



Kismet Hybrid Rocket Engine Static Fire 3

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* procedure comprises steps for operating the fill system and conducting a static fire 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 ☐ The **Heating Technician [HEAT]** operates the valves for the tank heating system.
- 7 ☐ **Perimeter Guard 1 [P1]**, **Perimeter Guard 2 [P2]**, and **Perimeter Guard 3 [P3]** 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 | <input type="checkbox"/> Operations Director [OPS] | _____ | _____ |
| 2 | <input type="checkbox"/> Primary Fill Operator [PRIMARY] | _____ | _____ |
| 3 | <input type="checkbox"/> Secondary Fill Operator [SECONDARY] | _____ | _____ |
| 4 | <input type="checkbox"/> DAQ Technician [DAQ] | _____ | _____ |
| 5 | <input type="checkbox"/> Control System Operator [CONTROL] | _____ | _____ |
| 6 | <input type="checkbox"/> Heating Technician [HEAT] | _____ | _____ |
| 7 | <input type="checkbox"/> Perimeter Guard 1 [P1] | _____ | _____ |
| 8 | <input type="checkbox"/> Perimeter Guard 2 [P2] | _____ | _____ |
| 9 | <input type="checkbox"/> Perimeter Guard 3 [P3] | _____ | _____ |

Prior to Start

- 1 ☐ Ensure that the following procedures are complete:
- 2 ☐ Combustion Chamber Assembly procedure
- 3 ☐ Oxidizer Tank Assembly procedure
- 4 ☐ Plumbing Setup procedure
- 5 ☐ Oxidizer Tank Stand Setup procedure
- 6 ☐ Tank Heating Setup procedure
- 7 ☐ Test Stand Setup procedure
- 8 ☐ Data Acquisition Setup procedure
- 9 ☐ Test Control System Setup procedure
- 10 ☐ Ensure that all personnel as defined above are available and have completed the sign-off.
- 11 ☐ Ensure that the following personnel have walkie-talkies and communication is functional:
- 12 ☐ OPS
- 13 ☐ SECONDARY
- 14 ☐ DAQ
- 15 ☐ P1
- 16 ☐ P2
- 17 ☐ P3
- 18 ☐ Ensure that all spectators and test personnel are wearing safety glasses and hearing protection.
- 19 ☐ Ensure that PRIMARY and SECONDARY are wearing face shields and have no exposed skin.
- 20 ☐ Ensure that PRIMARY is wearing thermal gloves.
- 21 ☐ Ensure that OPS is in possession of the system control key.

Fill System Check Procedure

- 1 ☐ **PRIMARY**: Confirm that the following valves are initially closed:
 - 2 ☐ Cylinder Valve
 - 3 ☐ Remote Fill Valve
 - 4 ☐ Parallel Fill Valve
 - 5 ☐ Tank Vent Valve
 - 6 ☐ Pressure Relief Valve
 - 7 ☐ Line Vent Valve
 - 8 ☐ Injector Valve
- 9 ☐ **PRIMARY**: Confirm that the following valves are initially open:
 - 10 ☐ Series Fill Valve
- 11 ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- 12 ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- 13 ☐ **OPS**: Confirm that all personnel in the testing area are aware of the test.
- 14 ☐ **P1, P2, and P3**: Close the perimeter and do not allow any further personnel to enter the testing area.
- 15 ☐ **SECONDARY**: Confirm that no personnel are present in the testing area other than **PRIMARY** and **SECONDARY**.
- 16 ☐ **PRIMARY**: Remove all plastic plugs and covers from the plumbing:
 - 17 ☐ Tank Vent Valve
 - 18 ☐ Pressure Relief Valve
 - 19 ☐ Line Vent Valve
 - 20 ☐ Nozzle
- 21 ☐ **PRIMARY**: Remove the cap from the carbon dioxide supply cylinder.
- 22 ☐ **PRIMARY**: Connect the fill line to the supply cylinder, hand tighten, and then tighten with a wrench. Do not force the connection.
- 23 ☐ **PRIMARY**: Slowly open the Cylinder Valve through $\frac{3}{4}$ of a turn.
 - If leaks are observed:
 - 24 ☐ **PRIMARY**: Close the Cylinder Valve.
 - 25 ☐ **PRIMARY**: Slowly open the Line Vent Valve.
 - 26 ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
 - 27 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
 - 28 ☐ **OPS**: Abort test procedures and revisit plumbing setup.
- 29 ☐ **PRIMARY**: Communicate the supply cylinder pressure as visible on the Pressure Gauge.
- 30 ☐ **DAQ**: Communicate the supply cylinder pressure as read by the Fill Pressure Transducer.
- 31 ☐ **DAQ**: Confirm that the two pressure measurements are in agreement.
- 32 ☐ **OPS**: Give the system control key to **CONTROL**.
- 33 ☐ **CONTROL**: Engage the key switch and power on the control boxes.

- 34 ☐ **CONTROL**: Open the Tank Vent Valve.
- 35 ☐ **CONTROL**: Open the Remote Fill Valve.
- If leaks are observed:
- 36 ☐ **CONTROL**: Close the Remote Fill Valve.
- 37 ☐ **PRIMARY**: Close the Cylinder Valve.
- 38 ☐ **PRIMARY**: Slowly open the Line Vent Valve.
- 39 ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
- 40 ☐ **CONTROL**: Open the Remote Fill Valve.
- 41 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
- 42 ☐ **OPS**: Abort test procedures and revisit plumbing setup.
- If the Remote Fill Valve fails to open:
- 43 ☐ **OPS**: Abort test procedures and revisit control system setup.
- 44 ☐ **DAQ**: Confirm that the oxidizer tank mass is increasing.
- 45 ☐ **DAQ**: Confirm that the oxidizer tank pressure is increasing.
- 46 ☐ **CONTROL**: Close the Remote Fill Valve
- 47 ☐ **CONTROL**: Open the Line Vent Valve.
- 48 ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- 49 ☐ **PRIMARY**: Close the Cylinder Valve.
- 50 ☐ **CONTROL**: Open the Remote Fill Valve.
- 51 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
- 52 ☐ **PRIMARY**: Disconnect the fill line from the supply cylinder.
- 53 ☐ **PRIMARY**: Replace the cap on the carbon dioxide supply cylinder.
- 54 ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- 55 ☐ **P1, P2, and P3**: Open the perimeter.
- 56 ☐ **OPS**: Proceed with final setup for Static Fire Test procedure.

Static Fire Test - Remote Control Procedure

- 1 ☐ **SECONDARY**: Confirm that the ignition wires are not connected to the engine.
- 2 ☐ **PRIMARY**: Confirm that the following valves are initially closed:
 - 3 ☐ Cylinder Valve
 - 4 ☐ Remote Fill Valve
 - 5 ☐ Parallel Fill Valve
 - 6 ☐ Pressure Relief Valve
 - 7 ☐ Tank Vent Valve
 - 8 ☐ Line Vent Valve
 - 9 ☐ Injector Valve
- 10 ☐ **PRIMARY**: Confirm that the following valves are initially open:
 - 11 ☐ Series Fill Valve
- 12 ☐ **DAQ**: Confirm that all pressure transducers are reading atmospheric pressure.
- 13 ☐ **DAQ**: Confirm that all load cells are reading the determined zero point.
- 14 ☐ **DAQ**: Confirm that all thermistors are reading ambient temperature.
- 15 ☐ **PAUSE POINT**
- 16 ☐ **P1, P2, and P3**: Close the perimeter and do not allow any further personnel to enter the testing area.
- 17 ☐ **SECONDARY**: Confirm that no personnel are present in the testing area other than **PRIMARY** and **SECONDARY**.
- 18 ☐ **PRIMARY**: Remove all plastic plugs and covers from the plumbing:
 - 19 ☐ Tank Vent Valve
 - 20 ☐ Pressure Relief Valve
 - 21 ☐ Line Vent Valve
 - 22 ☐ Nozzle
- 23 ☐ **SECONDARY**: Confirm that the resistance across the ignition coils is between 2.5 Ω and 3 Ω :
 - 24 ☐ Primary ignition coil
 - 25 ☐ Secondary ignition coil
- 26 ☐ **SECONDARY**: Connect the ignition connectors to the ignition box.
- 27 ☐ **PRIMARY**: Remove the cap from the nitrous oxide supply cylinder.
- 28 ☐ **PRIMARY**: Connect the fill line to the supply cylinder, hand tighten, and then tighten with a wrench. Do not force the connection.
- 29 ☐ **PRIMARY**: Slowly open the Cylinder Valve through $\frac{3}{4}$ of a turn.
 - If leaks are observed:
 - 30 ☐ **PRIMARY**: Close the Cylinder Valve.
 - 31 ☐ **PRIMARY**: Slowly open the Parallel Fill Valve.
 - 32 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
 - 33 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.

- 34 ☐ **OPS**: Abort test procedures and revisit plumbing setup.
- 35 ☐ **PRIMARY**: Communicate the supply cylinder pressure as visible on the Pressure Gauge.
- 36 ☐ **DAQ**: Communicate the supply cylinder pressure as read by the Fill Pressure Transducer.
- 37 ☐ **DAQ**: Confirm that the two pressure measurements are in agreement.
- 38 ☐ **PRIMARY** and **SECONDARY**: Retreat to the test control area, behind the blast shield.
- 39 ☐ **PRIMARY**: Confirm that all actuator controls are in the "off" position:
 - 40 ☐ Remote Fill Valve
 - 41 ☐ Tank Vent Valve
 - 42 ☐ Injector Valve
 - 43 ☐ Primary Ignition
 - 44 ☐ Secondary Ignition
- 45 ☐ **PAUSE POINT**
- 46 ☐ **OPS**: Poll the following personnel for GO/NO GO status:
 - 47 ☐ **P1**
 - 48 ☐ **P2**
 - 49 ☐ **P3**
 - 50 ☐ **HEAT**
 - 51 ☐ **DAQ**
 - 52 ☐ **CONTROL**
 - 53 ☐ **PRIMARY**
 - 54 ☐ **SECONDARY**
- 55 ☐ **OPS**: Give the system control key to **CONTROL**.
- 56 ☐ **CONTROL**: Engage the key switch and power on the control boxes.
- 57 ☐ **CONTROL**: Open the Tank Vent Valve.
- 58 ☐ **CONTROL**: Open the Remote Fill Valve.
 - If leaks are observed:
 - 59 ☐ **CONTROL**: Close the Remote Fill Valve.
 - 60 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.
 - 61 ☐ **OPS**: Proceed only when the oxidizer tank has fully vented.
 - 62 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
 - 63 ☐ **PRIMARY**: Close the Cylinder Valve.
 - 64 ☐ **CONTROL**: Open the Remote Fill Valve.
 - 65 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
 - 66 ☐ **OPS**: Abort test procedures and revisit plumbing setup.
 - If the Remote Fill Valve fails to open:
 - 67 ☐ **OPS**: Abort test procedures and revisit control system setup.
- 68 ☐ **SECONDARY**: Proceed only when a white plume is visible from the Tank Vent Valve.
- 69 ☐ **CONTROL**: Close the Tank Vent Valve.

- 70 ☐ **CONTROL**: Close the Remote Fill Valve.
- If the Remote Fill Valve fails to close:

71 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.

72 ☐ **PRIMARY**: Close the Series Fill Valve.

73 ☐ **PRIMARY** and **SECONDARY**: Retreat to the test control area, behind the blast shield.
- 74 ☐ **HEAT**: Open the Tank Heating Valve.
- 75 ☐ **DAQ**: Proceed only when the oxidizer tank pressure is at least 800 psi.
- If the oxidizer tank pressure does not reach 800 psi:

76 ☐ **HEAT**: Close the Tank Heating Valve.

77 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.

78 ☐ **OPS**: Proceed only when the oxidizer tank has fully vented.

79 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.

80 ☐ **PRIMARY**: Close the Cylinder Valve.

81 ☐ **CONTROL**: Open the Tank Vent Valve.

82 ☐ **CONTROL**: Open the Remote Fill Valve.

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

84 ☐ **OPS**: Abort test procedures and revisit water jacket setup.
- 85 ☐ **HEAT**: Close the Tank Heating Valve.
- 86 ☐ **PAUSE POINT**
- 87 ☐ **CONTROL**: Perform engine startup 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):

90 ☐ **CONTROL**: Disarm the Primary Ignition switch.

91 ☐ **CONTROL**: Arm the Secondary Ignition switch.

92 ☐ **OPS**: Revisit ignition procedure.
 - In the event of a second failed ignition (smoke not observed within 1 minute):

93 ☐ **CONTROL**: Disarm the Secondary Ignition switch.

94 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.

95 ☐ **OPS**: Proceed only when the oxidizer tank has fully vented.

96 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.

97 ☐ **PRIMARY**: Close the Cylinder Valve.

98 ☐ **CONTROL**: Open the Remote Fill Valve.

99 ☐ **CONTROL**: Open the Tank Vent Valve.

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

101 ☐ **OPS**: Abort test procedures and proceed to teardown.
- 102 ☐ **CONTROL**: Start the engine by opening the Injector Valve.
- 103 ☐ **ALL**: Observe the plume:
- If any unexpected events occur during the engine firing:

104 ☐ **PRIMARY**: Open the Line Vent Valve using the ropes.

105 ☐ **OPS**: Wait for 3 seconds.

106 ☐ **CONTROL**: Close the Injector Valve.

- 107 ☐ **PAUSE POINT**
- 108 ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- 109 ☐ **DAQ**: Confirm that the Oxidizer Tank Pressure Transducer is reading atmospheric pressure.
- 110 ☐ **CONTROL**: Open the Tank Vent Valve.
- 111 ☐ **PRIMARY** and **SECONDARY**: Approach the test plumbing.
- 112 ☐ **PRIMARY**: Close the Cylinder Valve.
- 113 ☐ **CONTROL**: Open the Remote Fill Valve.
- 114 ☐ **DAQ**: Confirm that the Fill Pressure Transducer is reading atmospheric pressure.
- 115 ☐ **PRIMARY**: Disconnect the fill line from the supply cylinder.
- 116 ☐ **PRIMARY**: Replace the cap on the nitrous oxide supply cylinder.
- 117 ☐ **OPS**: Wait for at least 3 minutes before proceeding.
- 118 ☐ **P1, P2, and P3**: Open the perimeter.
- 119 ☐ **DAQ**: Continue to monitor thermistor readings and inform **OPS** if the combustion chamber temperature exceeds 190 °C.
- 120 ☐ **OPS**: Proceed with teardown and disassembly.