Puma Flight Testing –Training Guide

The Pennsylvania State University
Lunar Lion Team

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1. Introduction

1.1. Training Overview

The Lunar Lion Team's Puma craft test program employs graduate and undergraduate students in the design, assembly, integration and operation of a rocket propelled craft to test the systems that have been created by the students on the team.

The students executing this work are required to receive training and satisfactorily demonstrate proficiency to the Test Director on H2O2 handling, usage, material compatibility, as well as general lab and fire safety prior to receiving certification for a specific test team role.

Different students fill different roles over time, so each role is defined below, and the necessary training required identified for each role. Periodic re-training is required for all positions.

Only trained students are allowed to fill these roles and actively participate in testing once their certification has been entered in this document. Proper and up-to-date training must be confirmed for each team member prior to testing. Role authorization must be indicated in this binder by completion of Personnel Training Checklist, signed off by Integration & Test Lead or Deputy.Description of Roles

Table 1: Description of Roles

Title	Abbreviation	Role
Test Technician	TT	Supports TC and TD in testing operations. Authorized to change and clean hardware and execute line-item specific actions (except H2O2 fill) as directed by TC.
Inspector and Safety Authority	ISA	Verify that all testing is following the safety protocols as defined in the Unit Specific Safety Plan. Inspector and Safety Authoritys will have the ability to stop testing if any unsafe activities are observed.
H2O2 Fill	NONE	Authorized to perform H2O2 fill procedure under the direction of TC
Test Conductor	TC	Follows the steps of a single sequence section with permission from TD
Test Director	TD	Final operational authority. Gives TC permission to advance to next sequence section
Test Track Technician	NONE	Gives TD permission to prepare for testing and begin Procedure or Sequence (except automatic shutdowns)
Integration and Test Lead	I&T	Integration and Test Lead
Deputy Integration	DI&T	Deputy Integration and Test Lead

and Test Lead		
Note: *If any personnel notice an unsafe condition, they have the authority and responsibility to stop the procedures.*		

Table 2: Description of Required Training

Role	Trained By	Training Required
TT	I&T or DI&T	• Lab Safety Training Course • H2O2 Safety Training Course • Participation in Test Track Fire Drill • Participation in Test Track H2O2 Spill Drill • Draw entire Puma P&ID • Explain the purpose of each component • Walk through the test stand at the test track and explain the purpose of each part • Walk through static/flight test stand and set ups • Walk through auxiliary power box operation and battery swaps • Identify primary H2O2 compatible and hazardous materials • List basic PPE required when working in test range • List full PPE required for handling H2O2 • Explain what determines Puma as "safe to approach" • Walk through DI fill • Walk through GN2 fill • Walk through water truck operation • Shadow DI fill 2 times • Walk TC through valve operation for DI fill. • Demonstrate proper pressure regulator operation • Identify fitting types and demonstrate proper installation • Shadow TT on test day at least once • Discussion of basic mechanism for H2O2 rocket engine operation
ISA	I&T or DI&T	**All training required of TT**
H2O2 Fill	I&T or DI&T	**All training required of TT and:** • Perform a dry run of the DI fill process, with a discussion of the order of steps • Perform DI fill process 10 times, under the supervision of the TD • Observe H2O2 fill process 10 times • Perform 3 dry runs of H2O2 fill process under supervision of TD
TC	I&T or DI&T	**All training required of TT and:**

		• Completion of Data Channels and Aborts sheet, listing NI modules, current data channel, and abort values for all test stand components, along with validation of those values • Discussion of Standard Operating Procedures • Discussion of Contingency Procedures
TD	I&T Lead and Mission Director Michael Paul	**All training required of TC and H2O2 Fill and:** • Serve as Test Conductor • Fully walk-through entire Design Documentation material • Full walk-through of Operating Procedures Binder

1.2.The Test Stand Plumbing & Instrumentation Diagram (P&ID)

1.2.1. P&ID Overview

A P&ID illustrates a general layout for all plumbing components (i.e. valves, pressure releases and filters) as well as monitoring components (i.e. pressure gauges, thermocouples) within the system.

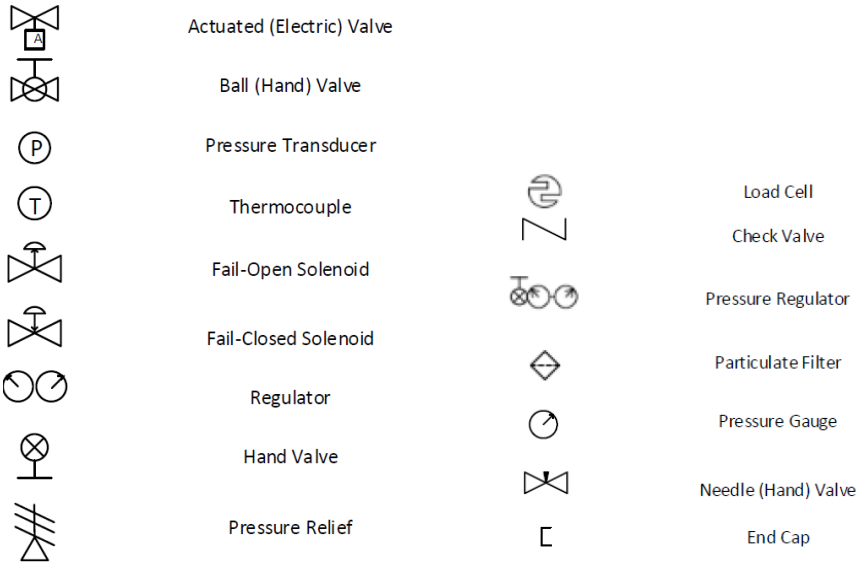
The purpose of this system is to monitor and regulate the flow of fuel (H2O2 in this case) through the system, ultimately allowing it into the engine and outputting a thrust force. The system also regulates the flow of inert gases (in this case, Gaseous Nitrogen – GN2) for the purpose of pressurizing the system.

The schematic does not attempt to represent where each component and circuit is to be placed onto Puma, only the layout of components within each circuit and relative to one another. Placement of each circuit onto Puma is up to the assembler of the physical system.

Once constructed, the propulsion system is integrated on Puma for the whole system to be tested.

1.2.2. Reading the P&ID

Abbreviation format is: XX#-L
-XX is component abreviation
-# is the number (if applicable)
- L is the location (ENGINE, PURGE, STAND, TANK, ULLAGE, MANIFOLD)



1.2.3. Component Functions

1.2.3.1. Valves

Use of valves is a primary way of regulating flow throughout the system. They are generally given their name by either location within the plumbing system, construction of the orifice or how operation is induced (opening and closing of the orifice).

Valve classifications commonly used in engine plumbing:

Bleed Valve: Placed in such a way that it allows fluid to bleed from the system on command. The opening of a bleed valve is usually for the purpose of relieving pressure in the system and is therefore commonly placed in a circuit with a pressure relief. It is also used to safely drain propellants from the lines.

Isolation (iso) Valve: Isolates fluid and prevents it from reaching a specific location in the plumbing system.

Ball Valve: A spherical shape seals the orifice

Needle Valve: Orifice is needle-shaped to significantly slow down and allow for fine control of the flow rate (e.g. kitchen faucet)

Check Valve: Limits the flow of a fluid to just one direction; prevents backflow. Every check valve has an arrow indicated flow direction. Be careful to install check valves with the arrow pointing downstream.

Actuated Valve: A motor operates the valve. Used when precise valve control is necessary (e.g. a 30° orifice opening within 4 seconds vs just having an immediate open or close). Can also be used in binary (on/off) operation.

Throttle Valve: A specific type of actuated valve which is located just upstream of the engine. It's used to control flow of propellant to the engine which will result in different levels of thrust.

Solenoid Valve: Will open or close when energized by an electric current. Fail-open solenoid valves close when energized and fail-closed solenoids open when energized. In the event of a system failure (e.g. a max pressure limit is reached), power is killed and each valve goes into the default state. This is used as a mitigation technique to avoid damage to the system as well as injury.

Solenoid Considerations

- Gems valves are prone to crack/leak if NPT fittings are over-tightened or the stem isn't torqued according to specs.
- Do not disassemble unless necessary.
- If disassembly is necessary:
    - Handle seals carefully. Remove with Teflon (e.g. floss picks) and replace if required.
    - Leak check reassembled valve with pressure before reinstalling on stand.

Hand Valve: Refers to a manually operated valve. The handle always points in the direction of flow when the valve is open; it is perpendicular when the valve is closed.

1.2.3.2. Pressure monitoring and control

Pressure Regulator: Monitors and regulates tank pressure; commonly referred to as a reg. We will be using a regulator to control the delivery pressure out of a gas cylinder. The reading on the right portion of the regulator displays the tank pressure while the left side displays the pressure being delivered into the system. The horizontal bar between the two gauges acts as a needle valve, allowing fine control of how much pressure from the tank to allow into the line. If too much pressure is allowed into the line, pressure cannot be returned through this valve. In this case, pressure entering the line from the tank must first be sealed off and then existing pressure in the line can be vented to the air through a second needle valve (not shown in figure).

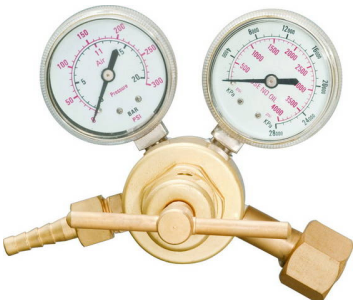


Figure 2 - pressure regulator http://lhpressuregauge.en.ec21.com/offer_detail/Sell_gas_welding_regulator_pressure--10083482.html?gubun=S

Pressure Relief: This is a specialized valve used to relieve pressure from the system. It is a mechanical component where an inner spring is released once a maximum pressure is reached, thus allowing pressure to be reduced

Pressure Transducer: Monitors pressure throughout the system by using a set of resistors, similar to the working principal of a strain gauge.

Pressure Gauge: General term for a pressure reading device, usually analog

1.2.3.3. Other Plumbing Components

Thermocouple: An electronic measuring device that measure temperature through gradients.

2. Test Technician Requirements

Outlined below is the material that must be covered before being considered a trained Test Technician for Puma Flight Testing.

2.1. Draw the Puma P&ID

Be able to draw the schematic from memory. *(See Puma P&ID v)*

2.2. Why Are Those Components There?

Explain the purpose of each component on the stand.

2.3. Common Types of Hazardous Material with H2O2

- Organics(cotton, wool, etc.): will catalyze H2O2 and, as heat and oxygen is generated, will combust
- Transition metals: will catalyze H2O2

2.4. Primary H2O2 Compatible Materials Used on System

- Stainless steel (316, 304)
- Aluminum (pure, no alloys)
- PVC
- Teflon (PTFE)
- Polyethylene (LDPE, HDPE)

2.5. Three Steps for Material Treatment and Passivation

The three steps involved with MTP and briefly explain the purpose of each.

- LOX cleaning – clean all components with a degreasing solution (Simple Green) to remove and residual dirt and oil leftover from manufacturer
- Passivation – soak all metal components in a 70% nitric acid bath for 5 hours to "passivate" the material. Surface impurities are removed and a protective oxide layer is formed.
- Propellant Conditioning – soak all components in a dilute, 30% H2O2 bath for a minimum of 48 hours to identify any troublesome spots

2.6. Explain the limits of the test range

Once operational procedure have begun, there are to be no persons in the test range (within 250 feet of the test stand) unless they are at least Test Technician trained or otherwise authorized by the Test Director. All persons within this area should be wearing proper Personal Protective Equipment (PPE). When hydrogen peroxide is out of its main storage shed, only those authorized to perform the hydrogen peroxide fill and wearing full PPE (as outlined below) are allowed in the test range.

2.7. Basic PPE Required When Working in Test Range (<250 feet of the stand)

- Safety glasses

- Close-toed shoes
- Long pants
- Nitrile gloves

2.7.1. PPE General Considerations

- Always wear basic PPE when working on the system.
    - Gloves should be worn when handling any passivated/LOX clean parts, on the system or off. Protects skin from residual peroxide and the components from finger oils and dirt.
- Always cap or cover exposed piping or components on the test stand or any other passivated/LOX cleaned parts.
- Bag components after removal. Ensure parts have been properly cleaned and passivated before installing on stand. If unsure, do not use.

2.8.PPE required when handling H2O2 (Full PPE)

- Tyvek coverall suit
- Rubber boots
- Safety glasses
- 8" face shield
- 22 millimeter thick nitrile gloves

2.9.Demonstrate Proper Pressure Regulator Operation

- The left gauge indicates delivery pressure. The right gauge indicates tank pressure.
- When opening the stem or main tank valve, open completely.
- Set delivery pressure while stem valve is closed and main valve is open.
    - An increase in delivery pressure will immediately be indicated on the gauge, but pressure must be bled through the stem to read a decrease in delivery pressure.
- When depressurizing lines, close tank supply but open stem valve to avoid trapping pressure in regulator. Vent through hand valve just downstream of regulator.
- Close stem valve and hand valve downstream of regulator after line is depressurized.

2.10. Identify Fitting Types and Demonstrate Proper Installation

The main three fitting types we use on this system are Swagelok, NPT, and AN. TTs should be able to identify these types, as well as demonstrate proper installation in the system.

2.10.1. Fitting Considerations

- This system uses three types of fittings—Swagelok, AN, and NPT—know the difference.
- Male NPT threads must be taped, Swagelok and AN should not be.
- Wrap the NPT fitting with Teflon tape in the direction of the threads, coming close to but not covering the face of the fitting.
- Be careful not to over-tighten NPT fittings. General rule of thumb: 1½ turns past "hand tight."
- Use two wrenches to install fittings—one to tighten the fitting, and another to hold the fitting to which it is being installed, to avoid putting torque on the system.
- Swagelok females must be installed directly straight into the fitting to catch the threads without binding.
- Never force binding threads. This can strip the fitting.

2.11. Discussion of H2O2 engine operation

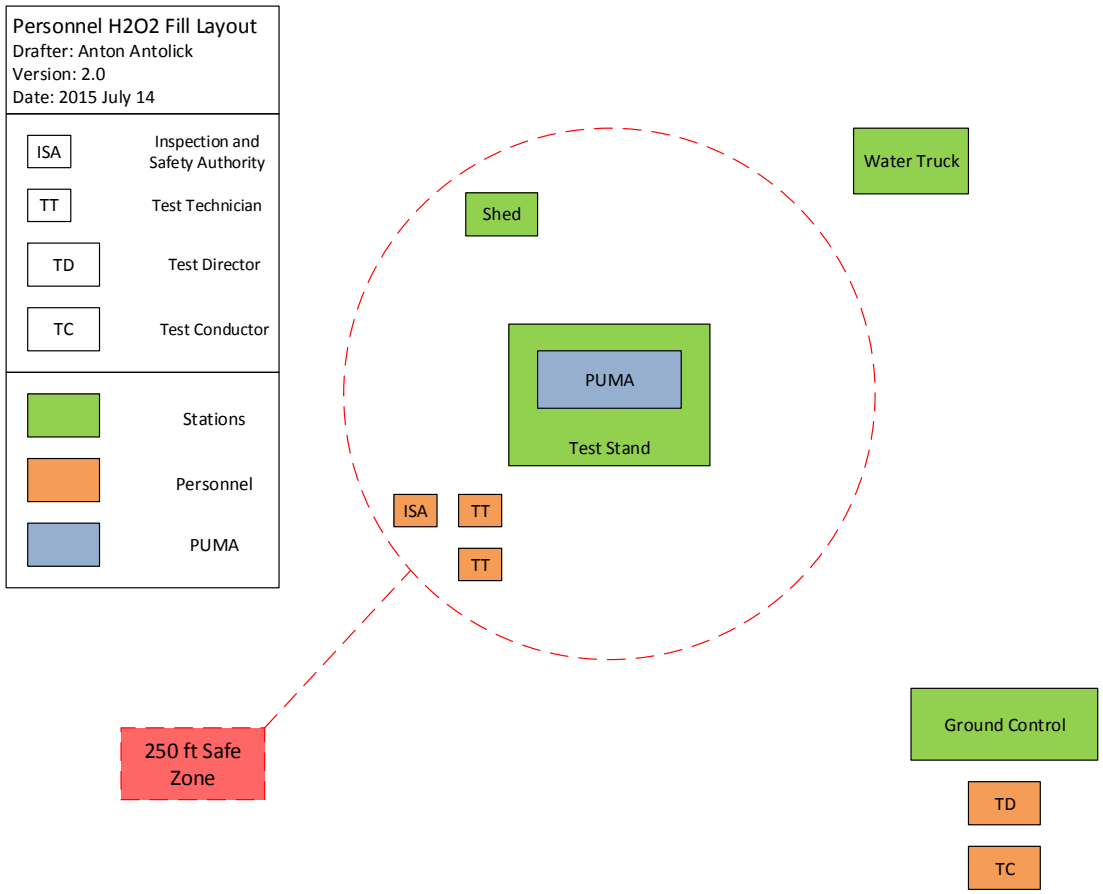
Key elements to discuss:

- The primary mechanism is hydrogen peroxide decomposition
- Concentrated 90% H2O2 enter the rocket engine, then passes through a catalyst bed made from 5 different pure metals: silver, gold, platinum, palladium, rhodium
- The catalyst decomposes the peroxide into oxygen and superheated steam (the reaction generates a lot of heat, which makes water change phase from liquid to gas)
- Products enter the rocket nozzle, which accelerates the gases and results in more thrust generated.

2.12. Discussion of Personnel Layout During H2O2 Fill

Key elements to discuss:

- The primary location stations, personnel, and Puma during this phase of testing.
- The responsibilities of all personnel during this phase of testing.



2.13. Discussion of Personnel Layout During Test

Key elements to discuss:

- The primary location stations, personnel, and Puma during this phase of testing.
- What criteria must be met in order for personnel to be allowed to enter safe zone.
- The responsibilities of all personnel during this phase of testing.