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2ND NEW ZEALAND PRESSURE EQUIPMENT WORKSHOP

B31E SEISMIC DESIGN OF PIPING

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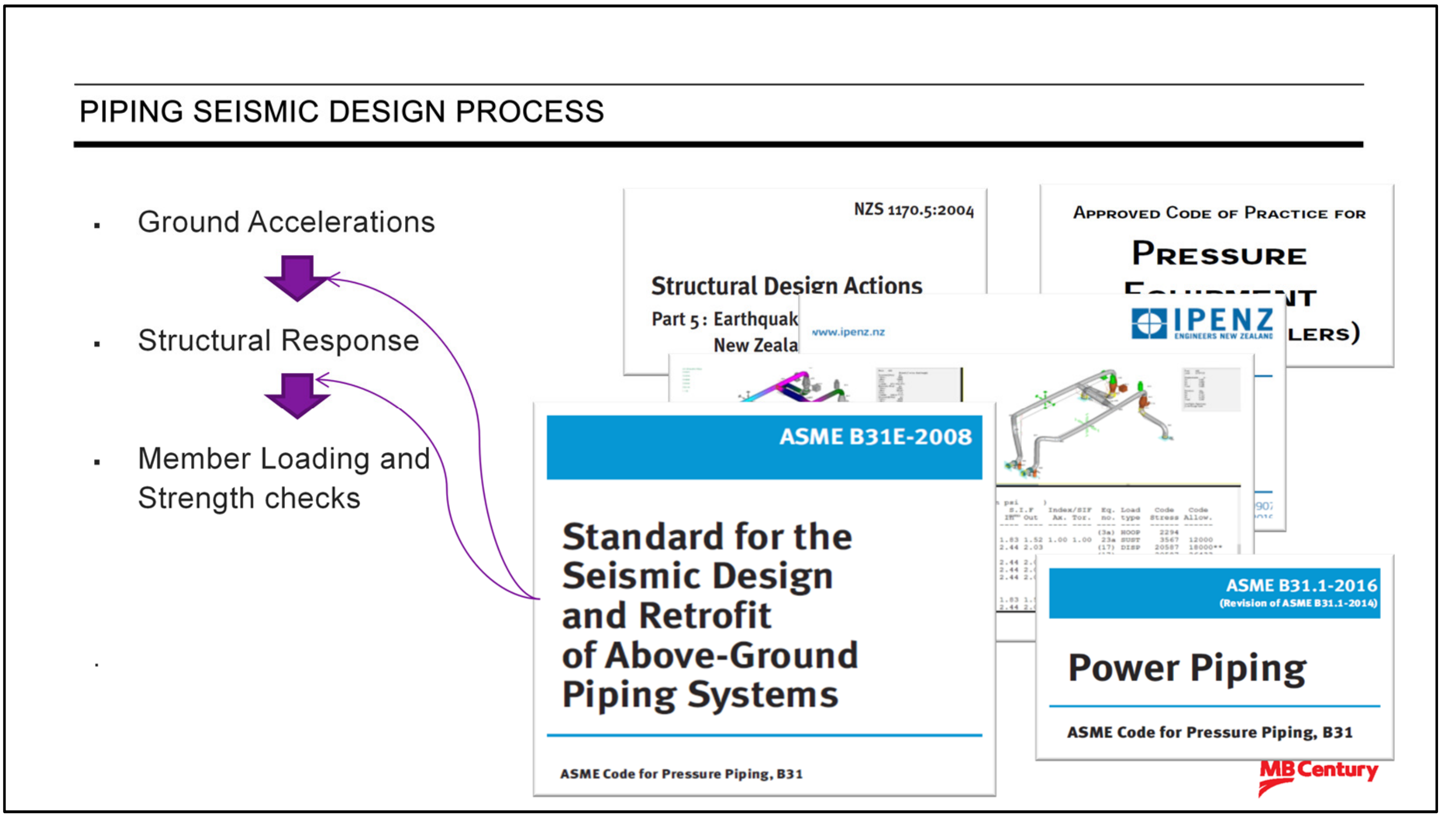

The Seismic Design process

1. derives the seismic motions/actions from local loading codes

2. models the behaviour of the structure

3. Checks material strength with (Piping) codes

But the these steps are effected by the piping code used.

The B31.x codes are very poor regarding seismic design. B31E addresses this problem.

PN19 refers to B31E but does differentiate between piping codes, Nor does NZS1170.5 regarding piping and parts.

B31E, B31.1 LOADS AND ALLOWABLE STRESS

	ASME B31E-2008	ASME B31.1-2016 (Revision of ASME B31.1-2014)
Load combination (Same)	$\frac{PD}{4t} + 0.75i\,\frac{M_{\text{sustained}} + M_{\text{seismic}}}{Z} \le \min\,[2.4S;\ 1.5S_Y;\ 60\text{ ksi }(408\text{ MPa})]$	$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \le kS_h \qquad (16)$
Allowable Stress (2x for B31E)	$S = S_h$	$k = 1.2$ $M_A = M_{\text{sustained}}$ $M_B = M_{\text{seismic}}$
	Operating Pressure & Temperature	Design Pressure & Temperature
	Corroded thickness	Nominal thickness (but see 102.4.1) (B31.3 use corroded thickness)
	Moment amplitude (zero to peak or ½ range. ASME III NC ND)	Moment loading

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B31.1 and B31.3 have the same loads combinations as B31E but B31E has much higher (2x for carbon steel) stress limits.

B31E design at operating pressure

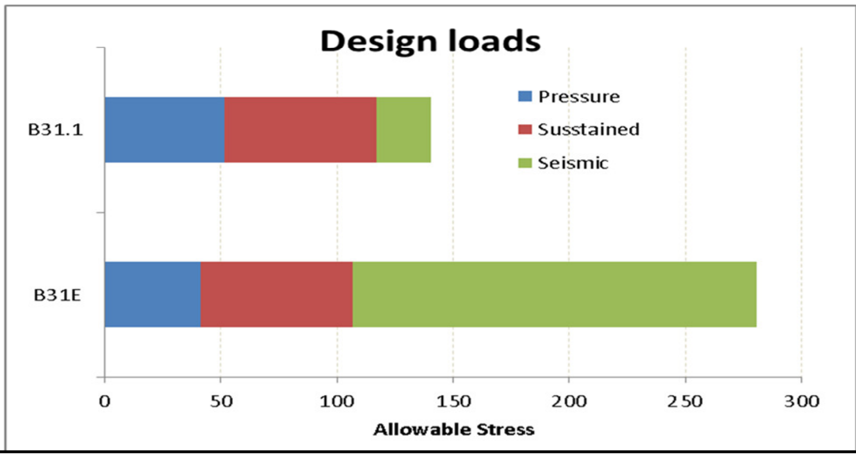
B31E must use corroded thickness

Moment amplitude is not defined but ASME nuclear piping code uses similar equations and defines amplitude zero to peak.

B31E, B31.1 LOADS AND ALLOWABLE STRESS

	ASME B31E-2008	ASME B31.1-2016 (Revision of ASME B31.1-2014)
Load combination (Same)	$\frac{PD}{4t} + 0.75i\frac{M_{\text{sustained}} + M_{\text{seismic}}}{Z} \leq \min\,[2.4S;\ 1.5S_Y;\ 60\text{ ksi }(408\text{ MPa})]$	$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \leq kS_h$ (16)

- Load combination (Same)
- Allowable Stress (2x for B31E)
- Seismic loads up to 700% higher?

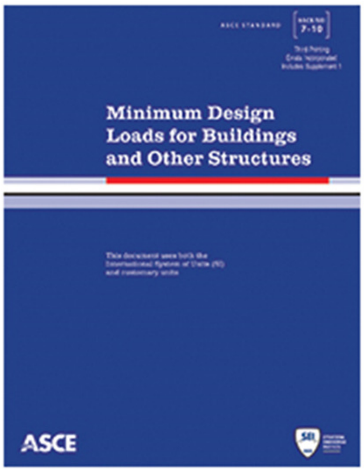


Twice the allowable stress for the load combinations and up to 700% more for the seismic component?

Note, the seismic load changes depending of the code being used. See next slide.

SEISMIC LOADING (DESIGN ACTIONS)

- B31E Refers to ASCE 7



American Society of Civil Engineers

Standards ASCE/SEI 7-10

2013 / 636 pp.

The B31 codes refer to ASCE/SEI 7-10 for the EQ loads. Similar to our NZ1170.5.

SEISMIC LOADING (DESIGN ACTIONS)

ASCE 7

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

NZS1170.5.

$$C(T) = C_h(T)\, Z\, R\, N(T,D)$$

$$C_d(T_1) = \frac{C(T_1)S_p}{k_\mu}$$

$$\geq (Z/20 + 0.02)R_u \text{ but not less than } 0.03R_u$$

$$C_p(T_p) = C(0)\, \cancel{C_{Hi}}\, C_i(T_p)$$

$$F_{ph} = C_p\cancel{(T_p)}\, C_{ph}\, \cancel{R_p}\, \cancel{W_p} \leq 3.6\, W_p$$

Component Response * Acceleration

$$a_p / R_p$$

$$C_{ph} \text{ or } S_p / k_\mu$$

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Comparing ASCE7 with NZS1170.5 reduces down to design EQ acceleration times a Complement Response factor.

SEISMIC LOADING (DESIGN ACTIONS)

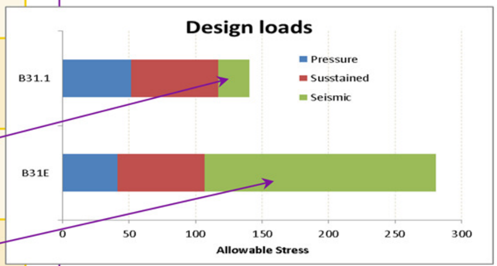
Component Response for Piping

- ASCE 7

	B31.x	Non B31.x	B31E
a_p	2.5	2.5	2.5
R_p	12.0	6.0	<3.5
a_p/R_p	0.21	0.41	>0.71

- NZS1170.5.

C_{ph} = 0.55



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The Complement Response factor in ASCE 7 depends on the piping code being used. Also the type of joints.

B31x codes have lower Complement Response factor because these codes have low allowable stress therefore these pipe are “rugged”

B31E has a minimum value for the Complement Response factor. There is no requirement to use a higher value.

Complement Response factor in NZS1170.5 or the ductility factor for piping does mote refer to any piping code. It should. A B31.x pipe is not the same as a B31E pipe.

SEISMIC LOADING (DESIGN ACTIONS)

Component Response for Piping

- B31E

$$a_p / R_p > 0.71$$

- NZS1170.5 & PN19.
  (Depends on T1)

$\mu = 1$

$$S_p / k_\mu = 0.7$$

$\mu = 1.25$ ✓

$$S_p / k_\mu = 0.78$$

$\mu = 2$

$$S_p / k_\mu = .41$$

- B31E ✗
- B31.x ✓

With NZ design you use μ = 1.25 and B31E

Or

For B31.x you can use μ = 2 or Cp = 0.55.
This does not mean the pipe will yield. Just allows for conservative design.

B31E CRITICAL PIPING

Critical Piping system must

- Remain leak tight and/or
- Operable (Deliver, control or shut down)

- Who decides?
  3.6 Specified by Owner?
  Hazard levels?

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critical piping: piping system that must remain leak tight or operable (see definitions) during or following the earthquake.

leak tightness: the ability of a piping system to prevent leakage to the environment during or following the earthquake.

operability: the ability of a piping system to deliver, control (throttle), or shut off flow during or after the design earthquake.

Table 1 Seismic Design Requirements, Applicable Sections

	Noncritical Piping		Critical Piping	
Acceleration	NPS (DN) ≤ 4 (100)	NPS (DN) > 4 (100)	NPS (DN) ≤ 4 (100)	NPS (DN) > 4 (100)
$a \leq 0.3\ g$	NR section 4 (interactions)	NR section 4 (interactions)	DR para. 3.3 (rule) para. 3.6 (mech. joints) para. 3.7 (restraints) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)
$a > 0.3\ g$	NR section 4 (interactions)	DR para. 3.3 (rule) para. 3.6 (mech. joints) para. 3.7 (restraints) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)	DA para. 3.4/3.5 (analysis) para. 3.6 (mech. joints) para. 3.7 (restraints) para. 3.8 (components) section 4 (interactions)

Leak tight

Position Retention

No rupture
Leak tight

a = peak spectral acceleration, largest in any of the three directions, including in-structure amplification, g
DA = design by analysis
DR = design by rule
NPS = nominal pipe size, in.
NR = explicit seismic analysis is not required, provided the piping system complies with the provisions of the applicable ASME B31 Code section, including design for loading other than seismic

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3.4 Design by Analysis

Where design by analysis is required in Table 1, or where it is applied by the designer as an alternative to the rules of para. 3.3, the elastically calculated longitudinal stresses due to the design earthquake (calculated

3.6 Mechanical Joints

For critical piping systems, the movements (rotations, displacements) and loads (forces, moments) at mechanical joints (nonwelded, nonbrazed, and nonsoldered joints) shall remain within the failure limits (for position retention) or leak tightness limits (for leak tightness and operability) specified by the owner.

3.7 See PN19

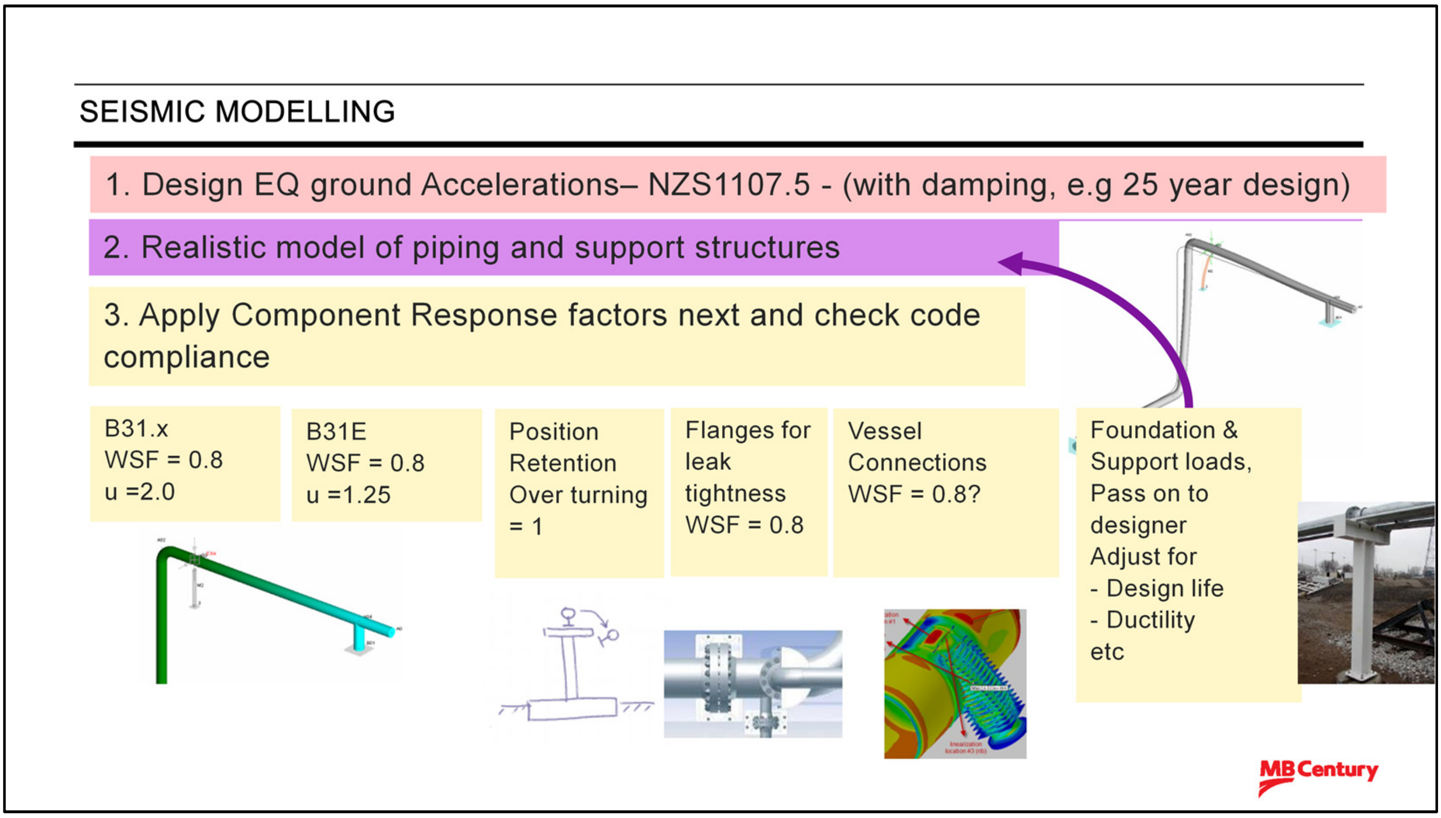
3.8 Equipment and Components

The seismic and concurrent loads applied by the pipe at equipment and component nozzles shall be qualified as part of the seismic design or retrofit of the piping system, to a degree commensurate with the required system function, as specified in para. 1.3.

For position retention, it is usually sufficient to show that the piping loads on equipment and components will not cause rupture. For leak tightness, the stress shall be maintained within yield or shown not to cause fatigue ruptures. For operability, the piping loads shall be kept within operability limits established by detailed analysis, testing, or similarity to seismically qualified equipment or components.

4 INTERACTIONS

Piping systems shall be evaluated for seismic interactions. Credible and significant interactions shall be identified and resolved by analysis, testing, or hardware modification.



1. Work out the design event ground accelerations.

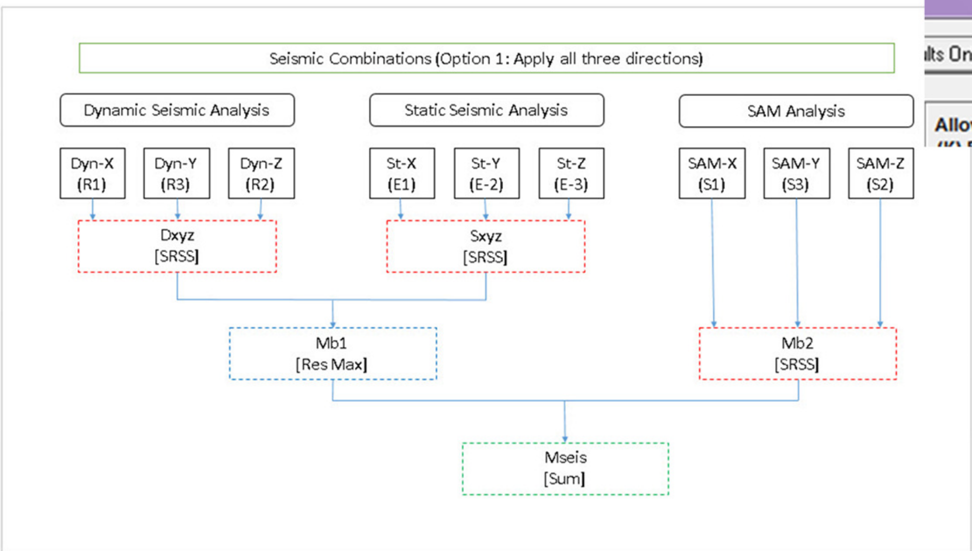
2. Model the piping and systems with realistic forces and displacements. For most piping this will be a programme like Autopipe and limited to elastic calculations. The model provides the "actual" pipe movement and loads on supports and other equipment.

3. These loads are factored to give stresses for use in the code checks. These factors are code dependent.

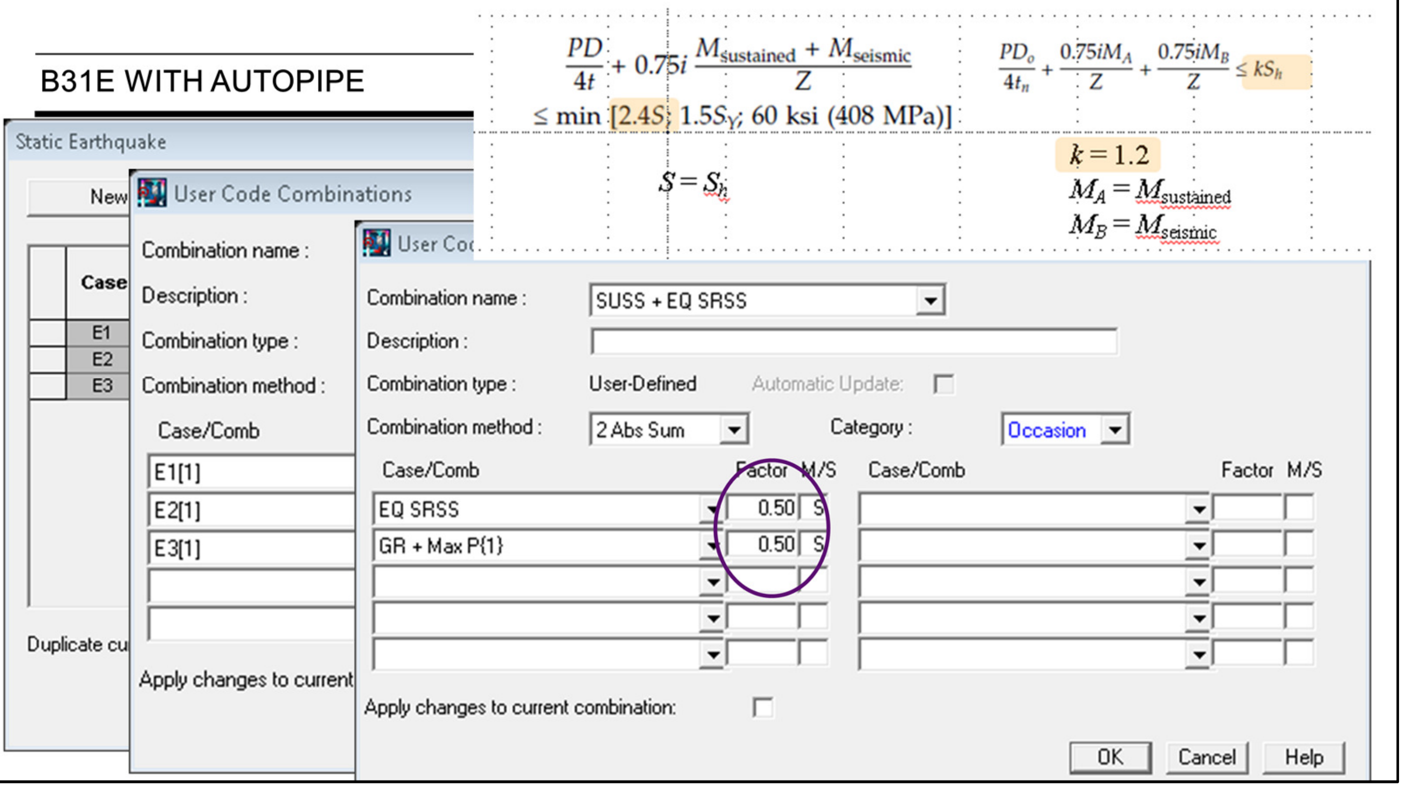
4. Integrations of the model maybe required to match the support stiffness. Be aware of the effect of plastic support behaviour on the pipe reactions and displacements.

B31E WITH AUTOPIPE

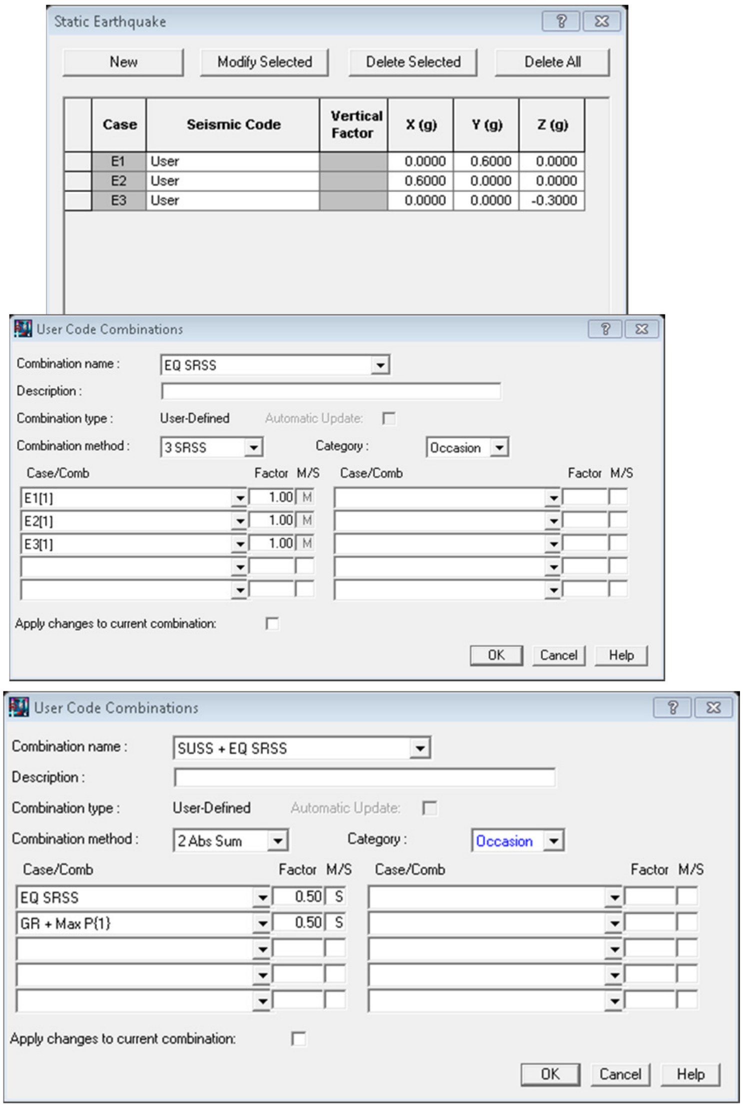
Bentley are working on it.



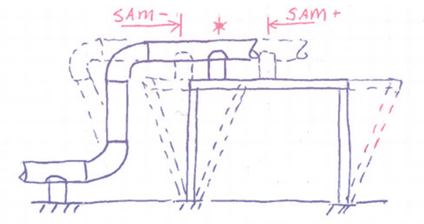
B31E WITH AUTOPIPE



1. Seismic accelerations
2. Combine with SRSS
3. Custom occ. case with ½ loads



SEISMIC RELATIVE ANCHOR MOTION SRAM



ASME B31E-2008	ASME B31.1-2016 (Revision of ASME B31.1-2014)
◆ Include in $M_{siesmic}$ $$\frac{F_{SAM}}{A} \le S_Y$$	◆ B31.1 Vague ◆ B31.3 interpretation 2-17 Add SAM to thermal stress range
◆ Pressure + sustained+ Seismic + SAM < 2.4S	◆ Pressure + Sustained + Thermal + SAM < 2.5S
◆ *Pressure + sustained+ Seismic + SAM + Thermal < 4.9S!*	◆ *Pressure + sustained+ Seismic + SAM + Thermal <3.7S!*

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SAM is better referred to as Seismic Relative Anchor Movement.

SAM design is different in B31.x and B31E.

I would assume the Complement Response factor for SRAM in B31E is the same as inertia loads.

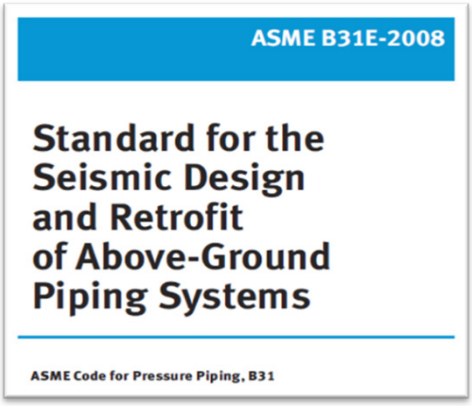
What Complement Response factor to use for SRAM in B31.x ???, be conservative use the actual movement of the anchor.

B31E DESIGN BY RULE

- Allowed for noncritical pipes.
- Specifies lateral restraint requirement without analysis.
- Requirement for longitudinal restraints.
- Still need to check thermal expansion stresses.

B31E SUMMARY

- B31E is more comprehensive than applying EQ loads as occasional loads in B31.x
- The allowable stresses and loads for B31E are higher that used with B31.x
- The Component Response factors for piping referred in NZ loading codes are too low for B31E design



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WHY BOTHER?

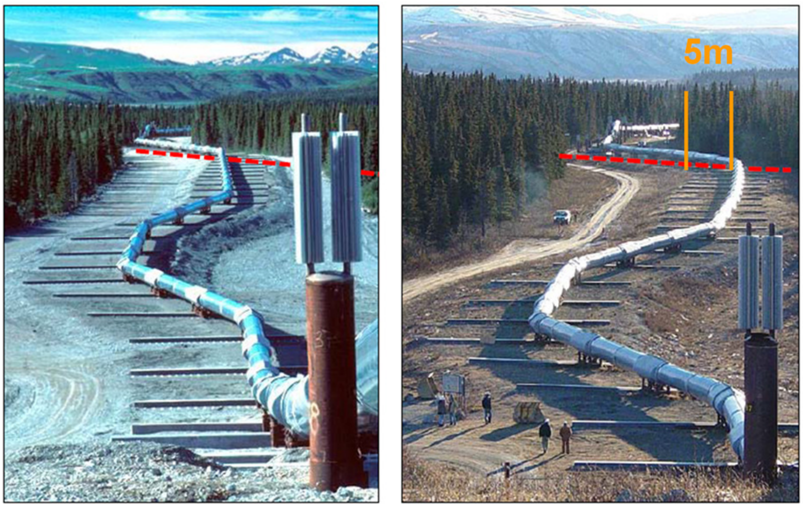

Figure 6. TAPS crossing of Denali Fault looking south before (left photo) and after (right photo) the 2002 fault rupture (location indicated by red dashed line). Right-lateral strike displacement at a 60° crossing angle was accommodated by lateral displacement of the pipeline on support beams and cold springing (bowing) of the pipe.

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The DOI Stipulations and U.S. DOT requirements through Title 49 of the Code of Federal Regulations, Part 195, and thereby ANSI Standard B31.4, provide regulations for the design, construction and operation of crude oil piping and pipelines. However, the regulations at that time were essentially "quiet" as to specific requirements for seismic design. Consequently, Alyeska undertook a major effort to adopt applicable American Society of Mechanical Engineers (ASME) loading and code provisions, with seismic and faulting input added in much the same way as was occurring in the nuclear power industry, the offshore pipeline industry, aerospace, and national defense.

https://nees.org/resources/12126/download/10NCEE-001172.pdf

10NCEE
Tenth U.S. National Conference on Earthquake Engineering
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Anchorage, Alaska

TRANS-ALASKA PIPELINE SEISMIC ENGINEERING LEGACY

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THANK YOU

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