Kismet Hybrid Rocket Engine
Static Fire 5

Static Fire Test Operations Procedures

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Static Fire Test Operations Procedures

Contents

This document contains two procedures:

- The *Fill System Check* procedure comprises steps for validating the integrity of the system plumbing and correct operation of the test data acquisition system, using carbon dioxide.
- The *Static Fire Test* comprises steps for operating the fill system and conducting a static fire test of the engine.

Personnel Required

The test operations team consists of nine personnel:

1 ☐ The **Operations Director [OPS]** directs operations procedures and communicates with the other test personnel.

2 ☐ The **Primary Fill Operator [PRIMARY]** operates all manual valves for the fill system.

3 ☐ The **Secondary Fill Operator [SECONDARY]** is the backup for **PRIMARY**, and communicates with OPS. If **PRIMARY** becomes incapacitated, **SECONDARY** is responsible for removing them from danger.

4 ☐ The **DAQ Technician [DAQ]** monitors and operates the test data acquisition system.

5 ☐ the **Control System Operator [CONTROL]** operates the test control system, including actuation of remote valves and engine ignition.

6 ☐ **Perimeter Guard 1 [P1]**, **Perimeter Guard 2 [P2]**, **Perimeter Guard 3 [P3]**, and **Perimeter Guard 4 [P4]** ensure that no unauthorized personnel enter the testing area during test operations.

Sign-Off

To be completed by all test personnel after reading and familiarization with procedures

1 ☐ **Operations Director [OPS]** _____ _____

2 ☐ **Primary Fill Operator [PRIMARY]** _____ _____

3 ☐ **Secondary Fill Operator [SECONDARY]** _____ _____

4 ☐ **DAQ Technician [DAQ]** _____ _____

5 ☐ **Control System Operator [CONTROL]** _____ _____

6 ☐ **Perimeter Guard 1 [P1]** _____ _____

7 ☐ **Perimeter Guard 2 [P2]** _____ _____

8 ☐ **Perimeter Guard 3 [P3]** _____ _____

9 ☐ **Perimeter Guard 4 [P4]** _____ _____

Prior to Start

- ☐ Ensure that the following procedures are complete:
  - ☐ Combustion Chamber Assembly procedure
  - ☐ Oxidizer Tank Assembly procedure
  - ☐ Plumbing Setup procedure
  - ☐ Oxidizer Tank Stand Setup procedure
  - ☐ Tank Heating Setup procedure
  - ☐ Test Stand Setup procedure
  - ☐ Data Acquisition Setup procedure
  - ☐ Test Control System Setup procedure
  - ☐ Perimeter Checks procedure
- ☐ Ensure that all personnel as defined above are available and have completed the sign-off.
- ☐ Ensure that the following personnel have walkie-talkies and communication is functional:
  - ☐ **OPS**
  - ☐ **SECONDARY**
  - ☐ **DAQ**
  - ☐ **P1**
  - ☐ **P2**
  - ☐ **P3**
  - ☐ **P4**
- ☐ Ensure that all spectators and test personnel are wearing safety glasses and hearing protection.
- ☐ Ensure that **PRIMARY** and **SECONDARY** are wearing face shields and have no exposed skin.
- ☐ Ensure that **PRIMARY** is wearing thermal gloves.
- ☐ Ensure that **PRIMARY** is in possession of the supply cylinder gasket.
- ☐ Ensure that **SECONDARY** is in possession of a multimeter.
- ☐ Ensure that **OPS** is in possession of the system control key.

Fill System Check Procedure

- ☐ **SECONDARY**: Confirm that the ignition wires are not connected to the engine.
- ☐ **CONTROL**: Actuate the Tank Heating Valve in order to test the tank heating system.
- ☐ **DAQ**: Confirm that the water temperature is increasing.
- ☐ **CONTROL**: Close the Tank Heating Valve.
- ☐ **PRIMARY**: Open the Tank Heating Drain Valve.
- ☐ **PRIMARY**: Confirm that the following valves are initially closed:
  - ☐ Cylinder Valve (SC-1)
  - ☐ Remote Fill Valve (MV-1)
  - ☐ Parallel Fill Valve (BA-2)

- ☐ Tank Vent Valve (MV-2)
- ☐ Line Vent Valve (BA-3)
- ☐ Injector Valve (IJ-1)

☐ **PRIMARY**: Confirm that the following valves are initially open:

- ☐ Series Fill Valve (BA-1)

☐ **OPS**: Confirm that ops is in possession of the system control key.

☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric.

☐ **DAQ**: Confirm that all load cells are reading the determined zero point.

☐ **P1**, **P2**, **P3**, **P4**: Close the perimeter and do not allow any further personnel to enter the testing area.

☐ **SECONDARY**: Confirm that no personnel are in the testing area other than **PRIMARY** and **SECONDARY**.

☐ **PRIMARY**: Remove all covers from the plumbing:

- ☐ Tank Vent Valve
- ☐ Pressure Relief Valve
- ☐ Line Vent Valve

☐ **PRIMARY**: Remove the cap from the carbon dioxide supply cylinder.

☐ **PRIMARY**: Connect the fill line to the supply cylinder with the gasket, hand tighten, and then tighten with a wrench. Do not force a connection.

☐ **PRIMARY**: Slowly open the Cylinder Valve (SC-1) through $\frac{3}{4}$ of a turn.

- If leaks are observed:
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **PRIMARY**: Slowly open the Line Vent Valve (BA-3).
  - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve (BA-2).
  - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
  - ☐ **OPS**: Abort test procedures and revisit the plumbing setup.

☐ **PRIMARY**: Communicate the supply cylinder pressure as visible on the Pressure Gauge.

☐ **DAQ**: Communicate the supply cylinder pressure as read by the Fill Pressure Transducer.

☐ **DAQ**: Confirm that the two measurements are in agreement.

☐ **OPS**: Give the system control key to **CONTROL**.

☐ **CONTROL**: Engage the key switch and power on the control boxes.

☐ **CONTROL**: Open the Tank Vent Valve (MV-2).

☐ **CONTROL**: Open the Remote Fill Valve (MV-1).

- If leaks are observed:
  - ☐ **CONTROL**: Close the Remote Fill Valve (MV-1).
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **PRIMARY**: Slowly open the Line Vent Valve (BA-3).
  - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve (BA-2).

- ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).
- ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
- ☐ **OPS**: Abort test procedures and revisit the plumbing setup.

- If the Remote Fill Valve fails to open:
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **PRIMARY**: Slowly open the Line Vent Valve (BA-3).
  - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve (BA-2).
  - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
  - ☐ **OPS**: Abort test procedures and revisit the plumbing setup.

☐ **DAQ**: Confirm that the oxidizer tank mass is increasing.

☐ **DAQ**: Confirm that the oxidizer tank pressure is increasing.

☐ **CONTROL**: Close the Remote Fill Valve (MV-1).

☐ **PRIMARY**: Open the Line Vent Valve (BA-3).

☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.

☐ **PRIMARY**: Close the Cylinder Valve (SC-1).

☐ **CONTROL**: Open the Remote Fill Valve (MV-1).

☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.

☐ **PRIMARY**: Disconnect the fill line from the supply cylinder.

☐ **PRIMARY**: Replace the cap on the carbon dioxide supply cylinder.

☐ **OPS**: Wait for at least 3 minutes before proceeding.

☐ **P1**, **P2**, **P3**, **P4**: Open the perimeter.

☐ **OPS**: Proceed with final setup for the Static Fire Test procedure.

Prior to Static Fire Test

- ☐ Confirm that the nozzle is filled with water and not leaking.
- ☐ Confirm that there are no fire hazards within the testing area.
- ☐ Confirm that the cameras are set up at the correct locations.

Static Fire Test - Remote Control Procedure

- ☐ **SECONDARY**: Confirm that the ignition wires are not connected to the engine.
- ☐ **PRIMARY**: Confirm that the following valves are initially closed:
  - ☐ Cylinder Valve (SC-1)
  - ☐ Remote Fill Valve (MV-1)
  - ☐ Parallel Fill Valve (BA-2)
  - ☐ Tank Vent Valve (MV-2)
  - ☐ Line Vent Valve (BA-3)
  - ☐ Injector Valve (IJ-1)
- ☐ **PRIMARY**: Confirm that the following valves are initially open:
  - ☐ Series Fill Valve (BA-1)
- ☐ **OPS**: Ensure that ops is in possession of the system control key.
- ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- ☐ **DAQ**: Confirm that all thermistors are reading ambient temperature.
- ☐ **PAUSE POINT**
- ☐ **P1**, **P2**, **P3**, **P4**: Close the perimeter and do not allow any further personnel to enter the testing area.
- ☐ **SECONDARY**: Confirm that there are no personnel present in the testing area other than **PRIMARY** and **SECONDARY**.
- ☐ **PRIMARY**: Remove all covers from the plumbing:
  - ☐ Tank Vent Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Nozzle
- ☐ **PRIMARY**: Turn on the air compressor by adjusting the regulator to maximum.
- ☐ **PRIMARY**: Confirm that the pressure gauge on the air compressor is reading approximately 85 psi.
- ☐ **PRIMARY**: Pressurize the Injector Valve.
- ☐ **DAQ**: Confirm that the pressure switch for the Injector Valve is reading 0V.
- ☐ **SECONDARY**: Confirm that the resistance across the ignition coils is between 2.5 Ω and 3 Ω:
  - ☐ Primary ignition coil
  - ☐ Secondary ignition coil

- ☐ **SECONDARY**: Connect the ignition connectors to the RLCS ignition cable.
- ☐ **PRIMARY**: Remove the cap from the nitrous oxide supply cylinder.
- ☐ **PRIMARY**: Connect the fill line to the supply cylinder with the gasket, hand tighten, and then tighten with a wrench. Do not force the connection.
- ☐ **PRIMARY**: Slowly open the supply cylinder through $\frac{3}{4}$ of a turn.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
    - ☐ **PRIMARY**: Slowly open the Line Vent Valve (BA-3).
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve (BA-2).
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **SECONDARY**: Disconnect the ignition connectors from the RLCS ignition cable.
    - ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
    - ☐ **OPS**: Abort test procedures and revisit the plumbing setup.
- ☐ **PRIMARY**: Communicate the supply cylinder pressure as visible on the Pressure Gauge.
- ☐ **DAQ**: Communicate the supply cylinder pressure as read by the Fill Pressure Transducer.
- ☐ **DAQ**: Confirm that the two pressure measurements are in agreement.
- ☐ **PRIMARY**: Turn on the camera.
- ☐ **PRIMARY** and **SECONDARY**: Retreat to the mission control area.
- ☐ **CONTROL**: Confirm that all actuator controls are in the "off" position:
  - ☐ Remote Fill Valve (MV-1)
  - ☐ Tank Vent Valve (MV-2)
  - ☐ Injector Valve (IJ-1)
  - ☐ Primary Ignition
  - ☐ Secondary Ignition
- ☐ **PAUSE POINT**
- ☐ **OPS**: Poll the following personnel for GO/NO GO status:
  - ☐ **P1**
  - ☐ **P2**
  - ☐ **P3**
  - ☐ **P4**
  - ☐ **DAQ**
  - ☐ **CONTROL**
  - ☐ **PRIMARY**
  - ☐ **SECONDARY**
- ☐ **OPS**: Give the system control key to **CONTROL**.
- ☐ **CONTROL**: Engage the key switch and power on the control boxes.
- ☐ **CONTROL**: Open the Tank Vent Valve (MV-2).
- ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).

- If leaks are observed:
  - ☐ **CONTROL**: Close the Remote Fill Valve (MV-1).
  - ☐ **PRIMARY**: Open the Line Vent Valve (BA-3) using the ropes.
  - ☐ **OPS**: Proceed only when the oxidizer tank has fully vented.
  - ☐ **PRIMARY**: and **SECONDARY**: Approach the test plumbing.
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).
  - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
  - ☐ **SECONDARY**: Disconnect the ignition connectors from the RLCS ignition cable.
  - ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
  - ☐ **OPS**: Abort test procedures and revisit plumbing setup.
- If the Remote Fill Valve fails to open:
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **PRIMARY**: Slowly open the Line Vent Valve (BA-3).
  - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve (BA-2).
  - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
  - ☐ **SECONDARY**: Disconnect the ignition connectors from the RLCS ignition cable.
  - ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
  - ☐ **OPS**: Abort test procedures and revisit the control system setup.

☐ **OPS**: Proceed only when a white plume is visible from the Tank Vent Valve (MV-2).

☐ **CONTROL**: Close the Tank Vent Valve (MV-2).

☐ **CONTROL**: Close the Remote Fill Valve (MV-1).

- If the Remote Fill Valve fails to close:
  - ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
  - ☐ **PRIMARY**: Close the Series Fill Valve (BA-1).
  - ☐ **PRIMARY** and **SECONDARY**: Retreat to the mission control area.

☐ **CONTROL**: Open the Tank Heating Valve.

☐ **DAQ**: Proceed only when the oxidizer tank pressure is at least 750 psi.

- If the oxidizer tank pressure does not reach 750 psi:
  - ☐ **CONTROL**: Close the Tank Heating Valve.
  - ☐ **PRIMARY**: Open the Line Vent Valve (BA-3) using the ropes.
  - ☐ **OPS**: Proceed only when the system has fully vented.
  - ☐ **PRIMARY**and **SECONDARY**: Approach the test plumbing.
  - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
  - ☐ **CONTROL**: Open the Tank Vent Valve (MV-2).
  - ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).
  - ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
  - ☐ **SECONDARY**: Disconnect the ignition connectors from the RLCS ignition cable.
  - ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
  - ☐ **OPS**: Abort test procedures and revisit the tank heating setup.

☐ **CONTROL**: Close the Tank Heating Valve.

☐ **PAUSE POINT**

- ☐ **P2**: Move to the viewing location.
- ☐ **CONTROL**: Perform the engine startup procedure:
  - ☐ Arm the Primary Ignition switch.
  - ☐ Hold down the Fire button until black smoke is observed. Continuously communicate the ignition current reading as displayed by the control box.
    - In the event of a failed ignition (smoke not observed within 1 minute):
      - ☐ **CONTROL**: Disarm the Primary Ignition Switch.
      - ☐ **CONTROL**: Arm the Secondary Ignition Switch.
      - ☐ **OPS**: Revisit ignition setup.
    - In the event of a second failed ignition (smoke not observed within 1 minute):
      - ☐ **CONTROL**: Disarm the secondary ignition switch.
      - ☐ **PRIMARY**: Open the Line Vent Valve (BA-3) using the ropes.
      - ☐ **OPS**: Proceed only when the oxidizer tank is fully vented.
      - ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
      - ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
      - ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).
      - ☐ **CONTROL**: Open the Tank Vent Valve (MV-2).
      - ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
      - ☐ **SECONDARY**: Disconnect the ignition connectors from the RLCS ignition cable.
      - ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
      - ☐ **OPS**: Abort test procedures and proceed to teardown.
  - ☐ **CONTROL**: Start the engine by opening the Injector Valve.
- ☐ **ALL**: Observe the plume.
- ☐ **PAUSE POINT**
- ☐ **P2**: Return to your assigned position.
- ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- ☐ **CONTROL**: Open the Tank Vent Valve (MV-2).
- ☐ **PRIMARY** and **SECONDARY**: Approach the plumbing setup.
- ☐ **PRIMARY**: Close the Cylinder Valve (SC-1).
- ☐ **CONTROL**: Open the Remote Fill Valve (MV-1).
- ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
- ☐ **PRIMARY**: Disconnect the fill line from the supply cylinder.
- ☐ **PRIMARY**: Replace the cap on the nitrous oxide cylinder.
- ☐ **PRIMARY**: Turn off the air compressor and depressurize the Injector Valve.
- ☐ **OPS**: Wait at least 3 minutes before proceeding.
- ☐ **DAQ**: Confirm that the nozzle thermistors are reading below 100 °C, unless suspected faulty.
- ☐ **P1**, **P2**, **P3**, **P4**: Open the perimeter.
- ☐ **DAQ**: Continue to monitor the thermistor readings and inform **OPS** if the combustion chamber temperature exceeds 190 °C.
- ☐ **OPS**: Proceed with teardown and disassembly.