Survey Outcomes on Failures in Thermal Energy Storage Systems: Key Findings and Insights

UNDERSTANDING CAUSES AND SOLUTIONS FOR SYSTEM RELIABILITY

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Background and Objectives of the Survey

Purpose of investigating thermal energy storage failures

Identify Common Failures

The survey focuses on detecting prevalent failure modes in thermal energy storage systems to improve system understanding.

Enhance Reliability

Understanding failure patterns enables improvements in system reliability and overall performance.

Risk Mitigation and Adoption

Insights from failures help stakeholders mitigate risks and encourage wider technology adoption.

Survey methodology and participant demographics

Data Collection Methods

We elaborated survey in both Chinese and English to gather worldwide inputs and spread it within our network and LinkedIn.

Participant Diversity

Participants included industry professionals and researchers from a variety of geographic regions and technology sectors.

English survey: 16 respondents

Chinese survey:8 respondents

Types and Frequency of Failures in Thermal Energy Storage

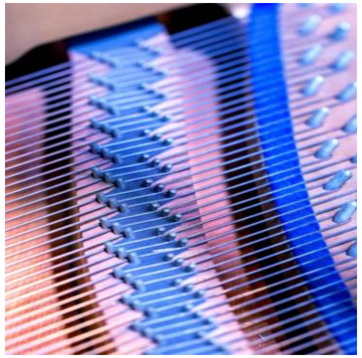
Common failure modes identified

Material Degradation

Material degradation is a common failure mode caused by wear, corrosion, or aging of components over time.

Mechanical Breakdowns

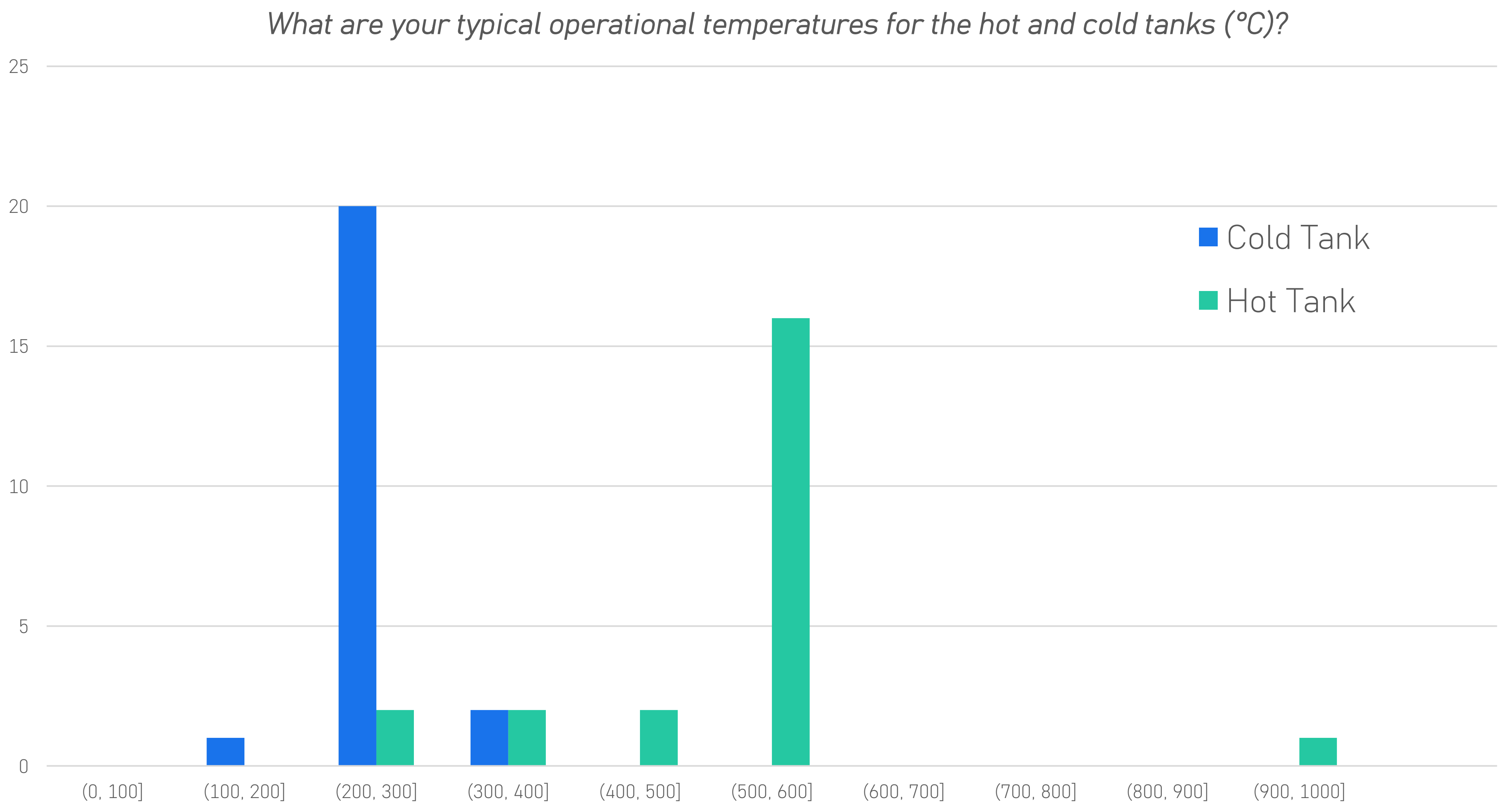
Mechanical breakdowns occur due to component failure or excessive stress affecting system performance and reliability.



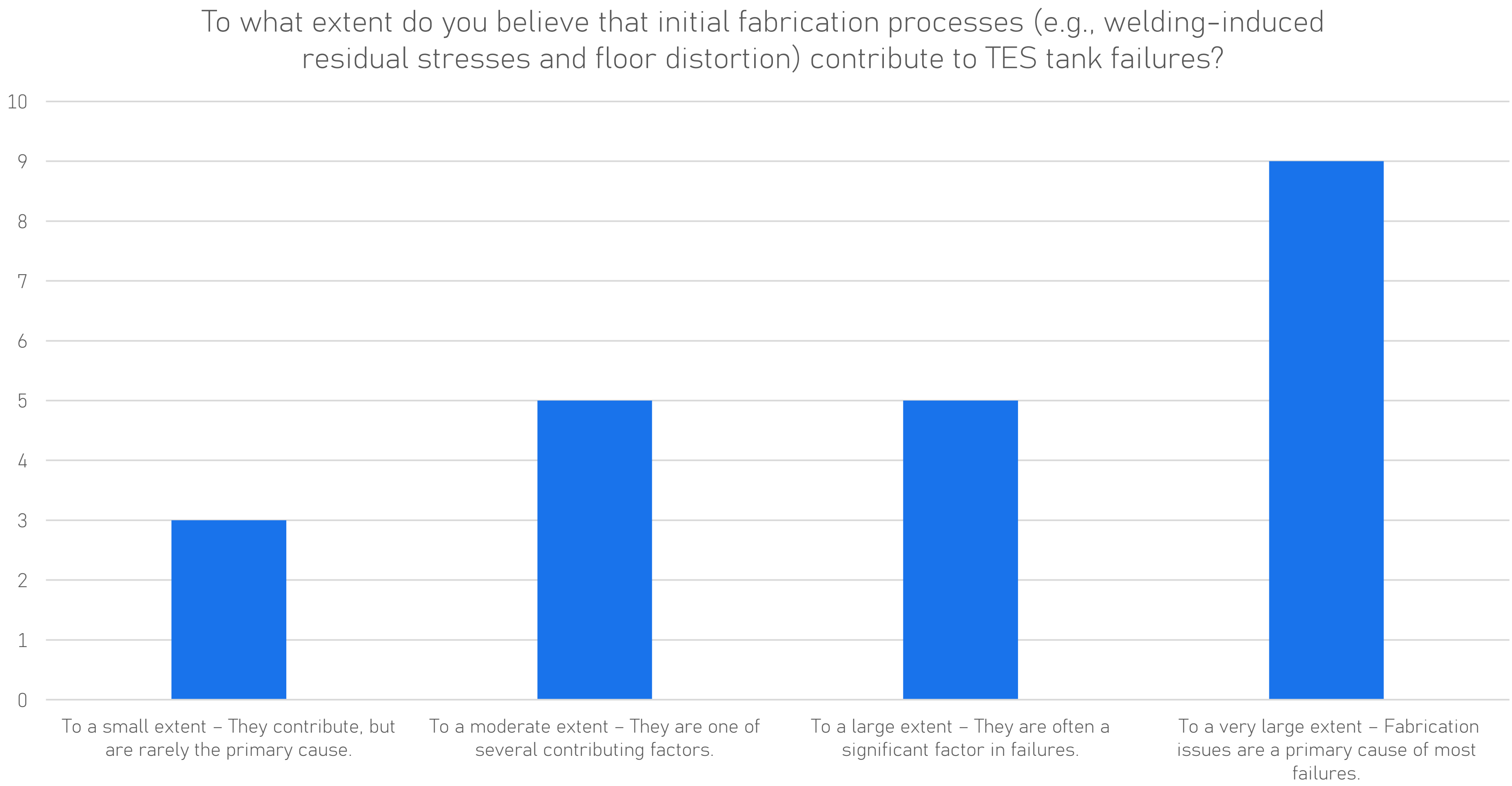
Thermal Inefficiencies

Thermal inefficiencies result from improper heat dissipation leading to overheating and reduced system efficiency.

Q3

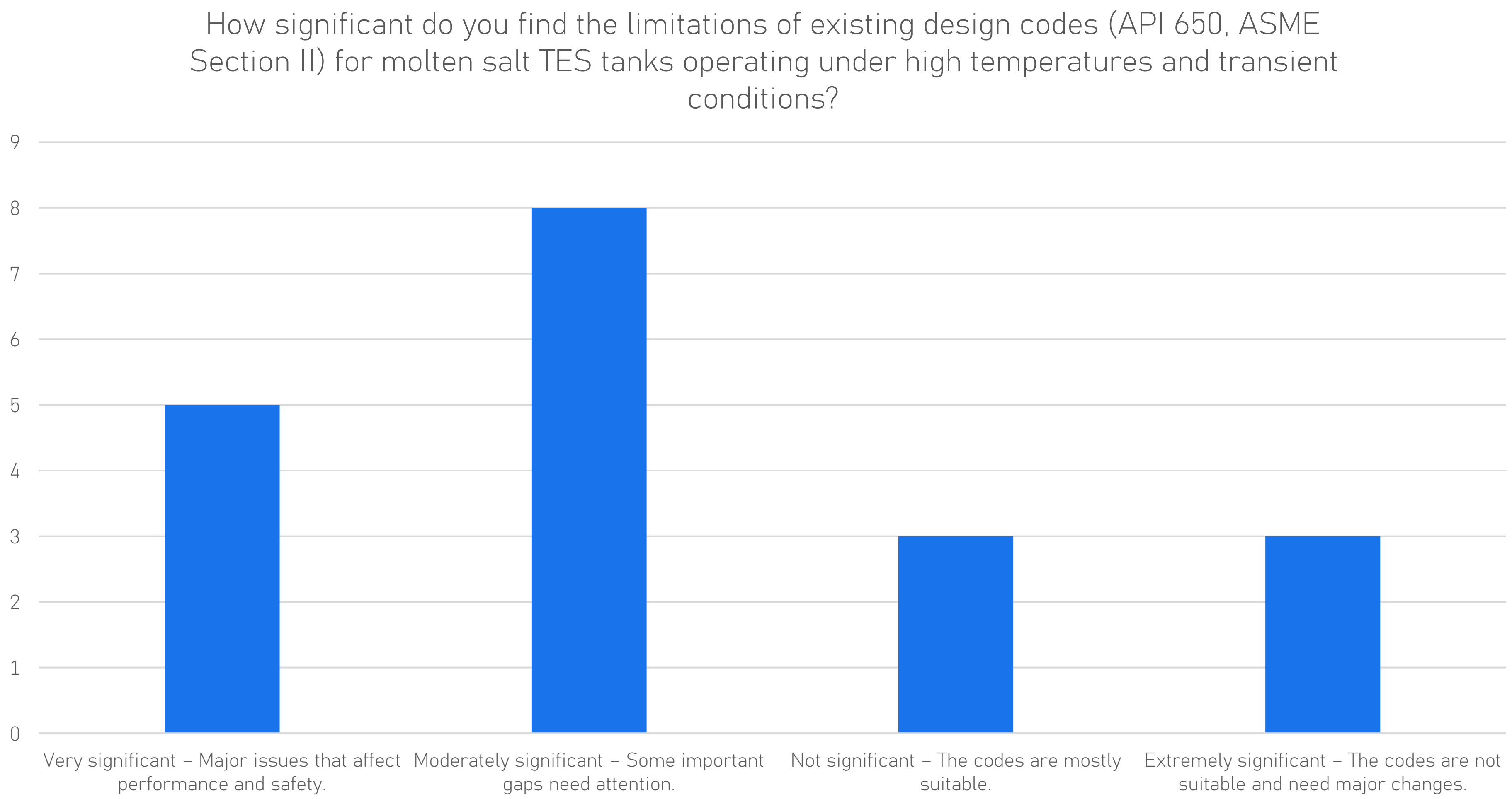

What are your typical operational temperatures for the hot and cold tanks (°C)?
25
20
15
10
5
0
Cold Tank
Hot Tank
(0, 100]
(100, 200]
(200, 300]
(300, 400]
(400, 500]
(500, 600]
(600, 700]
(700, 800]
(800, 900]
(900, 1000]

Q4

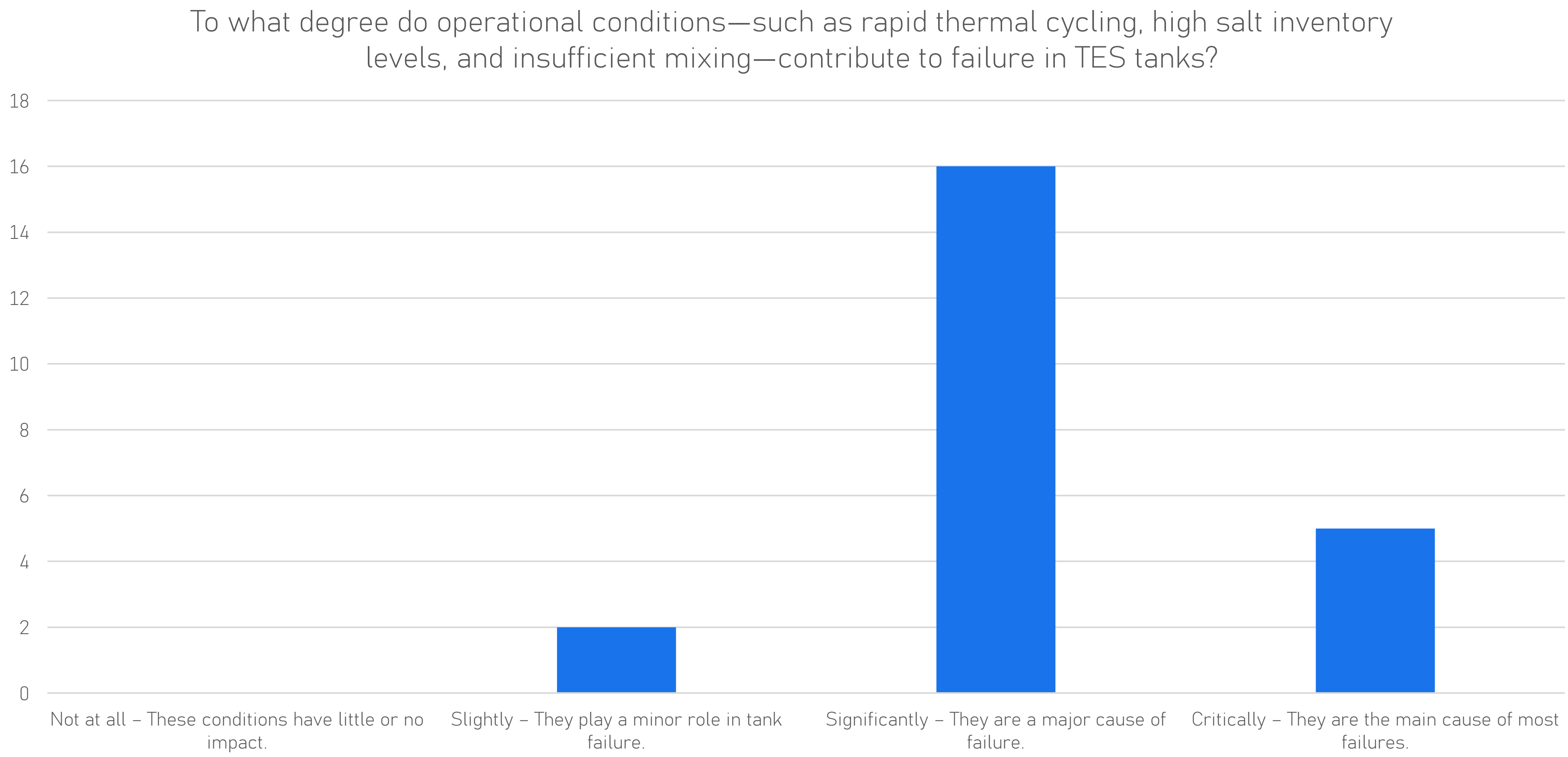


To what extent do you believe that initial fabrication processes (e.g., welding-induced residual stresses and floor distortion) contribute to TES tank failures?
10
9
8
7
6
5
4
3
2
1
0
To a small extent – They contribute, but are rarely the primary cause.
To a moderate extent – They are one of several contributing factors.
To a large extent – They are often a significant factor in failures.
To a very large extent – Fabrication issues are a primary cause of most failures.

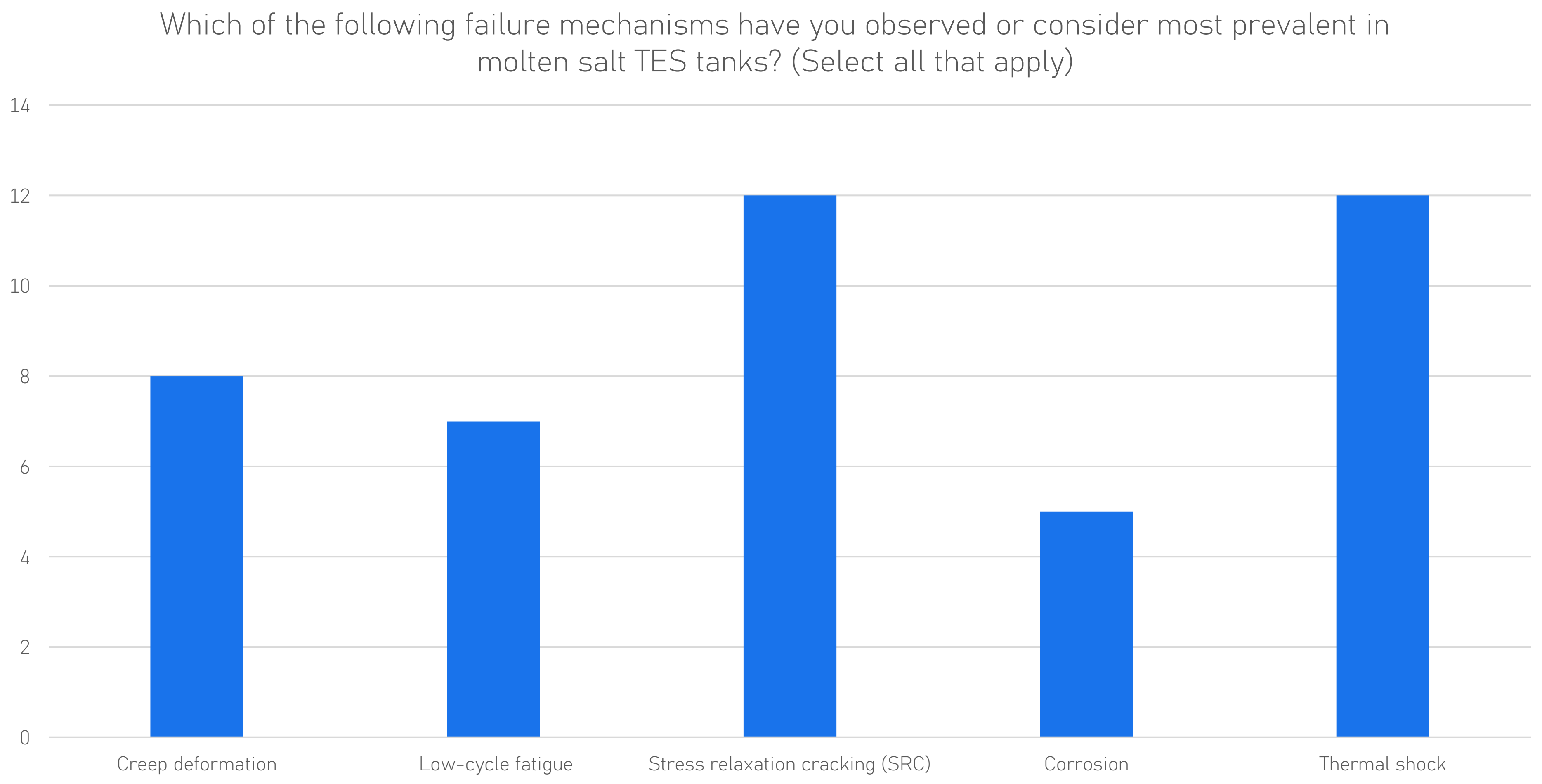
Q5


How significant do you find the limitations of existing design codes (API 650, ASME Section II) for molten salt TES tanks operating under high temperatures and transient conditions?
9
8
7
6
5
4
3
2
1
0
Very significant – Major issues that affect performance and safety.
Moderately significant – Some important gaps need attention.
Not significant – The codes are mostly suitable.
Extremely significant – The codes are not suitable and need major changes.

Q6


To what degree do operational conditions—such as rapid thermal cycling, high salt inventory levels, and insufficient mixing—contribute to failure in TES tanks?
18
16
14
12
10
8
6
4
2
0
Not at all – These conditions have little or no impact.
Slightly – They play a minor role in tank failure.
Significantly – They are a major cause of failure.
Critically – They are the main cause of most failures.

Q7



Which of the following failure mechanisms have you observed or consider most prevalent in molten salt TES tanks? (Select all that apply)
14
12
10
8
6
4
2
0
Creep deformation
Low-cycle fatigue
Stress relaxation cracking (SRC)
Corrosion
Thermal shock

Impact and Consequences of Failures

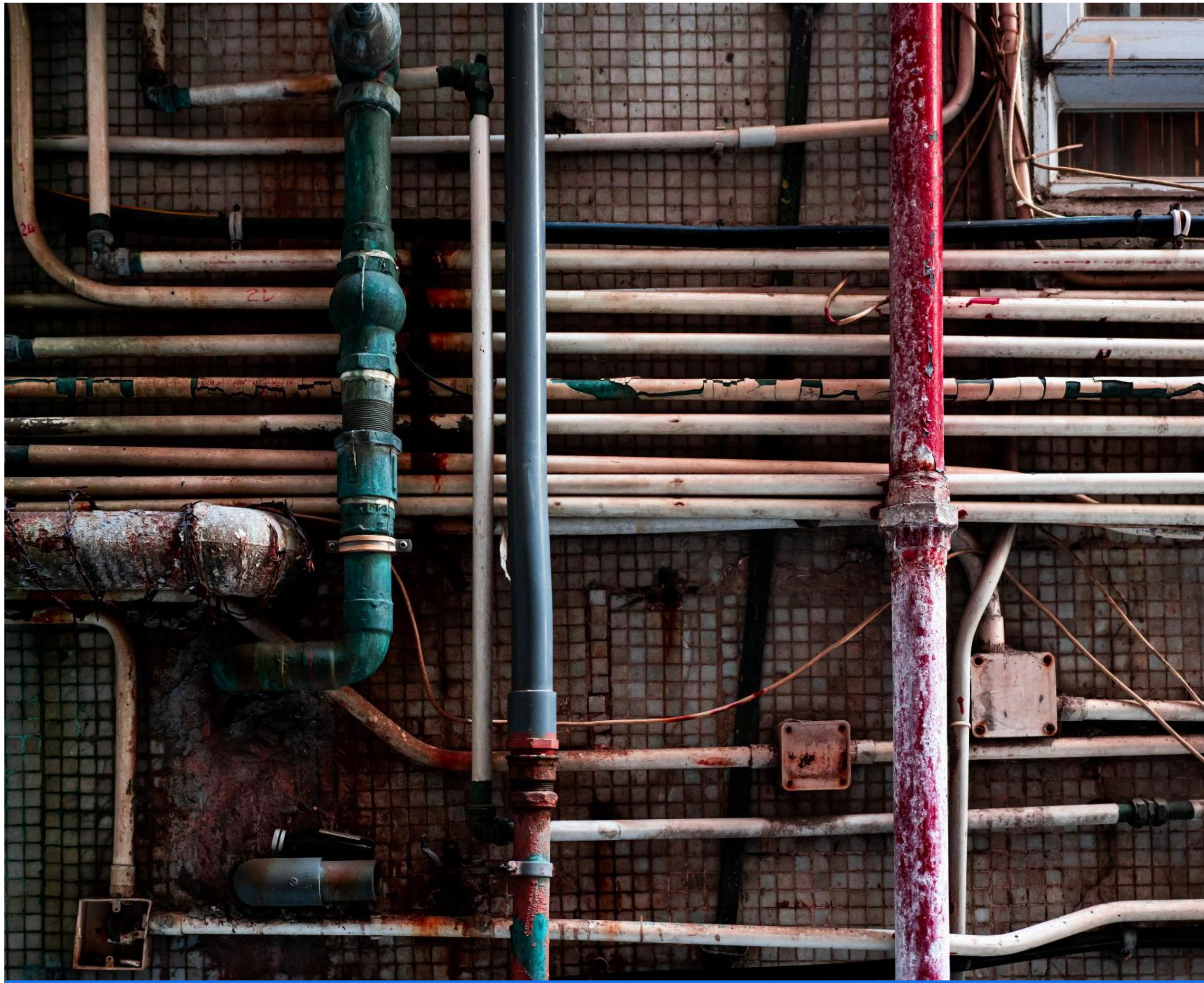
Performance degradation and energy losses

Impact of Failures

Failures cause a drop in thermal efficiency, adversely affecting overall system performance.

Energy Loss Increase

System failures result in higher energy losses, reducing operational effectiveness.



Economic implications for operators

Repair Costs

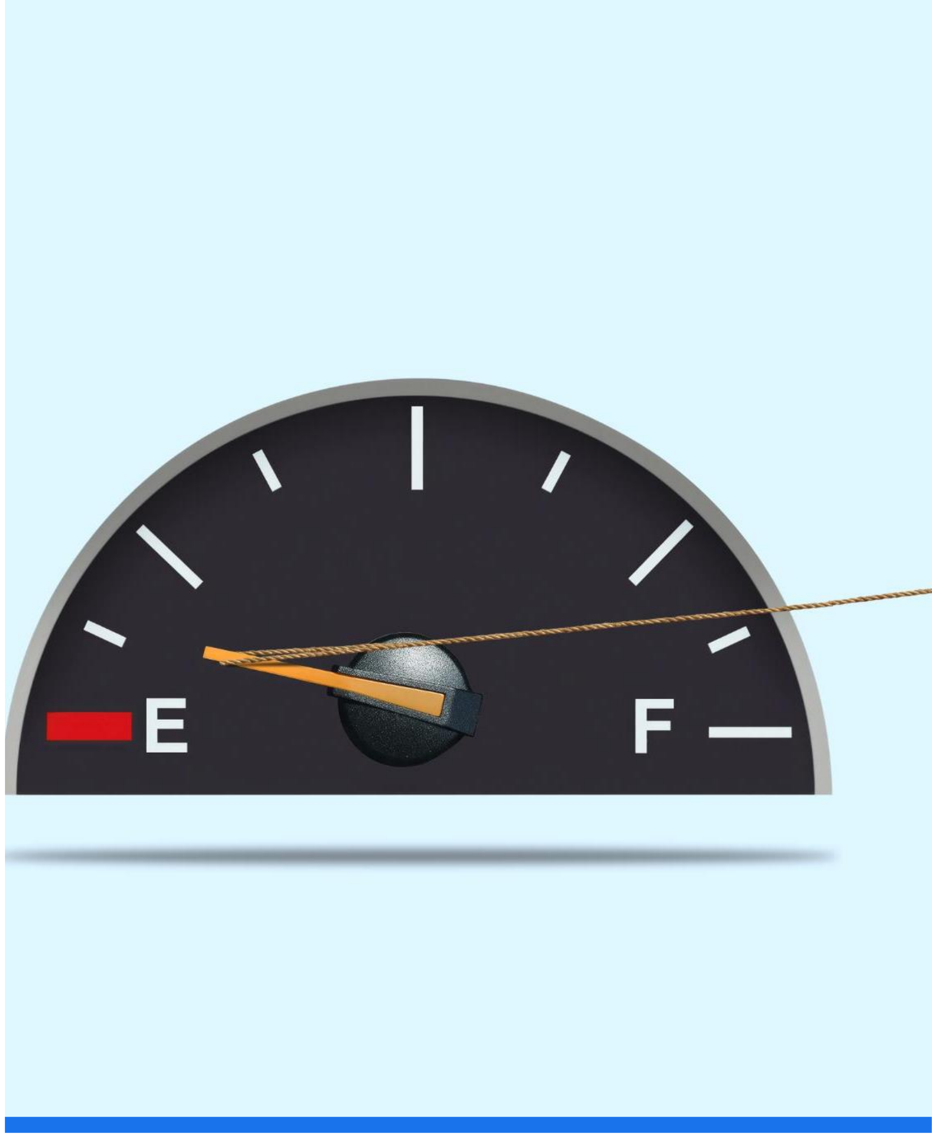
Operators face significant expenses due to necessary repairs, impacting overall financial health.

Downtime Losses

System failures cause downtime, leading to productivity and revenue losses for operators.

Potential Penalties

Failure to maintain reliable systems can result in penalties and regulatory fines for operators.



Safety concerns and regulatory considerations

Safety Hazards from Failures

Failures in processes or systems can create significant safety risks to people and property.

Regulatory Challenges

Failures often result in regulatory scrutiny requiring strict adherence to laws and standards.

Risk Management Importance

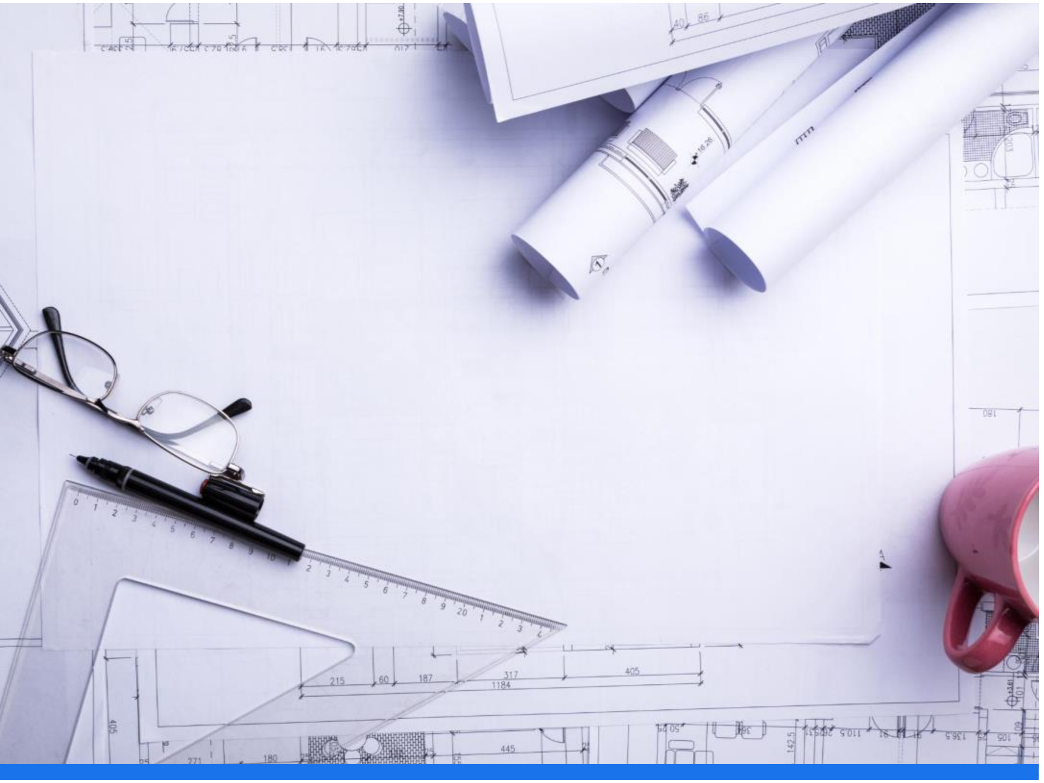
Effective risk management is essential to prevent failures and ensure regulatory compliance.

Recommendations and Best Practices for Failure Prevention (Survey)

Modifications & improvements currently being implemented

- ✓ <u>Foundation Design</u>: Improved materials, secondary support rings, and better thermal accommodation during startup.
- ✓ <u>Structural Enhancements</u>: Thicker floors, reduced tank diameter, minimized structural discontinuities, and improved bottom design.
- ✓ <u>Welding & Residual Stress Management</u>: Enhanced welding processes, alternative filler materials, and stress-reducing construction techniques.
- ✓ <u>Material Improvements</u>: Use of advanced materials, heat treatments, refractory linings, and additive manufacturing.
- ✓ <u>Modeling & Analysis</u>: Better modeling of transient conditions and creep-fatigue analysis (e.g., per ASME standards).
- ✓ <u>General Insight</u>: No universal solution; improvements are project- and context-specific.

Suggestions from the Survey



- ✓ Optimize tank geometry to minimize stress.
- ✓ Enhanced monitoring and predictive maintenance
- ✓ Select materials suited to high temperatures and account for creep and fatigue.
- ✓ Investigate advanced materials and improved weld fillers.
- ✓ Standarisation
- ✓ Monitor welds, temperature distribution, and system conditions in real time
- ✓ Reduce thermal gradients.
- ✓ Use CFD tools and real-world failure data to improve design codes.
- ✓ Share failure case studies to improve industry knowledge.

Conclusion

Key Findings

- Failure modes are recurrent across systems, with tank base cracking, weld failures, and corrosion being the most reported issues.

- Consequences include reduced thermal efficiency, energy losses, and prolonged downtime, directly impacting system performance and economic viability.

Design and Maintenance

- Design and materials matter (e.g., tank geometry, welds).

- Real-time monitoring and predictive maintenance are critical.

Strategic Insights

- No one-size-fits-all: Solutions must be context-specific.

- Sharing failure data benefits the entire industry.