CRYOVANGUARD

SOFTWARE REQUIREMENTS SPECIFICATION (SRS)

Cryogenic Single-Containment Tank Calculation Software – API 620 Annex Q / API 625 / API 650

1. Purpose and Scope

The objective is to develop a calculation and preliminary design software for single-containment cryogenic storage tanks, storing LIN, LOX and LNG, based on:

- API 620 (12th edition)
- API 620 – Annex Q (liquefied gas storage down to -325 °F)
- API 625 (tank systems for refrigerated liquefied gas storage)
- API 650 – Annex E (seismic design)
- API 650 – Annex V (buckling / external pressure)

The software must cover:

- Vertical welded tanks, flat bottom, single containment
- Primary liquid container in stainless steel (A240 TP 304), outer warm tank in carbon steel (A283 Gr C)
- Design pressures: -0.25 psig to +7 psig
- Fluids: LNG, LIN, LOX (≈ -160 to -196 °C)

The software is intended for internal engineering use, sales/pre-design, and optionally selected clients in read-only or restricted mode.

2. Applicable Standards

The software shall implement the rules of:

API 620 – Design and Construction of Large, Welded, Low-Pressure Storage Tanks

- Sections 4 to 7 (materials, design, mechanical calculations, welding, NDE)
- Annex Q – Liquefied gas storage (down to -325 °F)
- Annex L – Seismic design (working together with API 650 Annex E)

API 625 – Tank Systems for Refrigerated Liquefied Gas Storage

- Storage concept selection (here: single containment)
- Performance criteria, liquid levels, design loads, boil-off, foundations, seismic OBE/SSE/ALE

API 650 – Welded Tanks for Oil Storage

- Annex E – Seismic design of welded tanks
- Annex V – External pressure and buckling

Other referenced documents (ASCE 7, ACI 376, API 2000, NFPA 59A) may be used indirectly as referenced by the above standards.

3. Target Users and Use Cases

3.1 User Profiles

- Engineering (mechanical, structural, cryogenic)
- Sales / Pre-sales engineers (pre-sizing)
- Clients / EPCs (controlled read-only access)

3.2 Typical Use Cases

- Feasibility study for a new LIN/LOX/LNG single-containment tank
- Tender proposal with code-compliant preliminary design
- Verification of an existing geometry against the codes
- Sensitivity to site change (seismic, wind, temperatures)
- Calculation report generation for internal or customer review

4. Software Architecture

4.1 Platform

- Web application (Chrome/Edge/Firefox)
- Backend: Python / .NET / C++ (developer to propose)
- Cloud deployment (AWS/Azure/GCP)
- Containerized architecture (Docker or equivalent)

4.2 Security and Multi-User

- Authentication (login/password)
- Roles:
    - Admin: user management, settings
    - Engineer: full calculation abilities
    - Sales: simplified interface and parameters
    - Customer: read-only
- HTTPS encryption
- Project versioning and backups

5. Technical Scope – Structural Assumptions

The software handles metallic single-containment tanks only:

- Inner tank: primary liquid container
- Outer tank: warm vapor container

The design is fully Annex Q-driven:

- All cold-exposed components must follow API 620 + Annex Q
- Warm components follow standard API 620 (with API 650 contributions)

Default materials:

- Primary liquid container: ASTM A240 TP 304 (stainless steel)
- Outer tank: ASTM A283 Grade C (carbon steel)

Detailed concrete foundation design (reinforcement, rebar) is excluded;

The software shall supply all loads and moments for foundation engineers.

6. Functional Modules

6.1 Project Data Module

Inputs

- Product: LIN / LOX / LNG
- Net working capacity (m^3)
- Location (country + coordinates)
- Climatic data:
    - Tmin / Tmax
    - Lowest one-day mean ambient temperature
    - Wind data
- Seismic data:
    - Ss, S1 or PGA/S1 depending on region
    - Site class
    - Reference standard (ASCE 7 / NFPA 59A)
- Soil and foundation:
    - Bearing capacity
    - Expected settlements (global/differential)
    - Foundation type
- Design pressures:
    - Positive Pdesign (−0.25 to +7 psig)
    - Design vacuum
- Liquid levels:
    - Minimum normal level
    - Maximum normal level
    - Boil-off target
    - Overfill protection margin

Outputs

- Validation of "Annex Q domain" (error if outside)
- Project base data sheet

6.2 Material Module – Annex Q

Purpose

- Assign materials to each component following API 620 Section 4 + Annex Q + API 625.

Rules

- Cold-exposed components (inner shell, bottom, refrigerated roof, suspended deck, cold stiffeners, cold anchor elements):
  → A240 TP 304 (default), from Annex Q Table Q-1
- Warm vapor container components (outer shell, outer roof, outer stiffeners):
  → A283 Grade C (default)

The software must:

- Assign for each component:
  - selected material
  - Tmin (API 625 rule)
  - allowable stresses (Annex Q Table Q-3 for 304 / API 620 for A283C)
  - impact test requirements
- Block non-compliant material choices.

6.3 Geometry & Levels Module

Purpose

Compute:

- Tank diameter D
- Total height H
- Course distribution
- Heel, min/max operating level, design level
- Freeboard + seismic freeboard

Capabilities

- From networking capacity + starting D → compute H
- Compute:
- design liquid level (API 625)
- nominal freeboard (≥ 300 mm for suspended deck tanks)
- seismic freeboard (from seismic module)
- Ensure shell height satisfies:
- Hshell ≥ designLevel + freeboard + seismicFreeboard

Outputs: D, H, course heights, all levels.

6.4 Thermal Module – Boil-Off & ΔT

Objectives

- Compute Boil-Off Rate (BOR) under worst heat-inleak conditions
- Compute temperature profiles (shell, bottom, roof)

Calculations

- Heat flux through:
- bottom (including load-bearing insulation)
- wall and insulation
- roof/suspended deck
- BOR = Qtotal / (ρ × Lv × Volume)
- Compare BOR to target → suggest upgrades if needed
- Compute ΔT for mechanical modules.

6.5 Mechanical Module – API 620 + Annex Q

6.5.1 Shell Course Design

Thickness from:

- internal pressure
- hydrostatic head
- material allowables from Annex Q
- joint efficiency E (based on NDE)
- corrosion allowance

Check:

- hoop stress
- longitudinal stress
- biaxial reduction (API 620 stress interaction chart)

6.5.2 Bottom & Annular Ring

- Minimum thickness rules from API 620
    - Weld area stress checks
    - Settlement stress assessment (simplified)

6.5.3 Roof & Compression Ring

- Cone or dome design
- Thickness & stiffener calculation
- Compression ring design per API 620
- Load cases: dead load, snow, wind, internal pressure

6.6 Seismic Module – API 620 Annex L + API 650 Annex E + API 625

Purpose

- Perform seismic checks for OBE/SSE/ALE levels.

Algorithm

- Build seismic spectra (OBE, SSE/MCER, ALE)
- Compute impulsive and convective masses (API 650 Annex E)
- Compute base shear and overturning moments
- Compute sloshing height Hs → check freeboard
- Compute anchor loads and sliding
- Check stresses with Annex Q allowable + 33% increase for seismic
- Evaluate API 625 performance requirements

Outputs

- V, M, Hs
- Anchor tension/compression
- Foundation reaction envelope
- OK/not-OK and recommended modifications

6.7 Buckling / External Pressure Module – API 650 Annex V

Purpose

Verify stability of shells and roof under:

- Internal vacuum
- External pressure (wind + vacuum)

Procedure

For each shell segment:

- Compute external pressure Pext
- Compute critical elastic buckling pressure Pcr

Check:

- Pext ≤ Pcr / FS
- If non-conforming → propose:
- thicker shell
- additional stiffener
- reduced spacing between stiffeners

6.8 Anchorage Module

Purpose

Design or verify tank anchorage for:

- Wind
- Seismic
- Internal pressure
- Annex Q uplift cases

Outputs

- Required bolt number, diameter, spacing
- Anchor tensions

Sliding verification

Foundation loads

6.9 Foundation & Soil Module (Simplified)

The software shall:

- Provide soil bearing pressures and overturning moments
- Check predicted settlements vs allowable tank deformation limits
- Identify need for a base heating system (anti-frost)

No concrete/rebar design is included.

6.10 Bottom Load-Bearing Insulation Selection Module – Foam Glass

Objective

Select and verify the **bottom load-bearing insulation** made of **foam glass blocks**, the single chosen material due to:

- its high mechanical compressive strength,
- its stability at very low temperatures,
- its non-absorbing / closed-cell behaviour,
- its compatibility with **API 625** requirements.

Inputs

Vertical loads

- Self-weight of the inner tank
- Maximum liquid weight
- Weight of the roof / suspended deck
- Vertical anchor loads
- Vertical components of seismic loads (if they increase compression)

Geometrical data

- Tank diameter
- Effective bearing area on the insulation

Material data (internal database)

- Compressive strength of foam glass at the design temperature

- Long-term allowable compressive stresses (including creep reduction factors)

Thermal data

- Thermal conductivity λ of foam glass
- Minimum insulation thickness required to meet the Boil-Off Rate (BOR) target (from the thermal module)

6.11 Reporting & Export Module

Outputs:

Detailed PDF report:

- all inputs
- geometry
- thermal results (BOR)
- mechanical thicknesses and checks
- seismic and buckling results
- compliance summary

Excel / JSON exports:

- input table
- intermediate tables
- final calculation results

7. Non-Functional Requirements

- Performance: complete calculation including seismic in 10–30 seconds
- Traceability: each check references the exact clause (e.g., "API 620 Q.3.3.5")
- Modularity: architecture must allow future extension
- Internationalisation: English UI, scalable to FR/ES
- Units: SI default, optional US units

8. Out-of-Scope

The software does not include:

- Double or full containment tanks
- Membrane tanks (GTT…)
- Pressures > 7 psig (ASME VIII domain)
- Detailed concrete design (rebar, structural analysis)
- High-fidelity CFD sloshing
- Detailed fatigue analysis (beyond basic checks)