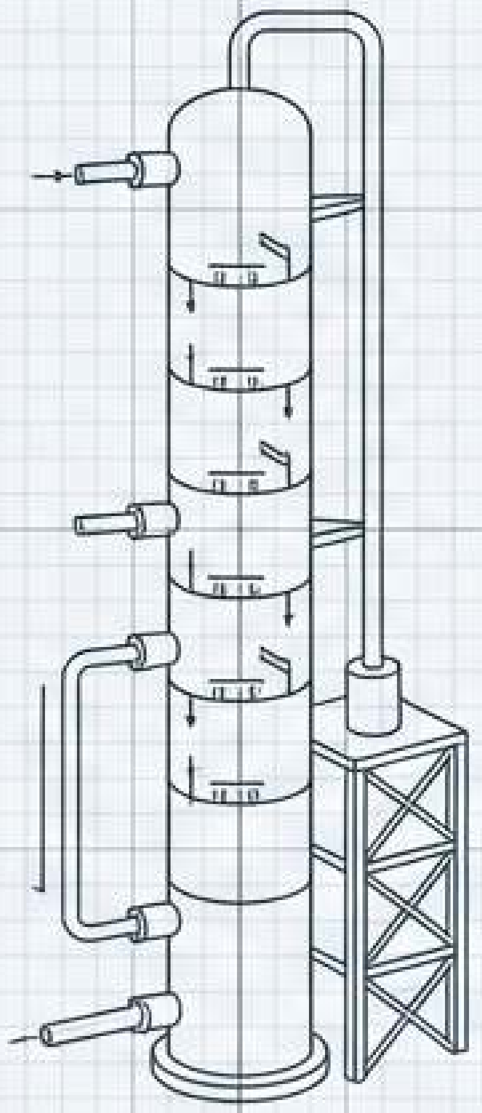
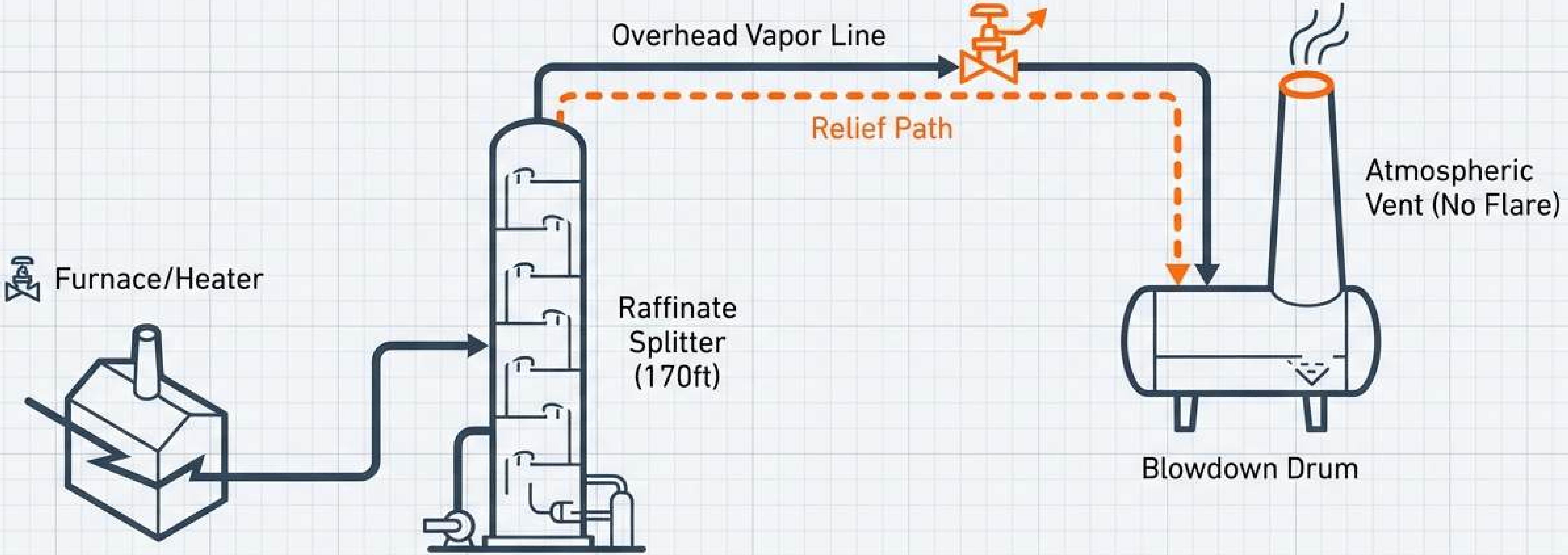
BP Texas City Refinery Explosion (2005)

A system-level examination of startup, detection, and escalation



CASE TYPE: SYSTEMIC FAILURE ANALYSIS
OPERATING CONTEXT: UNIT STARTUP
SOURCE: CSB FINAL REPORT

System Overview: Isomerization Unit and Relief Infrastructure



Core Asset

Raffinate Splitter. A distillation tower designed to separate light and heavy hydrocarbon components.

Energy Source

Furnace and feed pumps supplying heated flammable liquid hydrocarbons.

System Boundary

Blowdown Drum. A gravity-settling vessel vented directly to atmosphere. Not connected to a flare system.

Intended System Function

Functional Requirements

Primary Function:

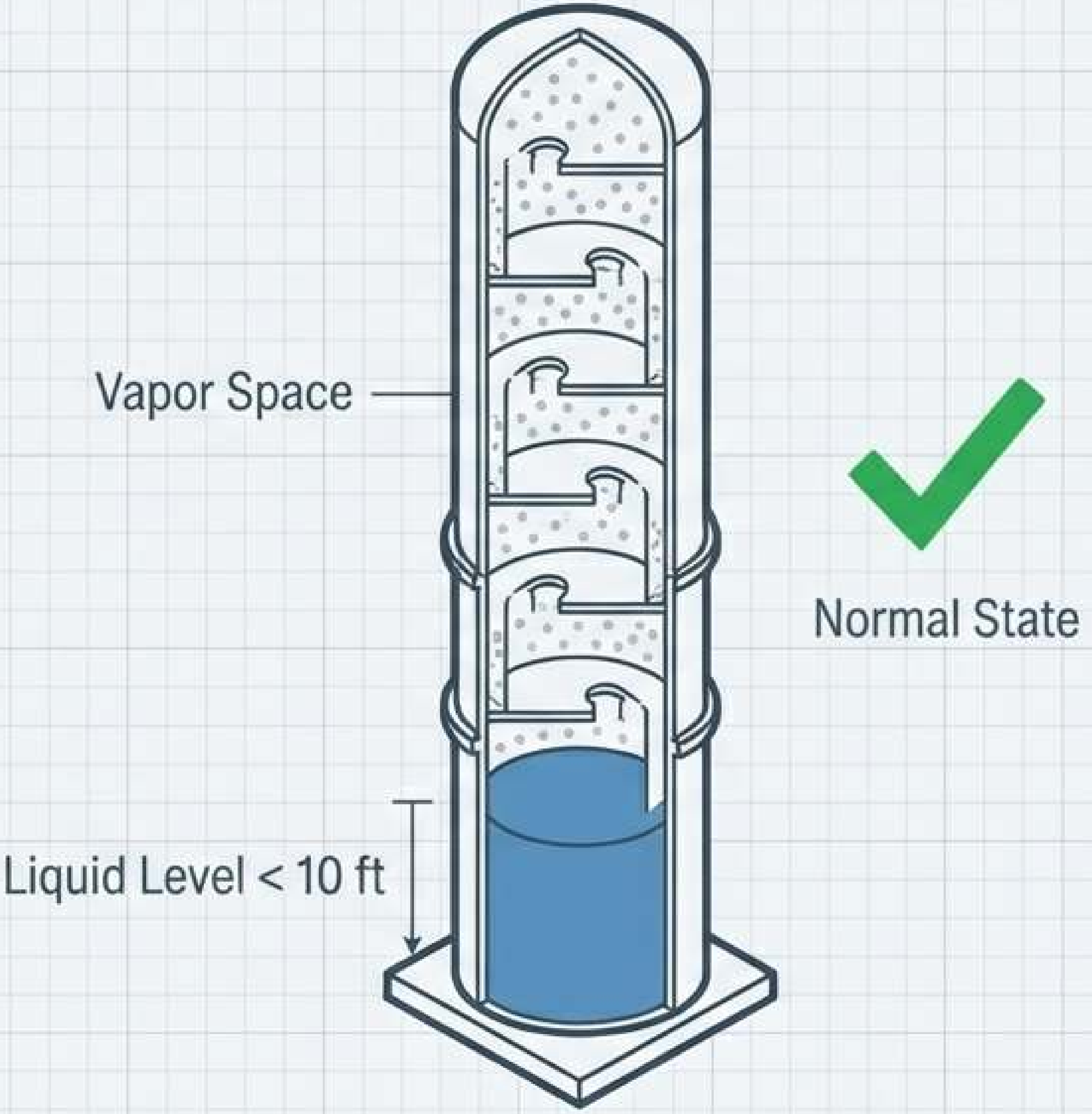
- Separate raffinate feed into light and heavy components via distillation.

Operational Requirements:

- Maintain liquid level within bottom operating range (<10 feet).
- Regulate pressure by venting non-condensable gases.
- Balance feed input with product output (Mass Balance).

Successful Startup Criteria:

- Gradual introduction of feed and heat.
- Continuous verification of visible liquid level.
- Safety relief valves remain closed.



Operating Context: Startup vs. Steady Operation

Steady State Operation

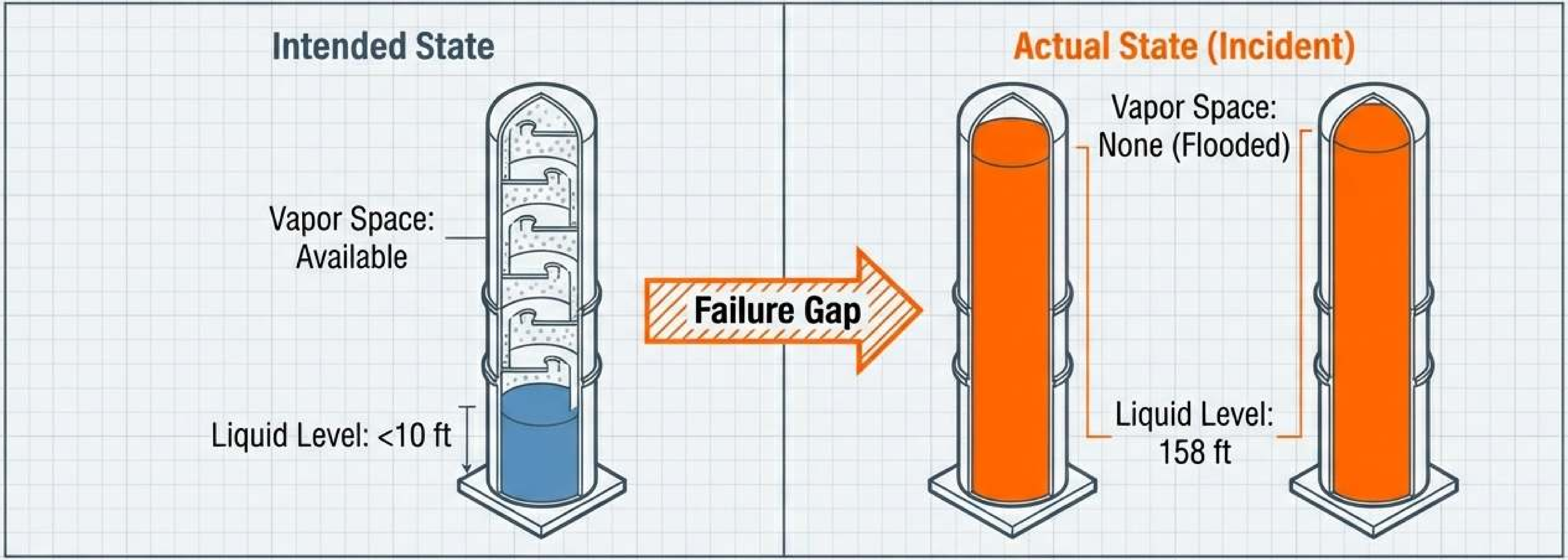
- **Condition:** Stable, Automated
- **Risk Profile:** Linear
- **Data:** Validated and constant
- **Reliance:** Automated Logic Loops

Startup Operation (Transition)

- **Condition:** Transient, Manual
- **Risk Profile:** Pattern F (Infant Mortality Zone)
- **Data:** Rapidly changing variables (Lag)
- **Reliance:** Manual Procedural Checks
- **Instrumentation:** Sensors stressed at range limits

Startup is a fundamentally different operating context where uncertainty is inherently high.

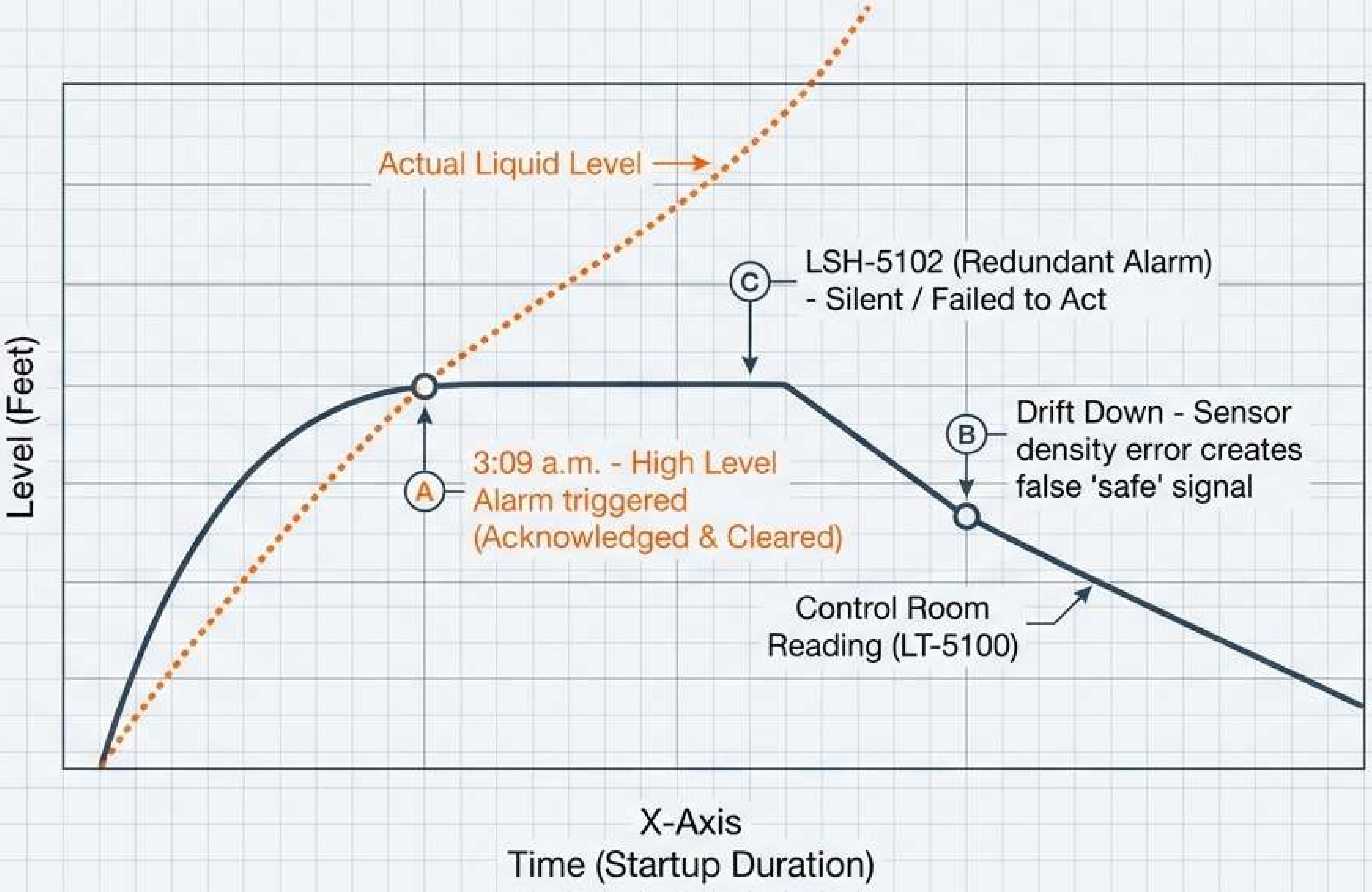
What the System Failed to Do



Functional Failures:

1. **Loss of Inventory Control:** System failed to regulate liquid level (15x normal volume).
2. **Failure of Indication:** System indicated 'safe' level while critical.
3. **Failure of Containment:** Tower and Blowdown Drum could not retain expanding liquid volume.

Warning Signs That Were Present

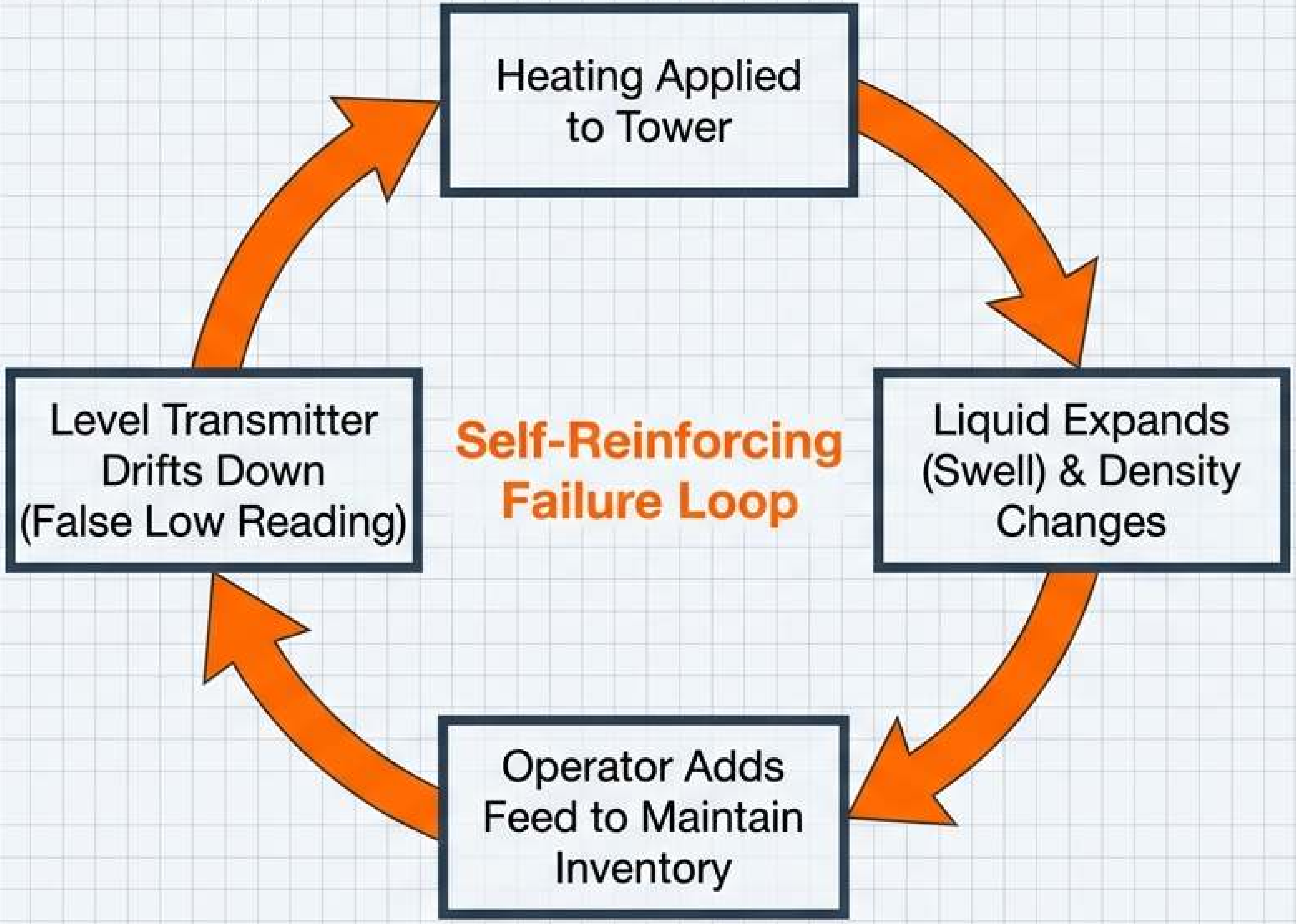


Normalization of Deviance

Prior startups exhibited similar alarms, leading operators to interpret these warnings as routine noise rather than critical state changes.

Plausible Failure Mechanisms

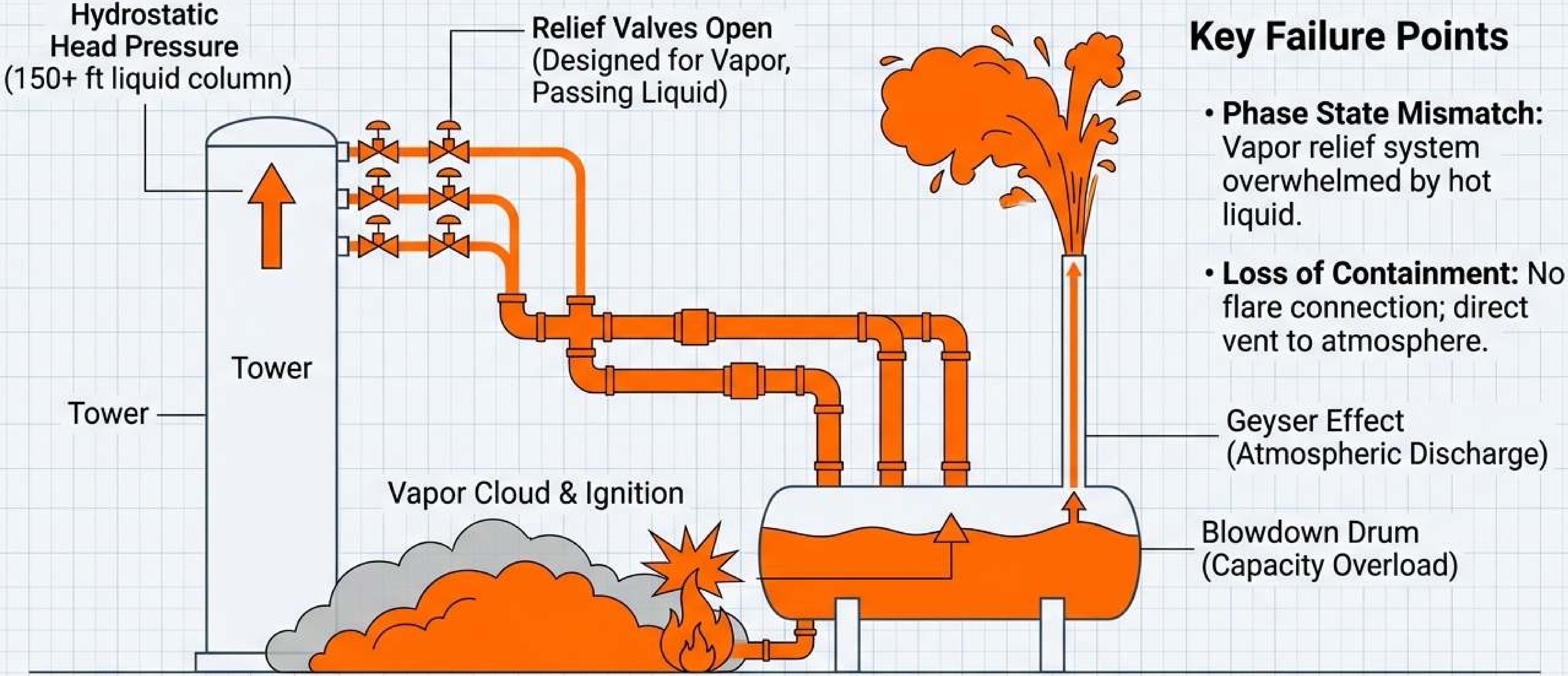
Feedback Loop



Instrumentation Saturation: Displacement sensors cannot distinguish between “100% full” and “Over-full”.

Latent Condition: Redundant alarm (LSH-5102) was mechanically failed before startup began.

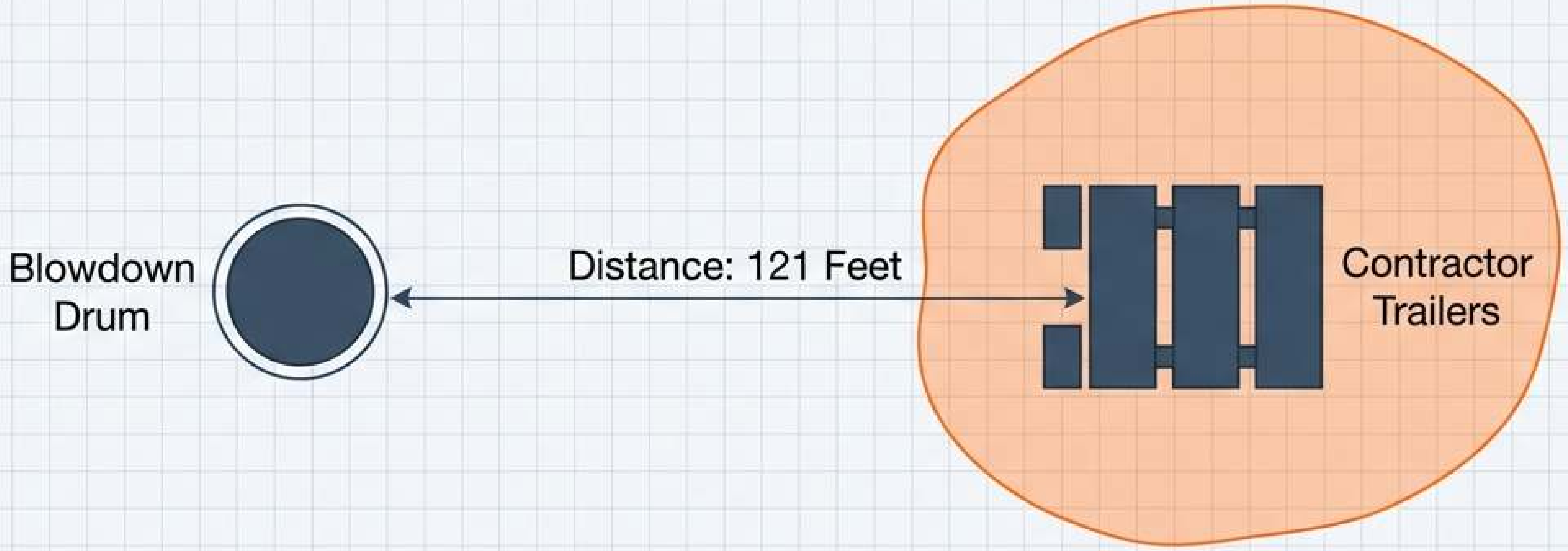
Why the Failure Escalated



Key Failure Points

- **Phase State Mismatch:** Vapor relief system overwhelmed by hot liquid.
- **Loss of Containment:** No flare connection; direct vent to atmosphere.

Consequences



Human Impact:

- 15 Fatalities
- 180 Injuries

Asset & Business Impact:

- Destruction of ISOM unit.
- Significant business interruption and reputational damage.

Siting Factor:

Fatalities concentrated in temporary trailers sited within the hazard zone of the blowdown vent.

Where Earlier Intervention Was Possible

Node 1: Failure Finding

MISSED

Testing of redundant alarm (LSH-5102) prior to startup would have revealed latent failure.

Node 2: Siting Assessment

MISSED

Risk assessment of startup hazards could have precluded trailer placement near the unit.

Node 3: Data Verification

MISSED

Cross-referencing Mass Balance (Feed In vs Product Out) against flatlining level sensor.

Node 4: Stop Work Authority

MISSED

Intervention when instrumentation provided ambiguous or conflicting data.

Transferable Insight

Fragility of Transition

Systems are vulnerable when moving between states. Steady-state protections may be ineffective during startup.

Hidden Failures

Protective devices fail silently. Without rigorous failure finding tasks, reliability is an illusion.

Normalization of Deviance

Accepting nuisance alarms or erratic data as ‘normal’ degrades safety margins to zero.

Validity of Data

A single data point should never override the physics of the process (Mass Balance).

Closing Reflection

Which of our systems are safe in steady operation — but fragile during transition?