PPPL Calculation Form

Calculation # NSTXU-CALC-12-14-00 Revision # 0 ___ WP #, if any (ENG-032) 2320

Purpose of Calculation: (Define why the calculation is being performed.)

Justification of Seismic Design Loads for E-DC11130, NSTX-U Casing Trial Asm Tool Fixture

Codes and versions: (List all codes, if any, used)

DOE-STD-1020-2016 references ASCE-7, which is used to determine Seismic Loads

References (List any source of design information including computer program titles and revision levels.)

See attached

Assumptions (Identify all assumptions made as part of this calculation.)

See attached

Calculation (Calculation is either documented here or attached)

See attached

Conclusion (Specify whether or not the purpose of the calculation was accomplished.)

The Seismic Loads for the Casing Trial Asm Tool Fixture, per ASCE-7 are the superposition of:

- "Normal Operating Loads" = Clamping Force from hold down studs
- 285 lbf of equivalent horizontal force, in the worst direction, at center of mass
- The worst case of either 100% Deadload or 60% Deadload
- Vertical load, applied in the worst direction, of 113 lbf

Resonance with the earthquake frequencies must be avoided. This should be done by modification of the system fundamental frequency through judicial design of support stiffness. These supports are necessary if the Casing is left installed, but not while active work is ongoing.

Cognizant Individual (or designee) printed name, signature, and date

Atiba Brereton Digitally signed by Atiba Brereton
Date: 2018.05.08 16:20:06 -04'00'

Preparer's printed name, signature and date

Michael Mardenfeld Digitally signed by Michael Mardenfeld
Date: 2018.05.02 16:53:57 -04'00'

I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct.

Checker's printed name, signature, and date

Irving J. Zatz Digitally signed by Irving J. Zatz
Date: 2018.05.03 10:03:49 -04'00'

David P. Pryor Digitally signed by David P. Pryor
DN: C=US, E=dpryor@pppl.gov, O=PPPL,
OU=Facilities, CN=David P. Pryor
Date: 2018.05.09 10:11:28-04'00'

National Spherical Torus eXperiment Upgrade

Justification of Seismic Design Loads for E-DC11130: NSTX-U Casing Trial Asm Tool Fixture

NSTXU-CALC-12-14-00

M. Mardenfeld

5/2/2018

Purpose

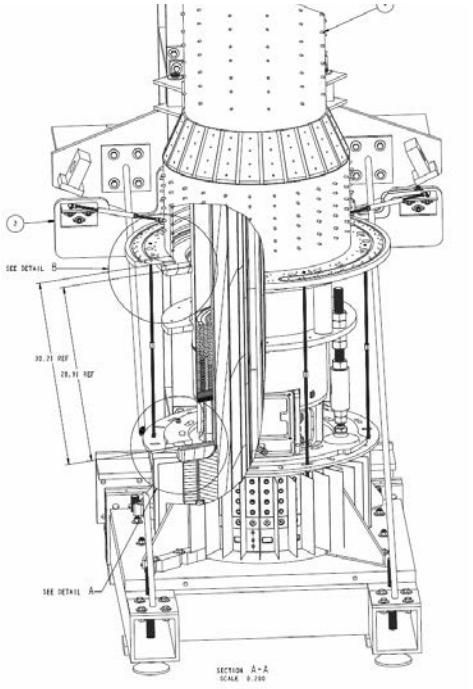
- It is desired to move forward with fabrication of components E-DC11130, NSTX-U Casing Trial Asm Tool Fixture
  - These components will be used for a trial assembly and alignment of the NSTX-U CS Casing on the TF/OH Bundle
  - The TF/OH Bundle will be standing in the Swing Fixture, E-DC1740, in the NSTX South High Bay

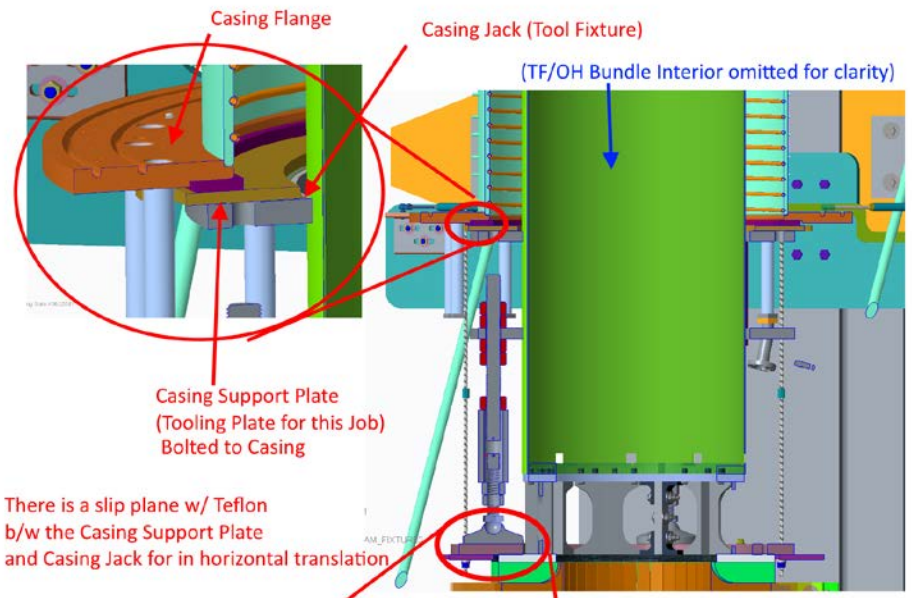
- A related calculation, NSTXU-CALC-12-13 qualified the stress analysis of this fixture under the assumption of superimposed [Normal Operating Loads] + [“Off Normal” Forces]
  - [Operational Loads] = weight of components + clamping force from studs
  - [“Off Normal”] = 1000 lbf, applied horizontally in the worst direction, at the center of mass of the casing (33% of weight)

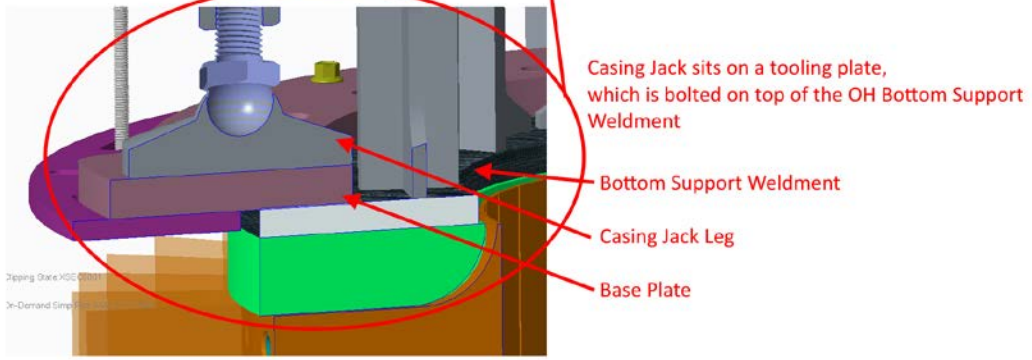
- Concerns were raised during the recently completed final design review regarding whether or not the side load was sufficient to represent seismic loading
  - A site wide engineering department standard regarding Seismic Design Criteria is currently being drafting, but not yet approved.
  - This calculation documents the actual Seismic Requirements for this type of equipment at PPPL, per governing code, to provide justification of the assumed loads while release of the site wide standard is pending

References

- Drawing E-DC11130
  - NSTX-U Casing Trial Asm Tool Fixture Field Setup
- NSTXU-CALC-12-13
  - Structural Qualification of E-DC11130, NSTX-U Casing Trial Asm Tool Fixture







Summary of Conclusions

- DOE Standard 1020 refers to ASCE 7 as the governing code for seismic qualifications of facilities like NSTX-U
- Fixtures like the Trial Fit Assembly Tooling can be classified as nonbuilding structures, not similar to buildings, supported by other structures, weighing less than 25% of the combined seismic mass
- The Seismic Design Earthquake Loads for the Tooling Fixture are:
  - 285 lbf of horizontal side load, at the center of mass of the [Tooling Fixtures + Casing] system
  - 113 lbf of vertical load, applied in the worst direction
- The load combinations that must be sustained are:
  - 70% of the Seismic Load + 100% of the normal operating loads + 100% Dead Weight
  - 70% of the Seismic Load + 100% of the normal operating loads + 60% Dead Weight
- Resonance with the earthquake frequencies must be avoided
  - This can be done by modifying the connection of the Casing to Swing Fixture to increase lateral stiffness, e.g., through threaded rods or shims, etc.
  - These bolstering lateral supports are necessary if the Casing is left installed on the Tooling Fixtures for more than a day or so, but they are not needed while active work is ongoing

Contents

- Requirements Traceability
- Site Characteristics
- Application of ASCE-7: Equivalent Static Force
- Application of ASCE-7: Vertical Force and Deflection
- Application of ASCE-7: Dynamic Response
- Application of ASCE-7: Load Combinations
- Conclusion
- Appendix

Requirements Traceability

Requirements Traceability

- DOE-STD-1020-2016, Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities is the governing order for seismic hazards at non-nuclear DOE facilities.
  - References IBC-2015 (International Building Code) for Seismic Design
- IBC-2015 references ASCE-7
  - American Society for Civil Engineers, Standard on Minimum Design Loads for Buildings and Other Structures
- This presentation uses ASCE 7-10 (2010)
  - Although there is a newer version of the code (ASCE 7-16 2016), the state of NJ has not yet adopted the new version. PPPL facilities, as a rule of thumb, follows the codes versions as adopted by NJ.

DOE-STD-1020-2016 references IBC-2015

2.2 NON-NUCLEAR FACILITIES

This Section applies to DOE facilities other than Hazard Category 1, 2, and 3 nuclear facilities. These facilities do not have nuclear material above DOE Hazard Category 3 thresholds (see DOE-STD-1027-92, Chg. 1, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*).

2.2.1 Facilities Without Chemical or Toxicological Hazards: For facilities that do not have any chemical or toxicological hazards, categorization and design of SSCs subjected to NPH loads shall be performed using the criteria and guidelines given in Chapter 16 of IBC-2015.

2.2.2 Facilities Containing Chemical or Toxicological Hazards: NPH design of these facilities is required to meet the requirements of the Occupational Safety and Health Administration and any applicable DOE rules and orders. NPH design of these facilities should follow a "graded approach." If the unmitigated failure consequences are such that the equivalent adverse effects are below those for "Highly Toxic" as defined in 29 CFR §1910.1200, *Toxic and Hazardous Substances,* Appendix A, the SSCs should be designed following IBC-2015 requirements, as applicable. (See also Footnote b to Table 1604.5 of IBC-2015.)

2.2.3 Radiological Facilities: NPH design of SSCs in radiological facilities shall follow the criteria of IBC-2015.

2.2.4 Criteria for Evaluating Lightning Hazards: Lightning protection shall be in accordance with the NFPA-780-2017, *Standard for the Installation of Lightning Protection Systems*. Annex L of NFPA-780-2017 provides guidance to determine if a lightning protection system is required. For facilities in which a Faraday cage is selected, Chapter X of DOE-STD-1212-2012, *Explosives Safety*, provides guidance on installation, inspection, and maintenance. According to

DOE-STD-1020-2016

IBC 2015 References ASCE 7

2015 International Building Code

Oct 2015

CHAPTER 16 STRUCTURAL DESIGN

SECTION 1613
EARTHQUAKE LOADS

1613.1 Scope.

Every structure, and portion thereof, including nonstructural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7, excluding Chapter 14 and Appendix 11A. The *seismic design category* for a structure is permitted to be determined in accordance with Section 1613 or ASCE 7.

Exceptions:

1. Detached one- and two-family dwellings, assigned to *Seismic Design Category* A, B or C, or located where the mapped short-period spectral response acceleration, S_S, is less than 0.4 g.
2. The seismic force-resisting system of wood-frame buildings that conform to the provisions of Section 2308 are not required to be analyzed as specified in this section.
3. Agricultural storage structures intended only for incidental human occupancy.
4. Structures that require special consideration of their response characteristics and environment that are not addressed by this code or ASCE 7 and for which other regulations provide seismic criteria, such as vehicular bridges, electrical transmission towers, hydraulic structures, buried utility lines and their appurtenances and nuclear reactors.

Site Characteristics

Site Soil Classification and Building Risk Category

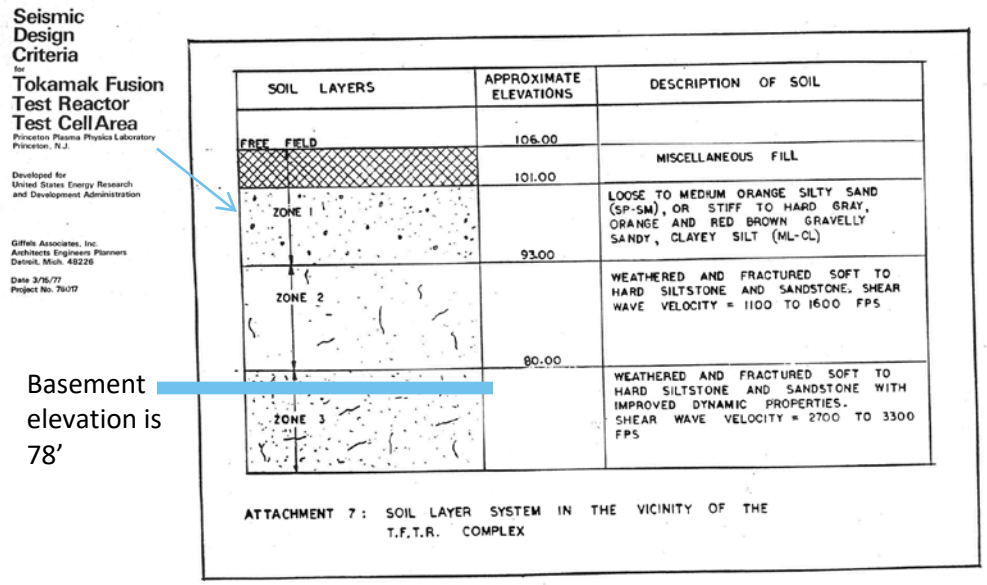
- This presentation makes conservative assumptions, because they do not affect the acceptability of the Tooling Fixture Components
- This is should not be interpreted to mean that the loads in this document are necessarily required for other equipment
- Assume
  - Building Risk Category is IV, because it is most conservative and D-Site is designated as an emergency shelter
  - Assume Site Soil Class is C, because a question was raised regarding whether B or C is more appropriate, and C is the more burdensome requirement

Site Soil Classification and Building Risk Category

Table 1.5-1 Risk Category of Buildings and Other Structures for Flood, Wind, Snow, Earthquake, and Ice Loads

Use or Occupancy of Buildings and Structures	Risk Category
Buildings and other structures that represent low risk to human life in the event of failure.	I
All buildings and other structures except those listed in Risk Categories I, III, and IV.	II
Buildings and other structures, the failure of which could pose a substantial risk to human life.	III
Buildings and other structures, not included in Risk Category IV, with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure.	
Buildings and other structures not included in Risk Category IV (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, hazardous waste, or explosives) containing toxic or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.[a]	
Buildings and other structures designated as essential facilities.	IV
Buildings and other structures, the failure of which could pose a substantial hazard to the community.	
Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.[a]	
Buildings and other structures required to maintain the functionality of other Risk Category IV structures.	

- Conservatively assume D-Site Experimental Areas are Risk Category IV
- Conservatively assume Soil Class is “C”, even though it might be “B”



Basement elevation is 78’

Table 20.3-1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the following characteristics: —Plasticity index $PI > 20$, —Moisture content $w \geq 40\%$, —Undrained shear strength $\bar{s}_u < 500$ psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

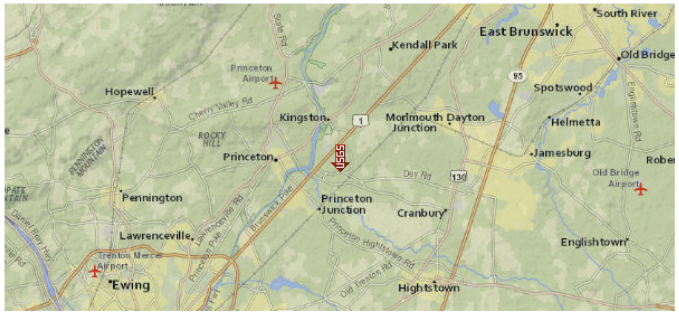
Seismic Design Parameters per ASCE 7

USGS Design Maps Summary Report

USGS science for a changing world — Earthquake Hazards Program

User–Specified Input

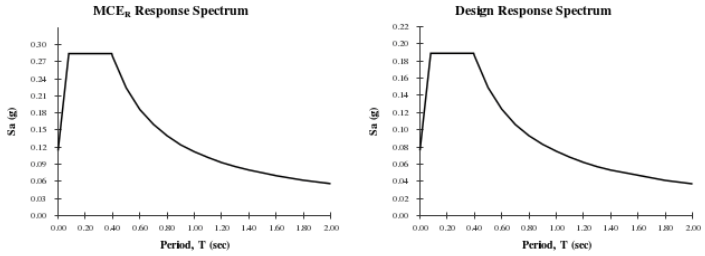
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	40.35075°N, 74.60408°W
Site Soil Classification	Site Class C – "Very Dense Soil and Soft Rock"
Risk Category	IV (e.g. essential facilities)



USGS–Provided Output

S_S =	0.237 g	S_{MS} =	0.284 g	S_{DS} =	0.189 g
S_1 =	0.066 g	S_{M1} =	0.112 g	S_{D1} =	0.075 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.



For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Although this information is a product of the U.S. Geological Survey, we provide no v
accuracy of the data contained therein. This tool is not a substitute for technical subj

S_S = mapped MCE_R, 5 percent damped, spectral response acceleration parameter at short periods as defined in Section 11.4.1

S_1 = mapped MCE_R, 5 percent damped, spectral response acceleration parameter at a period of 1 s as defined in Section 11.4.1

S_{DS} = design, 5% damped, spectral response acceleration parameter at short periods as defined in Section 11.4.4

S_{D1} = design, 5% damped, spectral response acceleration parameter at a period of 1 s as defined in Section 11.4.4

S_{MS} = the MCE_R, 5% damped, spectral response acceleration parameter at short periods adjusted for site class effects as defined in Section 11.4.3

S_{M1} = the MCE_R, 5 percent damped, spectral response acceleration parameter at a period of 1 s adjusted for site class effects as defined in Section 11.4.3

ASCE 7 provides detailed guidance on how to apply these numbers

S_S =	0.237 g	S_{MS} =	0.284 g	S_{DS} =	0.189 g
S_1 =	0.066 g	S_{M1} =	0.112 g	S_{D1} =	0.075 g

Application of ASCE-7 to the Trial Assembly Tooling Fixtures

Equivalent Static Horizontal Force

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass

15.3 NONBUILDING STRUCTURES SUPPORTED BY OTHER STRUCTURES

Where nonbuilding structures identified in Table 15.4-2 are supported by other structures and nonbuilding structures are not part of the primary seismic force-resisting system, one of the following methods shall be used.

15.3.1 Less than 25% Combined Weight Condition. For the condition where the weight of the nonbuilding structure is less than 25% of the combined effective seismic weights of the nonbuilding structure and supporting structure, the design seismic forces of the nonbuilding structure shall be determined in accordance with Chapter 13 where the values of R_p and a_p shall be determined in accordance to Section 13.1.5. The supporting structure shall be designed in accordance with the requirements of Chapter 12 or Section 15.5 as appropriate with the weight of the nonbuilding structure considered in the determination of the effective seismic weight, W.

13.1.5 Application of Nonstructural Component Requirements to Nonbuilding Structures. Nonbuilding structures (including storage racks and tanks) that are supported by other structures shall be designed in accordance with Chapter 15. Where Section 15.3 requires that seismic forces be determined in accordance with Chapter 13 and values for R_p are not provided in Table 13.5-1 or 13.6-1, R_p shall be taken as equal to the value of R listed in Section 15. The value of a_p shall be determined in accordance with footnote a of Table 13.5-1 or 13.6-1.

- Use Chapter 13 to compute design seismic design forces
- Use constants defined per Chapter 13 if applicable, else use constants per Chapter 15
- The Trial Fit Tooling Fixtures fit in this category

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Equation

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

13.3.1 Seismic Design Force. The horizontal seismic design force (F_p) shall be applied at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 13.3-1:

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

F_p is not required to be taken as greater than

$$F_p = 1.6 S_{DS} I_p W_p \qquad (13.3\text{-}2)$$

and F_p shall not be taken as less than

$$F_p = 0.3 S_{DS} I_p W_p \qquad (13.3\text{-}3)$$

where

F_p = seismic design force
S_{DS} = spectral acceleration, short period, as determined from Section 11.4.4
a_p = component amplification factor that varies from 1.00 to 2.50 (select appropriate value from Table 13.5-1 or 13.6-1)
I_p = component importance factor that varies from 1.00 to 1.50 (see Section 13.1.3)
W_p = component operating weight
R_p = component response modification factor that varies from 1.00 to 12 (select appropriate value from Table 13.5-1 or 13.6-1)
z = height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed 1.0
h = average roof height of structure with respect to the base

The force (F_p) shall be applied independently in at least two orthogonal horizontal directions in combination with service loads associated with the component, as appropriate. For vertically cantilevered systems, however, the force F_p shall be assumed to act in any horizontal direction. In addition, the component shall be designed for a concurrent vertical force $\pm 0.2 S_{DS} W_p$. The redundancy factor, ρ, is permitted to be taken equal to 1 and the overstrength factor, Ω_0, does not apply.

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Ip Constant

13.1.3 Component Importance Factor. All components shall be assigned a component importance factor as indicated in this section. The component importance factor, I_p, shall be taken as 1.5 if any of the following conditions apply:

1. The component is required to function for life-safety purposes after an earthquake, including fire protection sprinkler systems and egress stairways.
2. The component conveys, supports, or otherwise contains toxic, highly toxic, or explosive substances where the quantity of the material exceeds a threshold quantity established by the authority having jurisdiction and is sufficient to pose a threat to the public if released.
3. The component is in or attached to a Risk Category IV structure, and it is needed for continued operation of the facility or its failure could impair the continued operation of the facility.
4. The component conveys, supports, or otherwise contains hazardous substances and is attached to a structure or portion thereof classified by the authority having jurisdiction as a hazardous occupancy.

All other components shall be assigned a component importance factor, I_p, equal to 1.0.

Ip = 1.0

$$F_P = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Elevation Compensation

Z=0 is taken as the grade level.
Subgrade components are also taken Z=0

Since the Tooling Fixtures are mounted on the NSTX-U TC floor, Z=0 and:
[1+2(z/h)] = 1

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

z = height in structure of point of attachment of component with respect to the base. For items at or below the base, z shall be taken as 0. The value of z/h need not exceed 1.0
h = average roof height of structure with respect to the base

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Sds

- Sds value taken from previous slide
  - Sds = 0.189g

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

S_s =	0.237 g	S_{MS} =	0.284 g	S_{DS} =	0.189 g
S_1 =	0.066 g	S_{M1} =	0.112 g	S_{D1} =	0.075 g

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Ap

Table 13.6-1 Seismic Coefficients for Mechanical and Electrical Components

[a]A lower value for a_p is permitted where justified by detailed dynamic analyses. The value for a_p shall not be less than 1. The value of a_p equal to 1 is for rigid components and rigidly attached components. The value of a_p equal to 2½ is for flexible components and flexibly attached components.
[b]Components mounted on vibration isolators shall have a bumper restraint or snubber in each horizontal direction. The design force shall be taken as $2F_p$ if the nominal clearance (air gap) between the equipment support frame and restraint is greater than 0.25 in. If the nominal clearance specified on the construction documents is not greater than 0.25 in., the design force is permitted to be taken as F_p.
[c]Overstrength as required for anchorage to concrete. See Section 12.4.3 for inclusion of overstrength factor in seismic load effect.

13.1.5 Application of Nonstructural Component Requirements to Nonbuilding Structures. Nonbuilding structures (including storage racks and tanks) that are supported by other structures shall be designed in accordance with Chapter 15. Where Section 15.3 requires that seismic forces be determined in accordance with Chapter 13 and values for R_p are not provided in Table 13.5-1 or 13.6-1, R_p shall be taken as equal to the value of R listed in Section 15. The value of a_p shall be determined in accordance with footnote *a* of Table 13.5-1 or 13.6-1.

COMPONENT: A part of an architectural, electrical, or mechanical system.

Component, Nonstructural: A part of an architectural, mechanical, or electrical system within or without a building or nonbuilding structure.

Component, Flexible: Nonstructural component having a fundamental period greater than 0.06 s.

Component, Rigid: Nonstructural component having a fundamental period less than or equal to 0.06 s.

13.6.2 Component Period. The fundamental period of the nonstructural component (including its supports and attachment to the structure), T_p, shall be determined by the following equation provided that the component, supports, and attachment can be reasonably represented analytically by a simple spring and mass single degree-of-freedom system:

$$T_P = 2\pi\sqrt{\frac{W_p}{K_p g}} \qquad (13.6\text{-}1)$$

where

T_p = component fundamental period
W_p = component operating weight
g = gravitational acceleration
K_p = combined stiffness of the component, supports and attachments, determined in terms of load per unit deflection at the center of gravity of the component

Alternatively, the fundamental period of the component, T_p, in seconds is permitted to be determined from experimental test data or by a properly substantiated analysis.

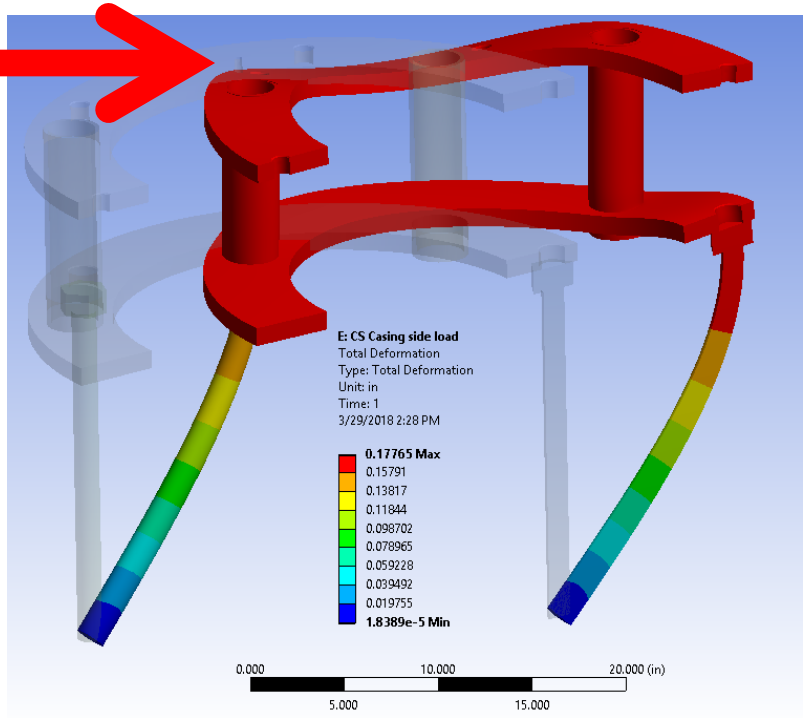
Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Ap

$$k = \frac{1000\ lbf}{0.17\ in} = 1e6\ \frac{N}{m}$$

$$T_p = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{1360\ \text{kg}}{1e6\ \ \text{N/m}}} = 0.23\ \text{sec}$$

1000 lbf



- Since Tp > 0.06 seconds, this is a “flexibly mounted component”
- So Ap = 2.5

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: R

Table 15.4-2 (*Continued*)

Nonbuilding Structure Type	Detailing Requirements[c]	R	Ω_0	C_d	Structural System and Structural Height, h_n, Limits (ft)[a,d] A & B	C	D	E	F
Pole: Steel		1.5	1.5	1.5	NL	NL	NL	NL	NL
Wood		1.5	1.5	1.5	NL	NL	NL	NL	NL
Concrete		1.5	1.5	1.5	NL	NL	NL	NL	NL
Frame: Steel		3	1.5	1.5	NL	NL	NL	NL	NL
Wood		1.5	1.5	1.5	NL	NL	NL	NL	NL
Concrete		2	1.5	1.5	NL	NL	NL	NL	NL
Amusement structures and monuments	15.6.3	2	2	2	NL	NL	NL	NL	NL
Inverted pendulum type structures (except elevated tanks, vessels, bins, and hoppers)	12.2.5.3	2	2	2	NL	NL	NL	NL	NL
Signs and billboards		3.0	1.75	3	NL	NL	NL	NL	NL
All other self-supporting structures, tanks, or vessels not covered above or by reference standards that are not similar to buildings		1.25	2	2.5	NL	NL	50	50	50

- R = 2.0

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Results

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

13.3.1 Seismic Design Force. The horizontal seismic design force (F_p) shall be applied at the component's center of gravity and distributed relative to the component's mass distribution and shall be determined in accordance with Eq. 13.3-1:

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)} \left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

- Ap = 2.5
- Sds = .189
- Rp = 2.0
- Ip = 1.0
- (1+2z/h) = 1.0

So Fp	=	0.095*mg
	=	0.095*3000 lbf
	=	285lbf

Application of ASCE-7 to the Trial Assembly Tooling Fixtures

Equivalent Vertical Force and Limits on Deflection

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Vertical Load

- There is also a vertical load and displacement criteria which need to be simultaneously applied

13.3 SEISMIC DEMANDS ON NONSTRUCTURAL COMPONENTS

The force (F_p) shall be applied independently in at least two orthogonal horizontal directions in combination with service loads associated with the component, as appropriate. For vertically cantilevered systems, however, the force F_p shall be assumed to act in any horizontal direction. In addition, the component shall be designed for a concurrent vertical force $\pm 0.2 S_{DS} W_p$. The redundancy factor, ρ, is permitted to be taken equal to 1 and the overstrength factor, Ω_0, does not apply.

So for the Trial Fit Tooling Fixtures:

Fv = 0.2*Sds*mg

= 0.2*.189*3000

= 113 lbf

Nonbuilding Structures

not similar to structures, supported by other structures, less than 25% mass: Displacement Criteria

- There is also a vertical load and displacement criteria which need to be simultaneously applied

13.6.5.2 Design for Relative Displacement. Component supports shall be designed to accommodate the seismic relative displacements between points of support determined in accordance with Section 13.3.2.

13.3.2.1 Displacements within Structures. For two connection points on the same structure A or the same structural system, one at a height h_x and the other at a height h_y, D_p shall be determined as

$$D_p = \Delta_{xA} - \Delta_{yA} \qquad (13.3\text{-}6)$$

Alternatively, D_p is permitted to be determined using modal procedures described in Section 12.9, using the difference in story deflections calculated for each mode and then combined using appropriate modal combination procedures. D_p is not required to be taken as greater than

$$D_p = \frac{(h_x - h_y)\Delta_{aA}}{h_{sx}} \qquad (13.3\text{-}7)$$

- This is not relevant for a component like the Trial Fit Tooling, which connects to the building (floor) at the same height for all points

Application of ASCE-7 to the Trial Assembly Tooling Fixtures

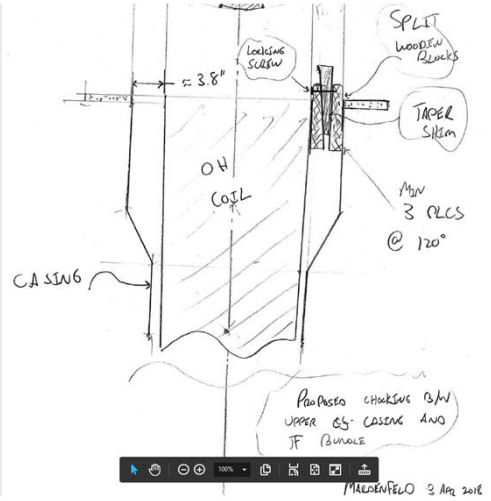
Check of Dynamic Response

Nonbuilding Structures

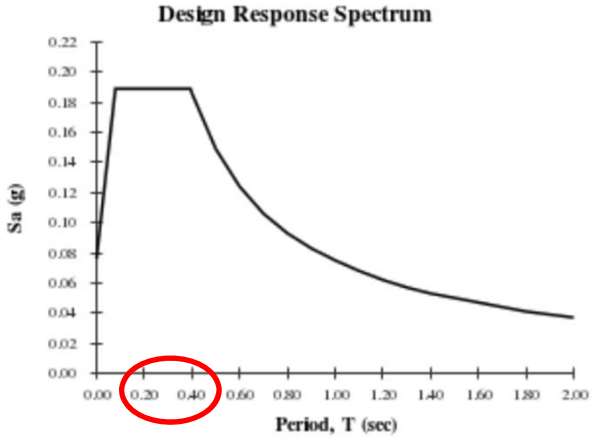
not similar to structures, supported by other structures, less than 25% mass: Dynamic Effects

13.6 MECHANICAL AND ELECTRICAL COMPONENTS

Where design of mechanical and electrical components for seismic effects is required, consideration shall be given to the dynamic effects of the components, their contents, and where appropriate, their supports and attachments. In such cases, the interaction between the components and the supporting structures, including other mechanical and electrical components, shall also be considered.



Shims: Concept Only



$$T_p = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{1360\ \text{kg}}{1e6\ \ \text{N/m}}} = 0.23\ \text{sec}$$

- The fundamental frequency of the tooling fixture structure is close to the Earthquake dominant frequency
  - This isn't acceptable
  - The plan to install shims between the top of the Casing and the TF Bundle is needed to change the effective stiffness and avoid resonance
    - The dominant stiffness will be compression of the blocks, rather than bending of the studs – expect a large increase in stiffness

Application of ASCE-7 to the Trial Assembly Tooling Fixtures

Load Combinations

Load Combinations described within ASCE 7

2.4 COMBINING NOMINAL LOADS USING ALLOWABLE STRESS DESIGN

2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member shall be considered. Effects of one or more loads not acting shall be considered.

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W \text{ or } 0.7E)$

6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$

6b. $D + 0.75L + 0.75(0.7E) + 0.75S$

7. $0.6D + 0.6W$
8. $0.6D + 0.7E$

A_k = load or load effect arising from extra ordinary event A
D = dead load
D_i = weight of ice
E = earthquake load
F = load due to fluids with well-defined pressures and maximum heights
F_a = flood load
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
L = live load
L_r = roof live load
R = rain load
S = snow load
T = self-straining load
W = wind load
W_i = wind-on-ice determined in accordance with Chapter 10

When using Allowable Stress Design, only a fraction of the Earthquake Load shall be used in combination with other types of loads.

Load Cases 5 & 8 are the most applicable to PPPL Experimental Equipment like the Trial Fit Tooling:

- **70% of Earthquake Load superimposed with**
- **100% of Stud Clamping Forcer**
- **Worst case of 60% or 100% of Dead Load**

taking off, taxiing, and parking of helicopters.

LIVE LOAD: A load produced by the use and occupancy of the building or other structure that does not include construction or environmental loads, such as wind load, snow load, rain load, earthquake load, flood load, or dead load.

CHAPTER 4
LIVE LOADS

ASCE STANDARD ASCE/SEI 7-10

Conclusions

Summary of Conclusions

- DOE Standard 1020 refers to ASCE 7 as the governing code for seismic qualifications of facilities like NSTX-U
- Fixtures like the Trial Fit Assembly Tooling can be classified as nonbuilding structures, not similar to buildings, supported by other structures, weighing less than 25% of the combined seismic mass
- The Seismic Design Earthquake Loads for the Tooling Fixture are:
  - 285 lbf of horizontal side load, at the center of mass of the [Tooling Fixtures + Casing] system
  - 113 lbf of vertical load, applied in the worst direction
- The load combinations that must be sustained are:
  - 70% of the Seismic Load + 100% of the normal operating loads + 100% Dead Weight
  - 70% of the Seismic Load + 100% of the normal operating loads + 60% Dead Weight
- Resonance with the earthquake frequencies must be avoided
  - This can be done by modifying the connection of the Casing to Swing Fixture to increase lateral stiffness, e.g., through threaded rods or shims, etc.
  - These bolstering lateral supports are necessary if the Casing is left installed on the Tooling Fixtures for more than a day or so, but they are not needed while active work is ongoing

Appendix

Comparison to SLAC Seismic Standard

Comparison to SLAC Seismic Design Guidance

Table 2 Seismic Ground Motion Values*

Location	S_s	S_1	S_{DS}**	S_{D1}	SDC R.C. I/II	SDC R.C. III	SDC R.C. IV
1	2.185	0.922	1.457	0.922	E	E	F
2	2.190	0.928	1.460	0.928	E	E	F
3	2.299	0.960	1.533	0.960	E	E	F
4	2.358	0.977	1.572	0.977	E	E	F
5	2.563	1.014	1.709	1.014	E	E	F
6	2.403	0.973	1.602	0.973	E	E	F
7	2.483	0.991	1.655	0.991	E	E	F
8	2.613	1.022	1.742	1.022	E	E	F
9	2.745	1.055	1.830	1.055	E	E	F
10	2.840	1.094	1.893	1.094	E	E	F
11	2.897	1.132	1.931	1.132	E	E	F
12	2.946	1.164	1.964	1.164	E	E	F
13	3.001	1.198	2.000	1.198	E	E	F
14	2.323	0.959	1.549	0.959	E	E	F

Table 1 Horizontal Earthquake Acceleration Values for Experimental Equipment

Horizontal Earthquake Acceleration		
280 and West, incl. Sector 25	East of 280	Experimental Equipment Structure Type Similar to the Following
0.80 g	0.70 g	▪ Elevated tanks, vessels, bins, or hoppers on symmetrically braced legs ▪ Horizontal, saddle supported welded steel vessels ▪ Flat-bottom ground-supported tanks (steel or fiber reinforced plastic) ▪ Steel and reinforced concrete distributed mass cantilever structures ▪ Components and systems isolated using neoprene elements
01.00 g	0.85 g	▪ Elevated tanks, vessels, bins, or hoppers on unbraced or asymmetrically braced legs ▪ Inverted pendulum type structure (except elevated tanks, vessels, bins or hoppers) ▪ Spring isolated components and systems

SLAC
ENVIRONMENT, SAFETY & HEALTH DIVISION

Seismic Design Specification for Buildings, Structures, Equipment, and Systems: 2016

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20 December 2016

- We can use comparison as a “sanity” check
- Design loads for simplified procedures are proportional to Sds
- PPPL has Sds between 9.5% and 13.0% of SLAC
  - 0.189/2.000 = 0.0945, 0.189/1.457 = 0.0129
- So PPPL should have design accelerations for experimental equipment between 0.066g and 0.130g
  - 0.0945*.70 = .066, 0.0130*1.0= 0.013