Test Report - VxScan Cold Storage

Pius Wong Sep 16, 2024

Purpose & Background

VotingWorks sought data on if VxScan v4.0 Build 0 could withstand cold storage testing without damage. The cold storage test is meant to simulate the high-fidelity test described in **VVSG 2.7-F: Ability to support storage temperatures in physical environment – non-operating**, which cites test standard MIL-STD-810H, Method 502.7, Procedure I-Storage. This test requires storage at -4°F (-20°C) for 72 hours past temperature stabilization, at humidity between 25-55%RH. Failures to watch out for in particular include general functional failures, material or structural failures due to brittleness and changes in geometry, and problems with electronic components.

The following components of VxScan v4.0 in particular were of interest, because their specifications did not explicitly indicate they could withstand temperatures down to -4°F:

- Thermal printer mechanism
- Solid state drive
- Card reader board
- USB drive (recommended brand of Samsung Bar 64GB)

Failures in those components could result in loss of essential functions: printing reports, saving data, logging into the machine, etc. Other components were deemed lower risk of failing due to cold, based on their specifications. This includes the ballot box bag material, tested previously.

Also, in a previous cold storage test of VxScan v3.1, the MCM resisted most cold damage, but it then showed faulty multi-sheet detection (MSD) behavior following cold storage. VxScan v4.0 uses a different scanner compared to v3.1; the scanner is from PDI and is rated for colder storage than VVSG 2.7-F, so this test can help confirm that it will perform better in cold storage.

A VxScan v4.0 unit was available for testing (Build 0 Unit 3) that was previously used for benchtop drop testing, with loose bolts reattached and retightened. It was checked for normal function, underwent a version of the VVSG 2.7-F cold storage test, and rechecked for normal function after storage.

Materials

1. Freezer

a. Insignia 14 cu. ft. garage-ready chest freezer - Available at VxAustin as of Jun 17, 2024, rated for temperatures down to -11°F.

2. Thermometer-hygrometer

a. Govee thermometer-hygrometer H5705 - Available at VxAustin as of Jun 17, 2024. Works with associated Govee app for bluetooth data collection.
   i. Ensure it has sufficient battery power. Replace the AAA batteries if needed.
   ii. Optionally it can be coupled with the Govee smart space heater to act as a "distributed gateway" for the device, to allow monitoring over wifi remotely. This smart heater is already configured with the VxAustin network as of Jan 1, 2024, and linked to the Govee app in Pius Wong's account. When logged into the app, thermometer data can be monitored remotely.
   iii. An alternative in the future may be a wifi-connected similar device from the same brand. That way it can be monitored out of bluetooth range without the Govee space heater.

b. Analog freezer thermometer - Available at VxAustin as of Jun 17, 2024. Rated for -20°F to 80°F. Backup to digital thermometer.

3. Test unit, testing tools, and documentation tools

a. MCM

    i. Imaged for UAT test ballots using this image: 2024-08-19-uat-rc2-vxscan.img.lz4
b. Printout of normal function checklists, along with associated tools, including:
    i. Appropriate ballots, using UAT test ballots
    ii. Allen wrenches, tools for testing fastener security
    iii. Light, camera

Procedures

Specific steps were as follows, only for testing the MCM, and not the ballot box nor UPS:

1. Check the unit for normal function before freezing.

a. Follow tests of normal function to confirm the test unit functions normally before any disruptive tests.
b. Document tests of normal function. Record any pre-existing problems. Use the pre-existing template.
c. For long-term tracking of units, record the life cycle history of the unit.

2. Prepare the freezer for testing.

a. Plan for at least 72 hours uninterrupted test time in the freezer past the initial stabilization time.
b. Ensure there is no excess moisture/humidity inside the freezer. Let it air out if needed.
c. Place protective material at the bottom of the freezer.
    i. Thick corrugated cardboard is available at VxAustin. Pile it up to protect both the freezer internal surface and the test unit. You can also pile enough to align the test unit horizontally if desired.

3. Prepare the test unit.

a. Put the test unit into storage configuration.
    i. For the MCM, that meant closed.
    ii. This unit did not have the rear power cord holder, and also past cold tests of v3.1 saw no issues with the power cord, and so the cord was not included in this test.

4. Freeze the test unit.

a. Place the test unit in the freezer.

b. Place the thermometer-hygrometer and backup thermometer in the freezer.
c. Close the freezer, ensuring it is sealed.
d. Add a note to the freezer to prevent people opening it up and introducing temperature and humidity changes.
e. Plug the freezer in and turn it on, aiming for a setpoint of -4°F.
    i. Note time of turning on.
    ii. Check the temperature without opening the freezer, if possible, to avoid introducing more humidity/condensation.
        1. Use the Govee app using the Govee thermometer.
    iii. If possible, aim for a humidity of 25-55% relative humidity (RH).
        1. This isn't possible for the Insignia freezer at VxAustin. Instead the humidity was read for the duration of the test.
        2. If this is possible, then cycle the humidity over 24 hours, changing every 12 hours from 25% to 55%.
f. Prepare to track internal freezer temperature after this time to see when temperature is stabilized down to -4°F.
    i. Note time of temperature stabilization.
    ii. Add 72 hours (3 full days) to this time of stabilization; plan to turn off the freezer at this future date and time.
g. Let the freezer sit until at least 72 hours have passed since stabilization.

5. Let the test unit naturally come back to room temperature and normal humidity.

a. At the end of the test period, turn down the freezer setting and unplug the freezer. Note the time of unplugging.
b. Leave the freezer closed; do not open until either the inside has come back up to room temperature (60-80°F), or 24 hours has passed.
    i. This is important to prevent condensation formation on or in the test unit.
c. Open the freezer and take out the unit.
d. Let the test unit sit outside to equilibrate for at least another hour.

6. Check the unit for normal function after freezing.

a. Follow tests of normal function to confirm the test unit still functions normally
b. Document tests of normal function. Note if any functions have changed. Use the pre-existing template.
c. For long-term tracking of units, record the life cycle history of the unit.

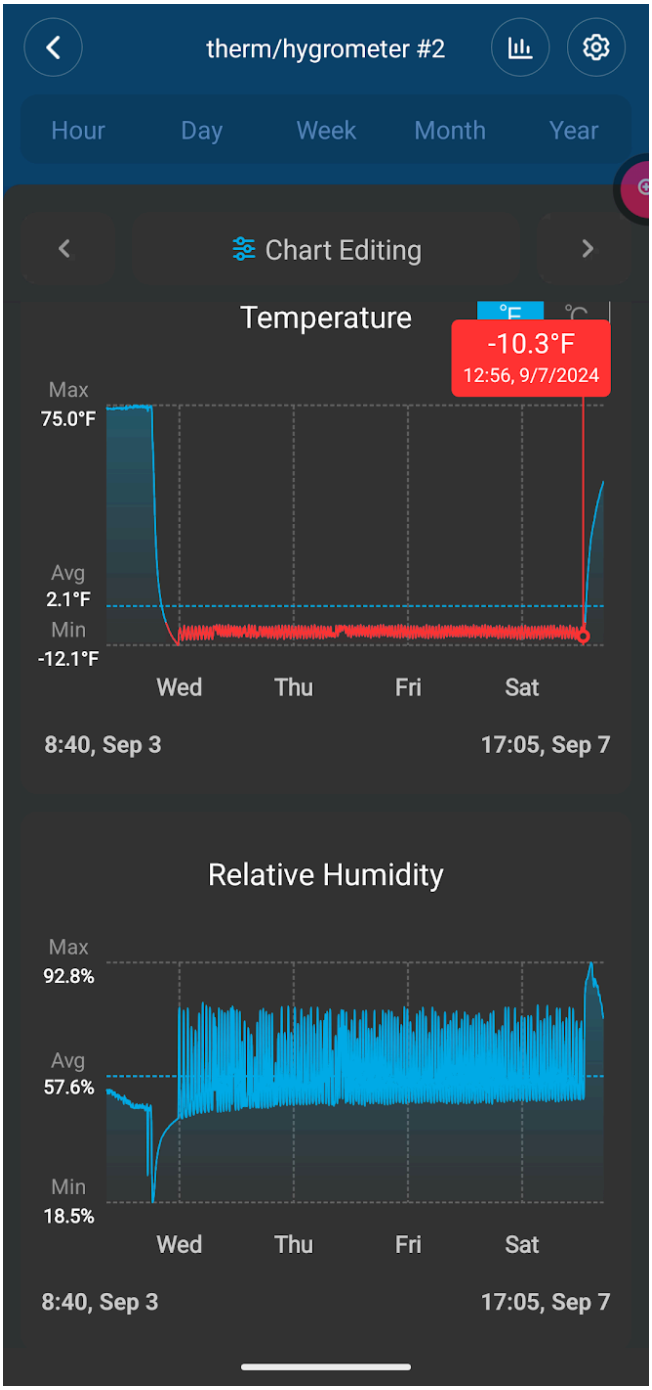
Results

1. Normal function was confirmed before freezing.

a. These tests were performed right after fixing loose components from drop tests on Sep 3, 2024.
b. Both hand-marked and machine-marked ballots were used for testing, taken from real voter-users from previous User Acceptant Testing (UAT) official tests. Scans of the 12 ballots (double-sided) are shown in this file:
ballots-vxscan-testsnormalfunction-sep2024.pdf
c. All essential functions showed no problems.
d. The rear power cord holder feature was not a part of this unit, as noted in previous drop tests.

2. The unit was held at -10 to -5°F for about 92 hours undisturbed.

a. The MCM was placed in the freezer, and the freezer was turned on from room temperature on Tuesday, Sep 3, 2024 at about 5pm. It reached below -4°F at approximately 9PM that night.
b. The freezer was closed and undisturbed over the next 4 days. Internal freezer temperature was monitored remotely and stayed between -10°F to -5°F. Humidity fluctuated between 46-80%RH throughout this time.
c. The freezer was turned off on Saturday, Sep 7, 2024, at about 1pm and remained closed. This corresponds to holding the unit between -10°F to -5°F for about 92 hours. This is longer than the VVSG requirements of holding at -4°F for 72 hours. An image of the temperature and humidity data collected during freezing is shown below:



d. The test unit was removed for analysis on Sep 9, 2024, after it had stabilized back up to ambient room temperature.

3. The unit retained normal function after freezing.

a. On Sep 9, 2024 the unit was analyzed for normal function again using the same ballots as before freezing and the same procedures.

b. All tested functions were normal and appeared to be the same as before freezing.
c. Ambient atmospheric humidity was about 40-50% in the test lab throughout testing both before and after freezing.

4. External structures appeared to be unaffected by freezing.
    a. Without opening it up, no problems were observed after freezing. See photos below for general appearance after freezing:

    b. All visible structures appeared to be the same as before freezing. The unit was not opened up for internal inspection because it had normal function.

Conclusions

1. VxScan v4.0 Build 0 should withstand cold storage test VVSG 2.7-F.

    Freezing appears not to affect any major functions in the MCM. The electronic components, flexible and polymeric materials, and other structures all appeared to function properly and were intact after freezing colder than -4°F and longer than 72 hours. Although humidity was not controlled tightly to 25-55%RH as in VVSG 2.7-F, the humidity still varied at higher humidity levels of 46-80%RH. This test likely was slightly more intense than VVSG 2.7-F cold storage test protocols, and so the unit should withstand the VVSG 2.7-F protocol.

    Notably, multi-sheet detection (MSD) worked without any problems before and after cold storage. This is in contrast to the VxScan v3.1 MCM that uses a Custom-brand scanner.

The PDI scanner does appear to be unaffected by cold storage, as suggested in its specification document.

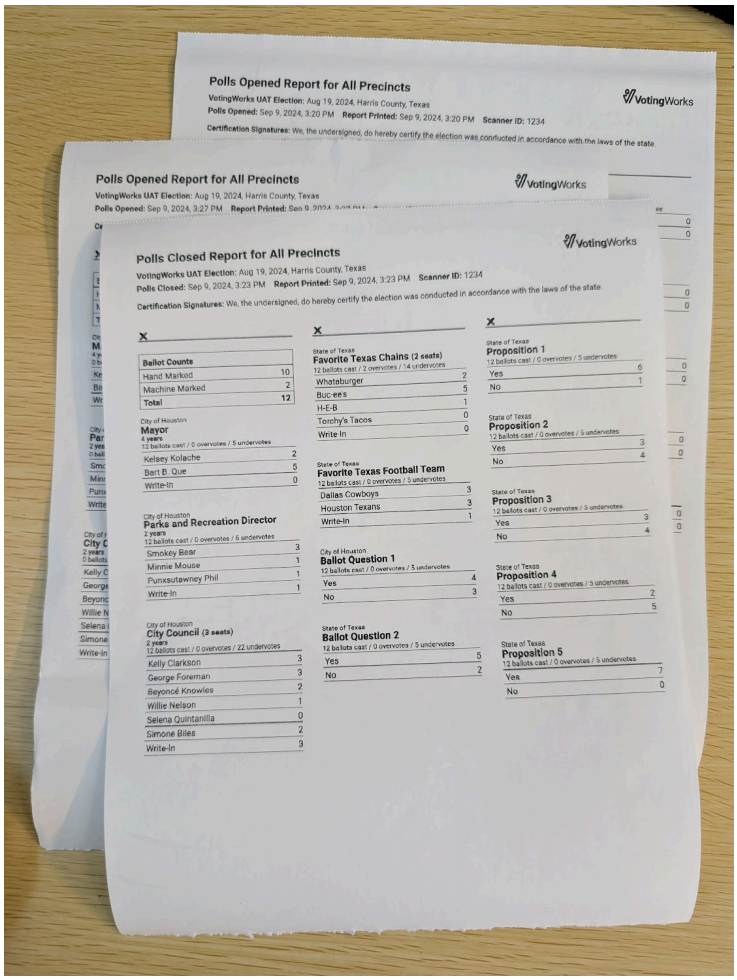
2. Specific MCM components of interest appear to have less risk to cold storage than previously thought.

The following key MCM components particularly were observed after freezing due to their storage specifications (or lack thereof), as noted earlier:

- Thermal printer mechanism
- Solid state drive
- Card reader board
- USB stick (recommended brand of Samsung Bar 64GB)

None of these components exhibited evidence of failure.

The thermal printer mechanism functioned properly as before freezing, with good print quality. The printer mechanism had no jams and no observable anomalies. A photo of example prints are shown below:



There were no signs of solid state drive failures. The software functioned as before freezing with no observable changes in speed, touchscreen responsiveness, audio, or data storage functions. No errors occurred in the software.

The card reader functioned normally, where all three access level smart cards worked as normal for essential tested functions. This suggests the card reader board did not change functionally.

The USB stick appeared to have no problems. CVRs were saved on the Samsung drive as expected.

Finally, other structures and materials of concern did not show any signs of damage in this test. There were no observed cracks, loosening, seizing, or other undesired characteristics in the flexible or polymeric materials that are accessible without opening up system panels. Although it is possible some changes or degradation could have happened to the unit, it was not detectable, and the unit would have to be analyzed in more depth to find these changes.