at 6264-67." State F. ¶ 241. This assertion is totally wrong. The stability calculation for the CTB computes the passive resistance to sliding provided by the soil cement around the building under various assumptions. See PFS Exh. VV at 18-29. The State's witnesses never expressed any disagreement with that calculation.[105]

R196. The State also asserts that there is no "analysis of the effects of separation and cracking caused by out of phase motion of the CTB mat foundation and the soil cement buttress; or how bending and tensile stresses that develop in the soil cement will resist seismic forces without cracking or separation. Tr. (Trudeau) at 6257;[106] (Ebbeson) at 6399;[107] Bartlett/Ostadan Tstmy, Post Tr. 7268 at 21." State F. ¶ 241. With respect to the effect of soil cement cracks on the passive resistance against sliding it provides, the evidence establishes that, since the cracks

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[105] The reference to Mr. Trudeau's hearing testimony at Tr. 6264-67 is erroneous. At that point in his testimony, Mr. Trudeau was asked if he had performed as part of his stability analyses for the CTB a series of soil-structure interaction analyses, such as the inertial interactions between the CTB and the soil cement. Mr. Trudeau answered that he had not, consistent with his position that soil structure interaction analyses are not necessary to determine the seismic stability of foundations such as those of the CTB and the pads. Mr. Trudeau did not say that PFS had not performed calculations to verify the passive resistance that the soil cement around the CTB would provide, nor was he asked that question.

[106] The reference to Mr. Trudeau's hearing testimony at Tr. 6257 is also obviously incorrect. On the cited page of the transcript, Mr. Trudeau was testifying about the Newmark analysis for the cask storage pad stability. No mention is made of the CTB in that testimony.

[107] The reference to Mr. Ebbeson's hearing testimony at Tr. 6399 is also incorrect. On the cited page of the transcript, Mr. Ebbeson was questioned about how cracking of the concrete base mat of the CTB was taken into account in the design. The testimony on that page does not refer at all to stresses or cracking of the soil cement around the building.

on the soil cement will be vertical, they will have no effect on the soil cement compressive strength and therefore will not diminish the soil cement's passive resistance to sliding. Trudeau Section D Dir. at A33-34, A36; Tr. 11296-97 (Trudeau). Should the horizontal loads from the earthquake exceed the shear strength of the clayey soils beneath the CTB, any existing cracks in the soil cement will close up and the soil cement adjacent to the CTB will provide its full passive resistance to sliding. Trudeau Section D Reb. at A10.

R197. On the effect of bending and tensile stresses on the soil cement, the design earthquake will only impose about 7 to 11 significant cycles of motion and, even assuming that the CTB is out of phase with the adjacent soil cement for every one of these cycles, the effect of such motions would be only to alternately open and close existing shrinkage cracks in the soil cement. Trudeau Section D Reb. at A11. Ultimately, bending and tensile stresses are immaterial because the design relies only on the compressive strength of soil cement to resist horizontal sliding loads. Tr. 6263, 11294-96 (Trudeau).

R198. The State contends that "[t]he base mat of the CTB is expected to settle three inches; the effects of this settlement of the integrity of soil cement and its separation from the CTB on the passive resistance have not been considered by PFS. Tr. (Trudeau) at 6261."[108] State F. ¶ 241. However, the stress distribution in the soil cement areas adjacent to the CTB basemat are approximately the same as those at the edge of the basemat, so that there will not be an abrupt differential settlement noted at the joint between the edge of the mat and the soil cement. The

[108] The cited testimony by Mr. Trudeau was to the effect that he did not know whether the CTB settlement had been taken into account in the structural design of the building. Mr. Trudeau went on to testify that the building settlement had not been taken into account when designing the soil cement buttress around the building because it does not affect the performance of the soil cement. Tr. 6262 (Trudeau).

resulting settlement profile will be dish-shaped, concave downward, extending some distance away from the edge of the mat, so no cracks will form due to differential settlement. The concave downward shape of the settlement profile will result in closing of the lower portion of the nearly vertical shrinkage cracks. This lower portion of the soil-cement profile provides a greater percentage of the resistance due to increased passive pressure at depth; therefore, this settlement is beneficial in improving the ability of the soil cement to provide passive resistance. Trudeau Section D Dir. at A35.

R199. The State argues that "there has been no dynamic analysis of the interaction of the soil cement with the CTB mat foundation for the 2,000-year design basis earthquake. State F. ¶ 242. No such analysis is needed. The soil cement is strong enough to withstand the loads that will be imparted on it by the earthquake and by the CTB, and stiff enough to minimize the movement of the CTB against it. Tr. 6266-67 (Trudeau).

R200. The State also claims that "[u]nder the design basis earthquake, the maximum horizontal acceleration response of the CTB mat is 1.047 g. Tr. (Trudeau) at 6192; PFS Exh. VV at 49. The free field peak horizontal ground acceleration response of the adjacent soil cement buttress is 0.71g. Tr. (Trudeau) at 6264. Consequently there is a 47 percent difference between the horizontal response of the CTB and the surrounding soil cement. Id." State F. ¶ 242. This argument by the State that compares the acceleration of the CTB mat with the free-field acceleration of the soil cement layer around the building is inconsistent with the State's arguments with respect to the pads and is altogether wrong. Elsewhere, the State castigates PFS for using the free-field ground acceleration to perform dynamic analysis of structures. See State F. ¶ 206. In this finding, by contrast, the State

tries to compare free-field ground accelerations for the pads with building seismic responses. Such a comparison is meaningless. In reality, the accelerations of the structure and the soil cement are expected to be similar in the vicinity of the structure. Thus, the loadings applied to the soil cement as a result of the differing accelerations of the building and the soil cement will not be substantial. Tr. 6264-65 (Trudeau).

R201. The State goes on to suggest a finding that "[t]he soil cement buttress is not structurally tied to the CTB mat foundation, and given the large differences in horizontal acceleration response between those two masses, there is a significant potential for out-of-phase motion resulting from this inertial interaction. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 21; Tr. (Trudeau) at 6265." State F. ¶ 242. This finding is erroneous because, as just stated, there will not be large differences in horizontal accelerations between the CTB basemat and the adjacent soil cement buttress. Also, as noted above, the soil cement is strong enough in compression to withstand the loads that will be imparted on it by the earthquake and by the CTB, and stiff enough to minimize the movement of the CTB against it. Tr. 6266-67 (Trudeau).

R202. The State proposes a finding that "PFS has not considered the reduction of foundation damping and the concomitant higher seismic loads or the kinematic motion of the CTB caused by the blanket of soil cement around the CTB foundation." State F. ¶ 242. However, it was demonstrated at the hearing that the main interface between the CTB and the subgrade occurs at the base of the foundation mat. Energy radiates downward and outward into the soil at this interface. The presence of a soil-cement cap around the CTB has no effect on this energy-dissipation

mechanism, because it is directed downward and not in the horizontal direction. Ebbeson Dir. at A31; Tr. 6429-30 (Ebbeson).

R203. Finally, the State "questions whether the Applicant has appropriately treated the CTB mat as rigid." State F. ¶ 243. That the State proposes such a finding is surprising, since PFS presented overwhelming proof that the CTB mat is indeed rigid. See PFS F. 384-88. Even more surprising, though, is that later in the same finding the State claims that "there are no design calculations to support the Applicant's assumption that the foundation mat is rigid. Bartlett/Ostadan Tstmy, Post Tr. 7268 at 21." Id. In reality, such a design calculation was performed by PFS in response to that very claim by the State's Dr. Ostadan in the course of discovery. A design calculation that establishes that the CTB is rigid was performed by PFS, was introduced into evidence as PFS Exh. YY, and was thoroughly discussed at the hearing. See Tr. 6391-6424. This calculation is not even mentioned in the State's proposed findings.

R204. On the issue of potential flexibility, Dr. Ostadan reiterated for the CTB basemat the same theory he expounded for the cask storage pads, i.e. that for purposes of the effect on radiation damping, it is not important how large the departures from rigid motion are, but how many times they occur over the length of the mat. Tr. 7667-69 (Ostadan). However, as discussed by Mr. Ebbeson, the maximum variation of vertical displacement along the centerline of the building in the N-S direction is 0.163 inches over the length of 279.5 ft., which represents a less than 0.005 percent deflection. The maximum variation of vertical displacement in the E-W direction is .333 inches over the length of 240 ft., or about 0.01 percent deflection. Ebbeson Reb. at A4. Such small displacements over an area of 67,200 square feet (240 feet times 280 feet) show that the CTB basemat acts like a rigid body under

earthquake loadings. Id.; Ebbeson Dir. at A24. Furthermore, the displacements do not take place over short distances, but rather over a distance of about 65 feet, and there is only one such occurrence, at the southern end of the mat; the northern end of the mat is quite rigid. Ebbeson Reb. at A5. Thus, applying Dr. Ostadan's own suggested approach of focusing on the number and distribution of displacements across the pad, the conclusion is reached that the CTB basemat is rigid. Id.

R205. There are other reasons why it is appropriate to treat the CTB basemat as rigid. Treating the CTB mat as rigid is also supported by Section 3.3.1.6 of industry code ASCE 4-86, which states: "The effect of mat flexibility for mat foundations and the effect of wall flexibility for embedded walls need not be considered in the SSI analysis." See PFS Exh. XX; Tr. 6409 (Ebbeson).

R206. Assuming the mat to be rigid is appropriate in view of the physical configuration of the mat (five-foot thick reinforced concrete, stiffened by shear walls connected to it), which provides the mat with significant resistance to deformation in the vertical and the horizontal directions. Ebbeson Dir. at A24; Ebbeson Reb. at A5; Tr. 6440 (Ebbeson). The assumption of mat rigidity is also consistent with the practice in the nuclear industry, which is to treat foundations for safety-related structures similar in design to the CTB at nuclear power plants as rigid. Ebbeson Reb. at A5.

R207. The State makes no mention of any of this in its proposed findings. Instead, it quotes Mr. Ebbeson as testifying that any "'potential effect of mat flexibility is accommodated by the factor of safety applied in the seismic stability calculations.' Ebbeson Tstmy, Post Tr. 6357 at 14; Tr. (Ebbeson) at 6427." State F. ¶ 243. This proposed finding is at best misleading. In the cited answer in his direct testimony Mr. Ebbeson, after explaining all the reasons why it is appropriate to

treat the CTB basemat as rigid, goes on to say: "Also, the allowable factor of safety against sliding to which Dr. Ostadan refers as slim is actually 1.1, which in itself represents a 10 percent design margin, since the onset of sliding will not occur until the factor of safety goes below 1.0. (This factor of safety is set in accordance with the guidance in NUREG-0800, the SRP for nuclear power plants.) Thus, the potential effect of mat flexibility is accommodated by the factor of safety applied in the seismic stability calculations." Ebbeson Dir. at A25. Clearly, Mr. Ebbeson was not offering the factor of safety in the sliding stability calculation as the reason why the flexibility of the CTB basemat could be disregarded, but responding to Dr. Ostadan's claim that the calculated margin of safety against sliding of the CTB was slim.

R208. The State also proposes three conclusory findings on the stability of the CTB in which it would have the Board rule that the CTB seismic loads may be larger than calculated by PFS, the effect of radiation damping as a mechanism for load reduction may be smaller, and PFS has failed to demonstrate that the soil cement buttress will perform as anticipated. State F. ¶¶ 244-46. Those proposed findings fly in the face of the evidence, as demonstrated above. Moreover, there is no finding by the State that addresses the ultimate significance of these alleged (and unproved) deficiencies. The evidence presented by PFS, and agreed to by the State's own witnesses, is that if all the State's allegations about the CTB were true and the b building failed to meet the factor of safety against sliding and indeed were to slide, such an event would have absolutely no safety consequences, because the building is free-standing and there are no safety-related components connected to it which could be affected by the sliding of the building. Tr. 7323-

25 (Bartlett, Ostadan); Trudeau Section D Dir. at A37; Ebbeson Dir. at A25; Ebbeson Reb. at A3.

F. Section D of Contention L/QQ: Seismic Design and Foundation Stability: Stability Analyses for the Storage Casks

1. Background

R209. The State prefaces its findings on cask stability with statements of general concern voiced by Dr. Ostadan about PFS's reliance on nonlinear analysis for an "unconventional nuclear facility design," lacking any "design redundancies," that is both "unique and unconservative." State F. ¶¶ 248-49. We have already addressed above the State's inaccurate characterization of the PFSF design as unprecedented and unconservative. See Section IV.C.1 above.

R210. Insofar as Dr. Ostadan's statements of general concern relate to adequacy of the Holtec cask stability methodology, we note that Dr. Ostadan provided no testimony concerning the Holtec methodology other than with respect to foundation loading issues discussed above. Furthermore, Dr. Ostadan disclaimed having any expertise on cask stability analyses. See Tr. 10676-77 (Ostadan). Thus, Dr. Ostadan's statements of general concern about the appropriateness of Holtec's analyses discussed in State F. ¶¶ 248-49 have no particular weight. An intervenor's burden of going forward requires more than mere expressions of concern by a non-expert.

R211. The State goes on to refer to the number of ISFSIs licensed to date (23), the total number of dry storage casks of all types currently in use (325); the number of HI-STORM 100 dry storage casks currently in use (12), the lower seismicity of existing ISFSI sites used Holtec casks; and the lack of use of soil cement at ISFSIs

elsewhere. State F. ¶¶ 250-51. Based on this recitation of facts, the State requests the Board to find "insufficient evidence that the Staff has licensed free standing, cylindrical dry casks at sites where the design basis ground motion equaled or exceeded 0.7g," and similar such findings of lack of precedence for the PFSF design. State F. ¶ 252. From such findings, the State would have the Board conclude that "PFS has an unconventional design that is unprecedented and unproven with no redundancies," and that, as a result, PFS must undertake "comprehensive analysis and testing . . . to determine whether the HI-STORM 100 casks will excessively slide, uplift, or tipover under the 2,000-year DBE." State F. ¶ 253.

R212. Again, as discussed above, the State's claims as to the uniqueness of the PFSF design are erroneous and have no evidentiary value. The issue here is whether the PFS seismic design adequately protects the public health and safety. To properly challenge the design, an intervenor must identify inadequacies in it, rather than express general concerns about its alleged novelty. Even if such claims were true – which is not the case here – such generalized concerns do not meet an intervenor's burden of going forward.

2. Standard

R213. The State states that the issue is whether "the Applicant has reasonably demonstrated that the HI-STORM cask will not tip over when subject to the proposed design basis earthquake." State F. ¶ 254. It then goes on to ask that the Board review the cask stability analyses performed by the parties with "a certain degree of circumspection." State F. ¶ 256. The State analogizes nonlinear analysis to the use of a "black box." Id.[109] The State also makes reference to statements by

[109] The State's source for that quote, however, is Dr. Ostadan, whose lack of expertise on the subject has been noted above.

Dr. Cornell and Dr. Soler concerning the use of computer models in an attempt to depict non-linear analyses as inherently unreliable. Id. The record does not, however, support the State's attempt to denigrate the reliability of nonlinear analyses.

R214. Specifically, the State claims that "Dr. Cornell emphasized that nonlinear analyses provide information and insight, but a critical question is 'how much information to take from [nonlinear analysis] away towards making subsequent design judgments.'" Id. Contrary to the implication of the State's proposed finding, Dr. Cornell testified that the Holtec and Sandia analyses had served to reduce uncertainty in the estimation of cask performance. Tr. 8022 (Cornell). Indeed, in responding to a question from Judge Lam on whether non-linear analysis is generally suspect or "unreliable," Dr. Cornell's response was emphatic: "Absolutely not. No. Typically they are reliable." Tr. 8010 (Cornell).

R215. Dr. Cornell went on to say that because non-linear analysis are not as simple as linear analyses, they do "depend to a greater extent on the expertise of the user than does a linear analysis . . . ." Id. at Tr. 8011. In this respect, we note that Drs. Singh and Soler have almost 20 years of experience doing nonlinear analyses for spent fuel racks and storage and transportation casks. Singh/Soler Dir. at A162. The computer code used to perform nonlinear analyses of the storage casks at the PFSF, DYNAMO, has been validated in accordance with NRC quality assurance requirements to provide accurate results. Singh/Soler Dir. at A30, A113, A118, A133-134. Similarly, the nonlinear analyses conducted by Sandia for the PFSF are the culmination of three years of extensive effort resulting in "a huge accumulation of experience" in performing nonlinear analyses for different dry cask storage systems under various conditions and assumptions so as to provide confi-

dence in the Sandia predictions for the PFSF. Tr. 6987 (Luk). In contrast, the State's witness, Dr. Khan, had never done this type of analysis before. See PFS Exh. 88 at 23-24, 67-69; Tr. 7136, 7154-55 (Khan).

R216. The State also refers to Dr. Cornnell's confirmation of Judge Farrar's observation that it is "possible to become too enamored of the models and lose sight of making sure they are anchored in reality." Tr. 8024 (Cornell). However, Dr. Cornell was speaking broadly in terms of models as he had just noted that "[a] shake table is another model." Id. at 8023. Moreover, there is no suggestion in Dr. Cornell's testimony (nor does the State cite to any) that he had any such concerns with respect the Holtec or Sandia models. Id. at 8022-24.[110] Again, we find this general concern is far more applicable to the cask stability analyses conducted by the State's expert than to those performed by Holtec, whose model has been validated per the applicable nuclear standards and which has undergone numerous NRC license application reviews.[111] In contrast, the model used by the State's expert was not validated and provide results that the State's own experts agree are not "anchored in reality." PFS F. ¶¶ 221, 230-234.

R217. The State also cites testimony by Dr. Soler to the effect that "you can't say, because the computer program says it's so, that means it's so." State F. ¶ 256, quoting Tr. 9775 (Soler). The State, however, completely distorts the meaning of Dr. Soler's statement. Dr. Soler provided this testimony in describing a professional seminar on the performance of HI-STAR casks. Tr. 9773-75 (Soler); State Exh. 199. At the presentation, Dr. Soler contrasted the results obtained using two

[110] Dr. Cornell reviewed both the Holtec and Sandia methodologies and identified no concerns with either. Tr. 7973-74, 7987-88 (Cornell).

[111] As discussed below, we find the State's challenges to the Holtec model raised in its findings to be devoid of merit.

computer codes, VisualNastran and DYNAMO, for a loading condition under which DYNAMO had predicted large cask rotations (on the order of 20 degrees), but not cask tipover. Id. In contrast, VisualNatran (a computer code capable of handling large deflections) did show tipover under the same conditions. Id. The point made by Dr. Soler, both in the presentation and his testimony, was that one had to be aware of the limits of applicability of computer codes and should not use a code beyond those limits. Id. At no time in his testimony did Dr. Soler express the view that the nonlinear analysis performed by Holtec gave unreliable results.

R218. Indeed, Holtec has validated and successfully used DYNAMO many times to model small deflections. Additionally, the results of both the DYNAMO and VisualNastran codes (further confirmed by Sandia's model) show that the 2,000-year return period DBE results in small displacements of the casks at the PFSF. Thus, DYNAMO was an appropriate tool for analyzing cask stability at the 2000-year ground motion level for the PFSF.

R219. In contrast, the State's witness used what he acknowledged was a small deflection program that produced unrealistically large displacements, which he nevertheless claimed to be valid results. Tr. 7173-74 (Khan). Unlike Holtec, the State witness had not previously used his model to predict displacements of large free standing bodies, nor had he ever validated the model in accordance with NRC quality assurance requirements. PFS F. ¶¶ 222-26. In such circumstances, the general caution sounded by Dr. Soler is appropriate and directly applicable to the results of the State's nonlinear analyses.