UXO Hybrid Rocket Engine
Static Fire 1

Static Fire Test Operations Procedures

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Static Fire Test Operations Procedures

Contents

This document contains three 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 Remote Control* procedure comprises steps for operating the fill system using the electrical control system and motorized ball valves.
- The *Static Fire Test Manual Control* procedure comprises steps for operating the fill system using manually operated ball valves.

Personnel Required

The test operations team consists of seven personnel:

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

2 ☐ The **Primary Fill Operator [PRIMARY]** is the main system operator. **PRIMARY** operates all manual valves as well as the test control 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 **Heating Technician [HEAT]** operates the valves for the tank heating system.

6 ☐ **Perimeter Guard 1 [P1]** and **Perimeter Guard 2 [P2]** 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 ☐ **Heating Technician [HEAT]** _____ _____

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

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

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
- ☐ Ensure that all technicians 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**
  - ☐ **HEAT**
  - ☐ **P1**
  - ☐ **P2**
- ☐ 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 **SECONDARY** is in possession of the system control key.

Fill System Check Procedure

- ☐ **PRIMARY**: Confirm that the following valves are initially closed:
  - ☐ Cylinder Valve
  - ☐ Remote Fill Valve
  - ☐ Parallel Fill Valve
  - ☐ Tank Vent Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Injector Valve
- ☐ **PRIMARY**: Confirm that the following valves are initially open:
  - ☐ Series Fill Valve
- ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- ☐ **OPS**: Confirm that all personnel in the testing area are aware of the test.
- ☐ **P1** and **P2**: Close the perimeter and do not allow any further personnel to enter the testing area.
- ☐ **SECONDARY**: Confirm that no personnel are present in the testing area other than **PRIMARY** and **SECONDARY**.
- ☐ **PRIMARY**: Remove all plastic plugs and covers from the plumbing:
  - ☐ Tank Vent Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Nozzle
- ☐ **PRIMARY**: Remove the cap from the carbon dioxide supply cylinder.
- ☐ **PRIMARY**: Connect the fill line to the supply cylinder, hand tighten, and then tighten with a wrench. Do not force the connection.
- ☐ **PRIMARY**: Slowly open the Cylinder Valve through $\frac{3}{4}$ of a turn.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Slowly open the Line Vent Valve.
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit 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.
- ☐ **SECONDARY**: Give the system control key to **PRIMARY**.
- ☐ **PRIMARY**: Engage the key switch and power on the control boxes.

- ☐ **PRIMARY**: Open the Tank Vent Valve.
- ☐ **PRIMARY**: Open the Remote Fill Valve.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Remote Fill Valve.
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Slowly open the Line Vent Valve.
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
    - ☐ **PRIMARY**: Open the Remote Fill Valve.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit plumbing setup.
  - If the Remove Fill Valve fails to open:
    - ☐ **OPS**: Abort test procedures and revisit control system setup.
- ☐ **DAQ**: Confirm that the oxidizer tank mass is increasing.
- ☐ **DAQ**: Confirm that the oxidizer tank pressure is increasing.
- ☐ **PRIMARY**: Close the Remote Fill Valve
- ☐ **PRIMARY**: Open the Line Vent Valve.
- ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
- ☐ **PRIMARY**: Close the Cylinder Valve.
- ☐ **PRIMARY**: Open the Remote Fill Valve.
- ☐ **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** and **P2**: Open the perimeter.
- ☐ **OPS**: Proceed with teardown and disassembly.

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
  - ☐ Remote Fill Valve
  - ☐ Parallel Fill Valve
  - ☐ Pressure Relief Valve
  - ☐ Tank Vent Valve
  - ☐ Line Vent Valve
  - ☐ Injector Valve
- ☐ **PRIMARY**: Confirm that the following valves are initially open:
  - ☐ Series Fill Valve
- ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- ☐ **PAUSE POINT**
- ☐ **P1** and **P2**: Close the perimeter and do not allow any further personnel to enter the testing area.
- ☐ **SECONDARY**: Confirm that no personnel are present in the testing area other than **PRIMARY** and **SECONDARY**.
- ☐ **PRIMARY**: Remove all plastic plugs and covers from the plumbing:
  - ☐ Tank Vent Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Nozzle
- ☐ **SECONDARY**: Confirm that the impedance 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 ignition box.
- ☐ **PRIMARY**: Remove the cap from the nitrous oxide supply cylinder.
- ☐ **PRIMARY**: Connect the fill line to the supply cylinder, hand tighten, and then tighten with a wrench. Do not force the connection.
- ☐ **PRIMARY**: Slowly open the Cylinder Valve through $\frac{3}{4}$ of a turn.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit 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** and **SECONDARY**: Retreat to the test control area, behind the blast shield.
- ☐ **PRIMARY**: Confirm that all actuator controls are in the "off" position:
  - ☐ Remote Fill Valve
  - ☐ Tank Vent Valve
  - ☐ Injector Valve
  - ☐ Primary Ignition
  - ☐ Secondary Ignition
- ☐ **PAUSE POINT**
- ☐ **OPS**: Poll the following personnel for GO/NO GO status:
  - ☐ **P1**
  - ☐ **P2**
  - ☐ **HEAT**
  - ☐ **DAQ**
  - ☐ **PRIMARY**
  - ☐ **SECONDARY**
- ☐ **SECONDARY**: Give the system control key to **PRIMARY**.
- ☐ **PRIMARY**: Engage the key switch and power on the control boxes.
- ☐ **PRIMARY**: Open the Tank Vent Valve.
- ☐ **PRIMARY**: Open the Remote Fill Valve.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Remote Fill Valve.
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
    - ☐ **SECONDARY**: Proceed only when the oxidizer tank has fully vented.
    - ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Open the Remote Fill Valve.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit plumbing setup.
  - If the Remote Fill Valve fails to open:
    - ☐ **OPS**: Proceed to the Manual Control procedure.
- ☐ **SECONDARY**: Proceed only when a white plume is visible from the Tank Vent Valve.
- ☐ **PRIMARY**: Close the Tank Vent Valve.
- ☐ **PRIMARY**: Close the Remote Fill Valve.
  - If the Remote Fill Valve fails to close:
    - ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.

69 ☐ **PRIMARY**: Close the Series Fill Valve.
70 ☐ **PRIMARY** and **SECONDARY**: Retreat to the test control area, behind the blast shield.
71 ☐ **HEAT**: Open the Tank Heating Valve.
72 ☐ **DAQ**: Proceed only when the oxidizer tank pressure is at least 750 psi.

- If the oxidizer tank pressure does not reach 750 psi:
  73 ☐ **HEAT**: Close the Tank Heating Valve.
  74 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
  75 ☐ **SECONDARY**: Proceed only when the oxidizer tank has fully vented.
  76 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
  77 ☐ **PRIMARY**: Close the Cylinder Valve.
  78 ☐ **PRIMARY**: Open the Tank Vent Valve.
  79 ☐ **PRIMARY**: Open the Remote Fill Valve.
  80 ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
  81 ☐ **OPS**: Abort test procedures and revisit water jacket setup.

82 ☐ **HEAT**: Close the Tank Heating Valve.
83 ☐ **PAUSE POINT**
84 ☐ **PRIMARY**: Perform ignition procedure:
85 ☐ Arm the Primary Ignition switch.
86 ☐ Hold down the Fire button until black smoke is observed.

- In the event of a failed ignition (smoke not observed within 1 minute):
  87 ☐ **PRIMARY**: Disarm the Primary Ignition switch.
  88 ☐ **PRIMARY**: Arm the Secondary Ignition switch.
  89 ☐ **OPS**: Revisit ignition procedure.
- In the event of a second failed ignition (smoke not observed within 1 minute):
  90 ☐ **PRIMARY**: Disarm the Secondary Ignition switch.
  91 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
  92 ☐ **OPS**: Proceed only when the oxidizer tank has fully vented.
  93 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
  94 ☐ **PRIMARY**: Close the Cylinder Valve.
  95 ☐ **PRIMARY**: Open the Remote Fill Valve.
  96 ☐ **PRIMARY**: Open the Tank Vent Valve.
  97 ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
  98 ☐ **OPS**: Abort test procedures and proceed to teardown.

99 ☐ **PRIMARY**: Start the engine by opening the Injector Valve.
100 ☐ **PRIMARY**: Observe the plume:

- If any unexpected events occur during the engine firing:
  101 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
  102 ☐ **PRIMARY**: Wait for 3 seconds.
  103 ☐ **PRIMARY**: Close the Injector Valve.

104 ☐ **PAUSE POINT**
105 ☐ **OPS**: Wait for at least 3 minutes before proceeding.

- ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- ☐ **PRIMARY**: Open the Tank Vent Valve.
- ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
- ☐ **PRIMARY**: Close the Cylinder Valve.
- ☐ **PRIMARY**: Open the Remote Fill Valve.
- ☐ **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 supply cylinder.
- ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- ☐ **P1** and **P2**: Open the perimeter.
- ☐ **OPS**: Proceed with teardown and disassembly.

Static Fire Test - Manual 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
  - ☐ Remote Fill Valve
  - ☐ Parallel Fill Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Injector Valve
  - ☐ Series Fill Valve
- ☐ **PRIMARY**: Confirm that the following valves are initially open:
  - ☐ Tank Vent Valve
- ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- ☐ **PAUSE POINT**
- ☐ **P1** and **P2**: Close the perimeter and do not allow any further personnel to enter the testing area.
- ☐ **SECONDARY**: Confirm that no personnel are present in the testing area other than **PRIMARY** and **SECONDARY**.
- ☐ **PRIMARY**: Remove all plastic plugs and covers from the plumbing:
  - ☐ Tank Vent Valve
  - ☐ Pressure Relief Valve
  - ☐ Line Vent Valve
  - ☐ Nozzle
- ☐ **SECONDARY**: Confirm that the impedance 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 ignition box.
- ☐ **PRIMARY**: Remove the cap from the nitrous oxide supply cylinder.
- ☐ **PRIMARY**: Connect the fill line to the supply cylinder, hand tighten, and then tighten with a wrench. Do not force the connection.
- ☐ **PRIMARY**: Slowly open the Cylinder Valve through $\frac{3}{4}$ of a turn.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit 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.
- ☐ **SECONDARY**: Confirm that the following actuator controls are in the "off" position:
  - ☐ Primary Ignition
  - ☐ Secondary Ignition
- ☐ **PAUSE POINT**
- ☐ **OPS**: Poll the following personnel for GO/NO GO status:
  - ☐ **P1**
  - ☐ **P2**
  - ☐ **HEAT**
  - ☐ **DAQ**
  - ☐ **PRIMARY**
  - ☐ **SECONDARY**
- ☐ **PRIMARY**: Open the Parallel Fill Valve.
  - If leaks are observed:
    - ☐ **PRIMARY**: Close the Parallel Fill Valve.
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Open the Parallel Fill Valve.
    - ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit plumbing setup.
- ☐ **SECONDARY**: Proceed only when a white plume is visible from the Tank Vent Valve.
- ☐ **PRIMARY**: Close the Parallel Fill Valve.
- ☐ **PRIMARY** and **SECONDARY**: Retreat to the test control area, behind the blast shield.
- ☐ **HEAT**: 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:
    - ☐ **HEAT**: Close the Tank Heating Valve.
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
    - ☐ **SECONDARY**: Proceed only when the oxidizer tank has fully vented.
    - ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
    - ☐ **PRIMARY**: Close the Cylinder Valve.
    - ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
    - ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
    - ☐ **OPS**: Abort test procedures and revisit water jacket setup.
- ☐ **HEAT**: Close the Tank Heating Valve.
- ☐ **PAUSE POINT**

- ☐ **PRIMARY**: Perform ignition procedure:
  - ☐ Arm the Primary Ignition switch.
  - ☐ Hold down the Fire button until black smoke is observed.
    - In the event of a failed ignition (smoke not observed within 1 minute):
      - ☐ **PRIMARY**: Disarm the Primary Ignition switch.
      - ☐ **PRIMARY**: Arm the Secondary Ignition switch.
      - ☐ **OPS**: Revisit ignition procedure.
    - In the event of a second failed ignition (smoke not observed within 1 minute):
      - ☐ **PRIMARY**: Disarm the Secondary Ignition switch.
      - ☐ **PRIMARY**: Open the Line Vent Valve 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.
      - ☐ **PRIMARY**: Open the Remote Fill Valve.
      - ☐ **PRIMARY**: Open the Tank Vent Valve.
      - ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
      - ☐ **OPS**: Abort test procedures and proceed to teardown.
- ☐ **PRIMARY**: Start the engine by opening the Injector Valve with the ropes.
- ☐ **PRIMARY**: Observe the plume:
  - If any unexpected events occur during the engine firing:
    - ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
- ☐ **PAUSE POINT**
- ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
- ☐ **PRIMARY**: Close the Cylinder Valve.
- ☐ **PRIMARY**: Open the Parallel Fill Valve.
- ☐ **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 supply cylinder.
- ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- ☐ **P1** and **P2**: Open the perimeter.
- ☐ **OPS**: Proceed with teardown and disassembly.