API 620 Annex L

Seismic Design of Storage Tanks - Public Reference Summary

What this PDF focuses on

Selected numeric checkpoints from API 620 Annex L for flat-bottom tanks: seismic zone factors, site coefficients, force coefficients, overturning resistance, shell compression, anchorage, sloshing height, and practical design limits.

Use boundary

Public-reference summary only. Verify final contract or approval work against the licensed standard and project-specific governing code.

Tank basis	Flat-bottom tanks; Annex L is not intended for skirt- or column-supported tanks.
Zone 0	No earthquake design is required for Zone 0.
Importance factor I	1.0 for all tanks by default; recommended not to exceed 1.25 for toxic or explosive service where accidental release could endanger the public.
Vertical acceleration	Public inquiry 620-I-17/00: vertical acceleration is not considered in Appendix L.

Source basis used for this public reference: current API public catalog scope for API 620 and the publicly accessible 2002 Appendix L text made available at law.resource.org.

1. Scope and Design Inputs

Appendix L establishes recommended minimum basic requirements that a purchaser may specify for storage tanks subject to seismic load. The appendix is written for **flat-bottom tanks** and treats two seismic response modes: (1) the shell/roof plus the portion of liquid moving in unison with the shell, and (2) the lower-frequency first-mode sloshing response of the liquid contents.

Seismic zone and importance inputs

Parameter	Exact Annex L value / rule	Project meaning
Seismic Zone Factor Z	Zone 1 = 0.075; 2A = 0.15; 2B = 0.20; 3 = 0.30; 4 = 0.40	Horizontal seismic acceleration factor used in overturning and lateral-force calculations.
Zone 0	No earthquake design required	Useful screening boundary at concept stage.
Importance Factor I	Default = 1.0; recommended maximum = 1.25	Higher value is recommended only for tanks storing toxic or explosive substances where accidental release could endanger the public.
Outside-U.S. examples	Table L-1 includes Ankara = 2B, Karamursel = 3, Puerto Rico = 3, Guam = 3, Wake Island = 0	Shows Annex L also tabulates selected non-U.S. locations.

Soil profile and site coefficient S

Soil profile	S factor	Public-reference description
S1	1.0	Rock-like material with shear-wave velocity > 2,500 ft/s, or stiff/dense soil where soil depth is < 200 ft.
S2	1.2	Dense or stiff soil where soil depth exceeds 200 ft.
S3	1.5	Soil profile >= 70 ft deep with > 20 ft of soft to medium stiff clay, but not more than 40 ft of soft clay.
S4	2.0	More than 40 ft of soft clay with shear-wave velocity < 500 ft/s.

If soil properties are not known in enough detail to classify the site, Appendix L says to use S3. S4 need not be assumed unless the authority having jurisdiction considers it possible or it is established by geotechnical data.

2. Force Coefficients, Sloshing Period, and Overturning

Annex L separates the total seismic action into an impulsive part and a convective/sloshing part. The effective masses W1 and W2 and the corresponding heights X1 and X2 are obtained from the D/H ratio using Figure L-2 and Figure L-3. The overturning moment at the bottom of the shell is then calculated from these weighted components.

Core coefficient rules

Item	Exact value / formula	Notes
Lateral coefficient C1	C1 = 0.60	Default Annex L value unless both ZIC1 and ZIC2 are established from a site-specific response spectrum.
Lateral coefficient C2 for T <= 4.5 s	C2 = 0.75 S / T	Depends on site coefficient S and first-mode sloshing period T.
Lateral coefficient C2 for T > 4.5 s	C2 = 3.375 S / T^2	Longer-period sloshing response branch.
Sloshing period	T = k D^0.5	k is obtained from Figure L-4 as a function of D/H.
Spectrum damping for ZIC1	2% of critical	For site-specific response spectrum method.
Spectrum damping for ZIC2	0.5% of critical	Same site-spectrum concept, modified for sloshing response.

Overturning-moment expression used in Appendix L

$$M = ZI(C1*Ws*Xs + C1*Wr*Hr + C1*W1*X1 + C2*W2*X2)$$

Where M is the overturning moment at the shell base; Z is the seismic zone factor; I is the importance factor; Ws and Wr are shell and roof weights; W1 and W2 are the effective impulsive and first-mode sloshing masses; and Xs, Hr, X1, X2 are the corresponding heights to the force-resultant centroids.

Practical seismic screening numbers

Check	Exact Annex L threshold / rule
No-design trigger	Zone 0 -> no earthquake design required.
Importance-factor limit	Recommended not to exceed 1.25.
C2 branch switch	T = 4.5 s.
Public inquiry note	Vertical acceleration is not considered in Appendix L (620-I-17/00 reply).

3. Overturning Resistance, Shell Compression, Anchorage, and Sloshing

This is the most useful data-heavy part for project work, because Annex L gives explicit numeric triggers for uplift resistance, shell compression, sloshing allowance, and anchorage checks.

Overturning resistance and bottom hold-down

Item	Exact Annex L rule / equation	Why it matters
Maximum product weight usable to resist overturning	WL = 7.9 * tb * sqrt(Fby * G * H)	Defines how much liquid weight adjacent to the shell can be credited for uplift resistance in unanchored tanks.
Upper cap on WL	WL shall not exceed 1.25 * G * H * D	Prevents unconservative uplift resistance credit.
Bottom plate thickness under shell tb	tb shall not exceed the bottom shell-course thickness or 1/4 in., whichever is greater	Sets the limit for the plate strip used in uplift resistance.
Minimum radial width of thicker bottom strip	>= 0.0274 * WL / (G * H)	Establishes the hold-down strip width when the plate under the shell is thickened.

Shell-compression thresholds

Check	Exact Annex L trigger
Base expression for unanchored tanks when M/[D^2(Wt + WL)] <= 0.785	b = Wt + 1.273 M / D^2
Intermediate range	If 0.785 < M/[D^2(Wt + WL)] <= 1.5, compute b from Figure L-5.
Instability trigger	If M/[D^2(Wt + WL)] > 1.57 or if b/(12t) > Fa, the tank is structurally unstable.
Allowable shell compression Fa for G H D^2 / t^2 >= 10^6	Fa = 10^6 * t / D
Allowable shell compression Fa for G H D^2 / t^2 < 10^6	Fa = (10^6 * t) / (2.5 D) + 600 * sqrt(G H)
Upper limit on Fa	Fa shall not exceed 0.5 * Fty

Anchorage, sloshing, and sliding

Item	Exact Annex L value / rule	Project note
Minimum seismic anchorage resistance	w_t = 1.273 M / D^2	Per foot of shell circumference when anchorage is required.
Piping flexibility	For unanchored tanks with bottom uplift, bottom-connected piping shall either lift with the bottom or be located at least the L.4.2 hold-down width plus 12 in. from the shell.	Mechanical piping detail that often gets missed in layout review.
Theoretical sloshing wave height	d = 1.124 Z I C2 T^2 tanh[4.77 (H/D)^0.5]	Annex L then requires a minimum additional 1 ft for liquid run-up on the shell.
Sliding friction assumption	0.40 times the force against the tank bottom	Annex L default unless otherwise required.

Practical note: current EIGA storage guidance references API 620 Annex L sloshing height and presents the extra shell run-up allowance as hs = 300 mm, which is the approximate metric equivalent of the Annex L 1 ft minimum addition.

4. What Designers and Buyers Should Check Early

Tank type boundary
Annex L is intended for flat-bottom tanks and is not intended for skirt- or column-supported tanks.

Ground motion basis
Confirm the project seismic zone, or supply a site-specific response spectrum if the purchaser wants to replace the default ZIC1 and ZIC2 route.

Soil profile
The S factor can shift from 1.0 to 2.0; if soil data are incomplete, Annex L defaults the project to S3 rather than assuming a harder site.

Uplift route
Check early whether the tank can remain unanchored or whether combined internal pressure and wind/seismic load will push the design into mechanical anchorage.

Freeboard
Sloshing is not only a structural issue. Annex L explicitly tells the purchaser to specify whether freeboard is desired to minimize overflow and roof or upper-shell damage.

Foundation and piping
Annex L pushes earthquake effects into the foundation and piping details: uplift, hold-down width, shell-base forces, and bottom-connected piping flexibility.

Reference basis used for this public summary

- API 2025 Publications Catalog public scope text for API 620 and its annex boundaries.
- Publicly accessible 2002 API 620 text at law.resource.org for Appendix L numeric values and formulas.
- EIGA DOC 127/23 public guidance note referencing Annex L sloshing allowance and freeboard application.

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