Frontera Space Emergency Procedure: Freeze Protection & cold Weather Emergency Operations

Revision: 01

Frontera Space Document: 000012

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1 PURPOSE

The purpose of Document 000012 is to define the required freeze-protection measures, operational limits, and emergency procedures associated with cold-weather conditions at the PTSD (Portable Test Stand by Dan).
This document establishes:

- Mandatory operational pause threshold
- Freeze-prevention steps for fuels, water systems, and FireX suppression
- Contingencies for frozen plumbing and impaired safety systems
- Cold-weather impacts to MMH and MON-3/N_2O_4 oxidizer systems
- Recovery requirements prior to resuming hazardous operations

This standalone procedure ensures safe and reliable hypergolic operations in alignment with Frontera Space safety standards.

2 SCOPE AND APPLICABILITY

This document applies to all operations involving PTSD

All personnel performing or supporting operations during cold-weather conditions are required to comply with the procedures and requirements outlined in this document.

3 OPERATIONAL PAUSE THRESHOLD

Cold-weather conditions introduce significant risks to propellant systems, water systems, FireX suppression, and overall stand safety. To mitigate these risks, PTSD operations must comply with the following freeze-condition thresholds and procedural requirements.

3.1 38°F Operational Pause Threshold

Hazardous operations at the PTSD shall be paused or prohibited based on the following ambient-temperature thresholds:

Pre-Start Rule — 4 Hours

Hazardous operations may not begin if the forecast indicates that ambient temperature will fall below 38°F (3°C) within 4 hours of the planned start of operations.

In-Progress Rule — 2 Hours

If hazardous operations are already underway and updated weather data indicates that temperature will fall below 38°F within 2 hours, then:

- Operations must cease immediately, and
- The stand must be placed in a safed configuration, preserving pressure in systems designed to remain pressurized while isolating flow paths and removing all armed or energized states

A “safed configuration” includes:

- Isolating flow-capable valves
- Terminating any ignition, actuation, or pressurization sequences
- Ensuring purge systems remain operational
- Applying heating if required to protect freeze-sensitive components

No armed, flow-capable, or hazardous configurations may be entered while a 38°F freeze-pause is in effect.

3.2 Heating Activation (<38°F)

When ambient temperature drops below 38°F**,** and both test-stand doors are closed:

- Two 25,000 BTU propane forced-air heaters shall be activated
- The enclosed stand area must be maintained above 40°F to protect valves, plumbing, detectors, and freeze-sensitive hardware

This heating requirement is continuous as long as freeze-pause conditions persist.

3.3 20°F Deionized Water FireX Drain Threshold

If outside temperatures are forecast to fall below 20°F (–6.7°C)**:**

- The 125-gallon deionized-water FireX system must be fully drained
- Compressed air shall be blown through all DI FireX lines and nozzles to eliminate standing water
- Any other water-based or wetted systems not inside a heated enclosure must be verified dry

The full-stand dry FireX system does not require drainage, as it contains no standing water.

This ensures protection against freeze expansion, manifold rupture, and burst lines.

3.4 Risk Rationale

The 38°F and 20°F thresholds are required to mitigate cold-weather risks that can compromise safe operation of the PTSD. These risks include:

- Frozen or partially blocked DI water and washdown plumbing, affecting purge and washdown functions
- Impairment of the FireX suppression system, including delayed or failed activation
- Possibility of burst FireX or water-based lines due to freeze expansion

- Slush formation or viscosity shifts in MON-3/N_2O_4, causing valve stiction, flow restriction, or unstable oxidizer behavior
- Reduced vapor detectability during N_2O_4/NO_2 evolution, as cold temperatures lower vapor pressure and slow leak evolution
- Reduced responsiveness of cold-soaked valves and seals, increasing the likelihood of mechanical malfunction
- Degraded purge performance, especially for DI water or mixed-phase oxidizer residues

Because these risks directly impact safety-critical functions—including shutdown, isolation, suppression, and leak detection—no hazardous operations may proceed or continue during freeze-pause conditions.

4 Water & Plumbing Freeze Protection

Water-bearing systems at the PTSD are susceptible to freeze-induced blockage, loss of function, and mechanical damage under cold-weather conditions. The following requirements provide the necessary controls to prevent frozen plumbing, protect FireX and purge capabilities, and ensure system readiness prior to hazardous operations.

4.1 Draining Requirement

Any water system not housed within a heated or temperature-controlled vessel must be fully drained prior to expected freezing conditions.
The following systems shall be drained:

- DI purge-water lines
- Washdown manifolds
- FireX suppression loops
- Any external or exposed plumbing not temperature-controlled

Draining shall be performed early enough to allow full line evacuation and compressed-air clearing when required.

5 Cold-Weather Impacts: MMH & N_2O_4

5.1 MMH Behavior in Cold Weather

MMH will not freeze under PTSD conditions (freezing point ≈ –52°C / –61°F).

5.2 N_2O_4 / MON-3 Freezing Behavior

MON-3/N_2O_4 can enter a solid-crystal phase near **12–14°F (–10 to –11°C)** depending on composition.

Freezing or partial freezing may cause:

- Slush or solid formation in lines and manifolds
- Blocked or restricted oxidizer flow
- Valve obstruction or non-closure
- Unexpected pressure behavior during pressurization
- Sudden downstream surges when crystals melt or shift
- Degraded NO_2 detector responsiveness due to reduced vapor formation

5.3 Required MON-3/N_2O_4 Freeze Contingencies

If ambient temperatures approach freezing(12-14°F):

1. Review MON-3 tank and line temperatures
2. Ensure Heat systems (Two 25,000 BTU propane forced-air heaters) remain active
3. Monitor pressure behavior for signs of partial crystallization

If MON-3 freezing is suspected:

- Immediately stop all oxidizer activities
- Do not attempt pressurization
- Maintain system warming until stable temperatures >40°F are achieved for ≥2 hours
- Perform full system cycling checks prior to restarting operations

6 FIREX SYSTEM FREEZE PLANNING

6.1 Freeze-Risk Factors

The FireX system contains water-based suppression and is susceptible to:

- Ice blockages
- Burst manifolds
- Nozzle obstruction
- Pump cavitation
- Delayed or failed suppression activation

6.2 Prevention Steps

- Maintain FireX tank temperatures above 40°F
- Activate heat Systems below 38°F
- Drain Deionized water system below 20°F
- Ensure Full Stand FireX remains dry and active(Standard operatin

FireX suppression must be fully functional before hazardous operations can resume.

7 Cold-Weather Operational Risks

Cold weather may produce:

7.1 System Performance Risks

- Valve stalls or misalignment
- Reduced detector sensitivity
- Slower purge sequencing
- Misleading pressure readings
- Hard-start conditions for MON-3-fed ignition

7.2 Safety System Risks

- FireX system inoperability
- Frozen DI purge lines
- Inability to execute emergency washdown
- Limited ability to decontaminate wetted hardware
- Reduced effectiveness of vapor suppression

7.3 Operational Readiness Constraints

Operations cannot continue until:

- All water systems are thawed and verified leak-free
- FireX systems are proven operational
- MMH and MON-3 subsystems complete cold-weather cycling checks
- Detectors operate at correct temperatures
- Pressurization and purge systems pass readiness testing

The Test Director must formally authorize the return to operations.

8 Post-Freeze Recovery Procedures

8.1 Controlled Warm-Up

- Gradually warm all lines, tanks, and manifolds
- Maintain heat system activation until verification is complete

8.2 Water & FireX Restoration

- Conduct full functional flow test and pressurized leak check of Deionized water plumbing.

- DeIonized Water System is filled above safety minimum
- Verify pressurized head pressure
- Confirm all nozzles, manifolds, and valves are unobstructed

9.3 Propellant System Verification

- Exercise MMH and MON-3 valves
- Validate detector responsiveness
- Reconfirm pressure stability
- Validate purge system performance

9.4 Return-to-Operations Authorization

Only the **Test Director** may clear PTSD for restart after:

- All freeze effects are resolved
- All systems are operational
- FireX system is fully restored

9 POST-FREEZE RECOVERY PROCEDURES

Documentation Requirements

Following any freeze event or freeze-pause:

- Complete freeze-event report
- Document system impairments
- Record corrective actions
- Update training logs
- Perform equipment inspection entries

System failures or near-misses must be logged and included in continuous-improvement reviews.

10 PROGRAM MAINTENANCE

Frontera Space Document 000012 shall be:

- Reviewed annually
- Updated after any freeze-induced impairment
- Revised when systems or processes change
- Incorporated into periodic safety drills and readiness checks