EM50-OWI-037

Hydrometeor Impact Gun

Materials and Processes Laboratory
Environmental Effects Branch
Space & Environmental Effects Team

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

! This Instruction Contains Descriptions of **HAZARDOUS OPERATIONS** !

Release Authority	Name	Title	Organization	Date
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Revision	Date	Originator	Description	Affected Pages
Baseline	4/07/06	Whitney Hubbs		

This document baselines the Organizational Work Instruction (OWI) for the Hydrometeor Impact Gun in Building 4571. Any change to this OWI shall be submitted to and approved by the Environmental Effects Branch Chief, EM50. Revisions may be also be submitted to the concurring organizations listed below for review and concurrence by memo. The original OWI and all changes shall be maintained by EM50.

Concurring organizations:
EM50 Space Environmental Effects Branch Chief
Environmental Health, AD60M

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1.0 Scope

1.1 Scope

This Organizational Work Instruction (OWI) describes the operation of the Hydrometeor Impact Gun (HIG) located in the Impact Testing Facility (ITF), Building 4571, in the East Test Area at Marshall Space Flight Center (MSFC). This system provides the ability to test the response of various materials to rain impacts.

1.2 Purpose

The purpose of this document is to outline the procedure for operating the HIG. Rain, sand, and hail pose a serious damage threat to missiles, aircraft components, and spacecraft components. The HIG has been deemed a national asset by the Army, Navy, and Air Force. Every Department of Defense (DoD) infrared (IR) window, IR dome, and radome over the last 20 years has been tested by this system. This testing is done in support of materials and processes investigations conducted by the NASA/MSFC Environmental Effects Branch.

1.3 Applicability

This instruction applies to the Environmental Effects Branch of the Materials and Processes Laboratory at MSFC. This document only applies to the subject test system and is not a substitute for formal training.

2.0 Applicable Documents

EM50-OWI-002. *Work Request Process*

EM50-OWI-003. *Control of Records*

EM50-OWI-004. *Control of Customer-Supplied Products*

MPR 8730.5. *Control of Inspection, Measuring, and Test Equipment*

MPR 1040.3. *MSFC Emergency Plan.*

MPR 1840.2. *MSFC Hazard Communications Program.*

MPR 8715.1. *MSFC Safety, Health, and Environmental (SHE) Program.*

MWI 3410.1. *Personnel Certification Program.*

MWI 8621.1. *Close Call and Mishap Reporting and Investigation Program.*

MWI 8715.10. *Explosives, Propellant, and Pyrotechnics Program.*

MWI 8715.15. *Ground Operations Safety Assessment and Risk Mitigation Program*

NASA NSS 1740.12. *Safety Standards for Explosives, Propellants, and Pyrotechnics.*

Note: Personnel **shall always refer** to the current version of applicable documents.

3.0 Definitions

3.1 Definitions

Hot Charge: The powder/cartridge/breech assembly connected to the launch tube

NASA: Marshall Space Flight Center EM50 responsible personnel.

Prepared Charge: A weighted amount of powder without the cartridge.

Range: Building 4571.

Range Operator: Person responsible for the day-to-day operation of the HIG

Sabot: The vehicle carrying the sample through the HIG

3.2 Acronyms

COTR	Contracting Officer's Technical Representative
HIG	Hydrometeor Impact Gun
ITF	Impact Testing Facility
MPR	Marshall Procedural Requirements
MSFC	Marshall Space Flight Center
MWI	Marshall Work Instruction
NASA	National Aeronautics and Space Administration
OWI	Organizational Work Instruction
PPE	Personal Protective Equipment
S&MA	Safety and Mission Assurance (office)
SHE	Safety, Health, and Environmental (program)

4.0 Instructions

The purpose of testing with the Hydrometeor Impact Gun is to investigate various materials responses to a known rain drop size at a known velocity. Unless otherwise noted, tolerance for projectile velocity **shall be** ±5%. For a physical description of the HIG, see section 9.1.

A minimum of two authorized personnel **shall be present** for all HIG loading and firing operations. All operations of this equipment **shall be conducted** using the applicable documents referenced above (section 2). All critical measuring devices **shall be** in current calibration (section 9.4). All data and test results **shall be recorded** on data sheets (section 7.2), which are compiled in notebooks and recorded on a laboratory computer. A summary of pertinent test information and test results **shall be compiled** in an electronic database, with hardcopies stored in files.

Materials submitted for testing **shall be provided** with appropriate records and defined requirements for handling, testing, and environmental exposure. Material submittals **shall include** all appropriate work request forms and quality tracking records.

4.1 Equipment Checkout

Before initiating any test, personnel **shall:**

- **Visually inspect** all components for signs of stress, *i.e.,* cracks. Components to be inspected **include**, but are not limited to, breech, launch tube, impact chamber, brake tube (recovery tube), and catch tube. *If any defects are noted,* **remove** the component from service immediately. *If component defects become apparent during a test,* the system **shall be vented** immediately and the component taken out of service.
- **Ensure** that all HIG components are clean. *If the gun requires cleaning,* **follow** the cleaning procedure described in section 4.10.

Note: All equipment used in support of this test **shall be** in proper working order. Tools and materials used in cleaning, setup, and testing **shall not damage** the facility or the hardware provided for testing. All samples and hardware **shall be handled** with proper care to prevent damage.

4.2 Pre-Test Photography

Representative samples **shall be photographed** before they are prepared for test. Any anomalous sample **shall be photographed** before it is prepared for test.

4.3 Water and Sabot Preparation

4.3.1. Preparing the test water. Personnel **shall prepare** the test water as follows:

4.3.1.1. **Don** eye protection.

4.3.1.2. **Fill** a large syringe with ethylene glycol (30 ml) and deionized water (70 ml).

4.3.1.3. **Screw** a filter tip on end of syringe; **replace** the filter when it appears dirty.

4.3.1.4. **Filter** the solution into a clean flask.

4.3.1.5. **Place** the flask on a hotplate, and **bring** the solution to a boil.

4.3.1.6. When the solution boils, **remove** the solution from the hotplate, and **press** a rubber stopper firmly into the flask (air tight).

4.3.1.7. **Place** the flask in a beaker of water that is at room temperature.

4.3.1.8. When the flask has returned to room temperature, **place** it in a second beaker of boiling water on the hotplate for ~1 minute.

4.3.1.9. **Remove** the flask from the boiling water, **ensure** that the stopper is firmly secured, and **set** the flask aside until it cools.

Note: This process should pull a vacuum on the stopper. When ready to shoot the gun, *if the flask does not have a vacuum,* most likely there is too much air in the water. **Repeat** the water preparation steps.

4.3.1.10. **Fill** the appropriate syringe with the degassed mixture. **Log** the syringe size on the shot sheet.

Note: The syringe is determined by the size of the target water drop, which should be designated on the test work order.

4.3.2. Preparing the sabot. Personnel **shall prepare** the sabot as follows:

The sample resides in the sabot and is shot at the water droplet.

Figure 4.3-1.
Sabot unassembled.

4.3.2.1. **Install** a sample onto a plastic insert, and **insert** sample/insert into the top piece of the sabot. (Figure 4.3-1.)(The angle of the sample determines insertion technique.) (Figure 4.3-2.)

Figure 4.3-2.
Sample geometries.

Figure 4.3-3.
Sabot assembled

4.3.2.2. **Attach** the bottom of the sabot.

CAUTION: Take care not to damage the sabot fin (Figure 4.3-3).

4.3.2.3. **Drill** holes into the side of the sabot assembly where the top and bottom pieces overlap.

4.3.2.4. **Insert** nylon string into the assembly holes to secure the sabot sections together. **Shave** off excess string so that the string in flush with the sabot surface. (Figure 4.3-3).

4.3.2.5. **Measure** the mass of the sabot assembly, and **record** this on the shot sheet (Figure 7.3-5).

4.4 System Setup

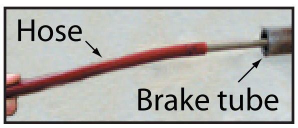


Figure 4.4-1.
Using hose to estimate spacing

Personnel **shall perform** the following actions to prepare the system for test:

4.4.1. **Pack** and **seal** the brake tube.

4.4.1.1. From the recovery end, **pack** the brake tube using the appropriate packing materials and spacing, according to the test velocity. **Use** the red hose marked at specific lengths for insert placements (Figure 4.4-1).

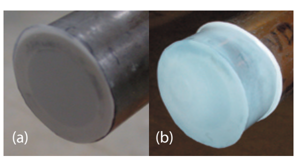


Figure 4.4-2.
Brake tube (a) sealed with disk, (b) prophylactic covering disk

Note: To determine the spacing of the packing, **consult** data from past tests.

4.4.1.2. **Seal** the brake tube with a disk that is slightly lubricated with vacuum grease (Figure 4.4-2a). **Place** one or two prophylactics over the recovery end of the brake tube to obtain good vacuum pressure (Figure 4.4-2b).

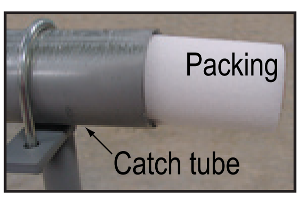


Figure 4.4-3.
Packing the catch tube

4.4.2. **Prepare** and **position** the catch tube.

4.4.2.1. **Replenish** the foam packing in the catch tube, *if necessary.* (Figure 4.4-3).

4.4.2.2. **Attach** the metal end cap to the end of the catch tube (Figure 4.4-4).

Figure 4.4-4.
End cap on catch tube

4.4.2.3. **Position** the catch tube so that it surrounds the end of the brake tube (Figure 4.4-5). **Ensure, however,** that the sealed end of the brake tube does not touch the packing foam, else cleanup for the HIG after firing will be extensive.

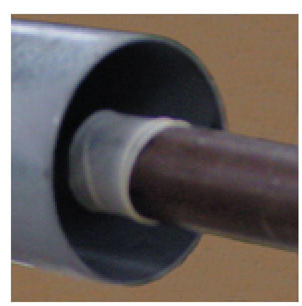


Figure 4.4-5.
Catch tube correctly positioned around brake tube

4.4.3. Ensure lids on impact chambers are secure.

4.4.4. **Plug** the breech end of the HIG assembly with a rubber stopper (Figure 4.4-6), and **turn on** the vacuum pump.

Note: *If there are no leaks in the system,* the vacuum should be 200 millitorr.

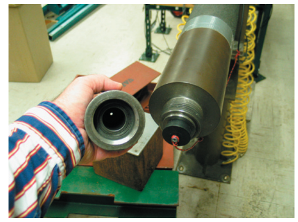


Figure 4.4-6
Breech end of launch tube plugged

4.4.5. **Don** face shield, and **wear** long sleeves and appropriate gloves for working with LN_2.

4.4.6. **Fill** the LN_2 trap, and **allow** the roughing pump to pull a vacuum on the target chamber to <200 millitorr.

4.5 Breech Loading

4.5.1. **Calibrate** the shot velocity. (**See** section 7.1 for instructions for generating powder/mass calibration curves.) *If the powder/mass calibration curve exists,* **determine** the powder charge required to attain test velocity.

4.5.2. **Activate** the building warning beacon.

4.5.3. **Verify** that the exit doors are closed and secure.

4.5.4. **Ensure** that all personnel in the HIG area are authorized by the Range Operator.

4.5.5. **Load** the breech.

Note: The primer charge and the main charge act together to launch the sabot. The primer is a .38 special cartridge that uses a primer.

CAUTION: Only a minimum of two authorized personnel are allowed in the preparation area during charge preparation and loading.

CAUTION: Charge preparation **shall be performed** on the grounded, non-sparking table in Building 4571.

CAUTION: Remove all jewelry, wrist watches, keys, *etc.*, before preparing the charge.

CAUTION: Wear face shields and wrist stats when preparing and loading a charge. **Attach** wrist stats to ground points at the preparation table. Before performing the following steps, **ensure** that wrist stats are connected to ground.

4.5.5.1. **Press** a new primer into the cartridge using the Auto Prime Primer Loader (Figure 4.5-1).

4.5.5.2. **Don** face shields and wrist stats.

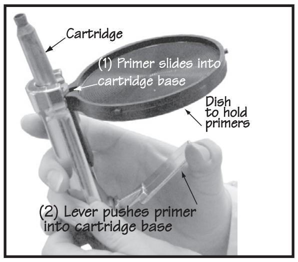


Figure 4.5-1.
Assembling primer and cartridge

4.5.5.3. **Test** wrist straps with a calibrated meter to ensure that the resistivity of the grounding system between the wearer and the wrist ground clip is between 25,000 ohm and 1 Mohm. **Ensure** that the grounding table resistivity is between 25,000 ohm and 1 Mohm.

4.5.5.4. **Remove** a container of the appropriate powder from the magazine. **Place** powder container on the loading table.

4.5.5.5. **Connect** wrist stats to ground. **Place** weighing dish on scales, and zero out the scales.

4.5.5.6. **Pour** enough powder into the dish on the scales to obtain the required weight for the total charge, as calculated in step 4.5.2.

4.5.5.7. **Pour** the weighed powder into a cartridge shell, until the shell is nearly full.

4.5.5.8. **Insert** the cartridge into the breech, being careful not to spill any powder.

Note: Pour any spilled powder into the canister designated for contaminated powder.

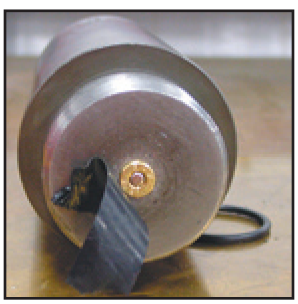


Figure 4.5-2.
Electrical tape to hold primer and cartridge in breech

4.5.5.9. **Place** electrical tape over the cartridge/primer so primer will not fall out when loading the main charge (Figure 4.5-2).

CAUTION: Set the breech with the cartridge/primer installed upright on the grounded, non-sparking table atop an O-ring, so that the cartridge/primer assembly is not in contact with the table (Figure 4.5-3). This will prevent accidental ignition of the powder.

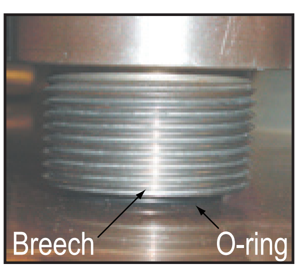


Figure 4.5-3.
Breech assembly resting on O-ring on grounded, non-sparking table

4.5.5.10. **Pour** remaining powder into the center of the breech. **Make sure** that the powder does not collect on the sides of the breech and does go into the cartridge. **Use** a wooden dowel to tamp the powder into the cartridge.)

4.5.5.11. Using the breech press tube, which is wired to a voltmeter, **press** a foam plug down over the powder charge (Figure 4.5-4).

4.5.5.12. **Install** the breech press assembly over the press tube and plug, and **screw** the assembly down until *the voltmeter* reads 15 mV. **Allow** this assembly to stand and settle until ready to shoot (Figure 4.5-5).

Figure 4.5-4.
Breech press tube

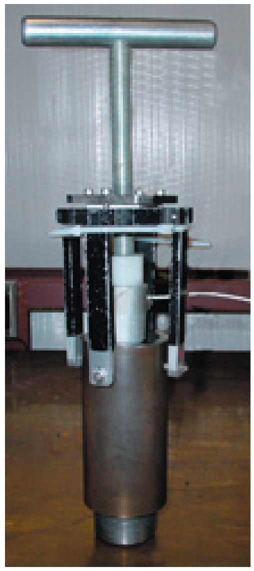


Figure 4.5-5.
Breech assembly

4.5.5.13. **Return** the powder container to the magazine.

4.6 Detailed Test Procedure

Note: Before conducting the actual test, personnel **shall conduct** at least one dry run (without water drops) and one calibration shot to confirm that nothing within the gun will damage the sample.

4.6.1. **Backfill** the system (target chamber and launch tube) with helium to reduce any distortion of the water drop from the sabot shock front.

4.6.1.1. **Valve off** the test chamber when the appropriate vacuum (<200 millitorr) is reached.

4.6.1.2. **Open** the K bottle valve and the helium flow valve to **purge** the test chamber with helium gas. Continue gas flow until the metal cover of the liquid **drop** dispenser (Figure 4.6-1) pops, indicating positive pressure.

Figure 4.6-1.
Metal cap on liquid drop dispenser

4.6.2. **Insert** sabot into launch tube. **Use** a small amount of vacuum grease to ensure a good seal.

4.6.3. **Install** the breech assembly (Figure 4.6-2)

4.6.3.1. **Remove** the breech press, and **screw** the breech assembly into the launch tube, using the special wrench to tighten.

4.6.3.2. **Remove** the electrical tape holding the cartridge/primer in the breech.

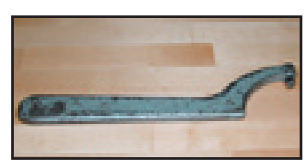
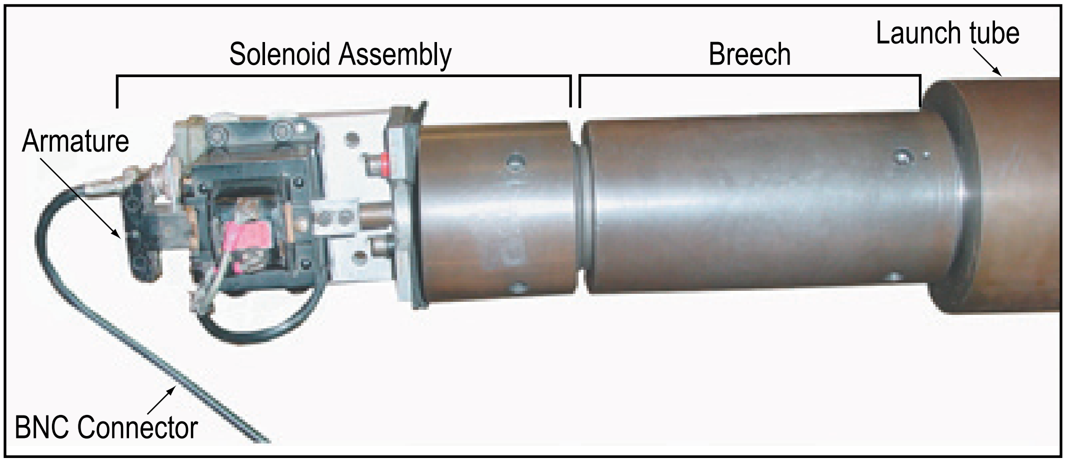


Figure 4.6-2.
Breech installing wrench

4.6.3.3. **Screw** the firing pin solenoid onto the breech, making sure that the pin is flush to its base (Figure 4.6-3).

Figure 4.6-3.
Firing pin solenoid and breech assemblies attached to launch tube



4.6.3.4. **Place** a metal sleeve over the launch tube/breech/solenoid sections of the HIG.

4.6.3.5. **Connect** the BNC connector to the solenoid, and **pull** the armature back until it stops.

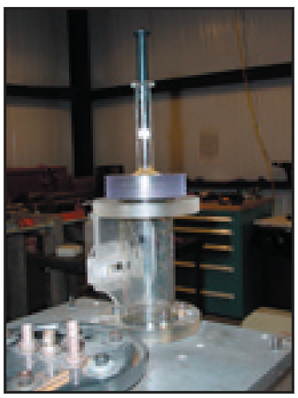


Figure 4.6-4.
Syringe installed in liquid drop dispenser

4.6.4. Gently **insert** the syringe into the liquid drop dispenser, being careful not to generate unnecessary air in the syringe (Figure 4.6-4).

4.6.5. **Pump** down **to** <200 millitorr by pressing the pump valve switch.

4.6.6. **Close** the helium flow valve.

4.6.7. **Open** the vacuum valve, and **allow** the HIG to pump to 200 millitorr.

4.6.8. **Set up** the high speed camera and back light.

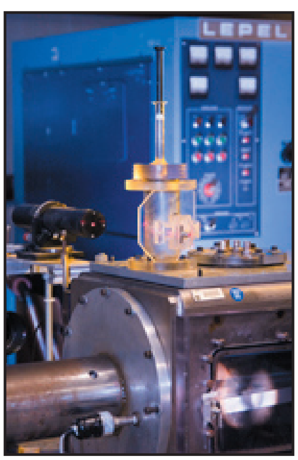


Figure 4.6-4.
Laser optimized

4.6.9. **Optimize** the laser, ensuring it is aligned so that it will hit the falling drop. (Figure 4.6-5).

4.6.10. **Examine** camera images of the drops to confirm drop size and drop fall time. **Record** these data on the HIG shot sheet (Figure 7.3-5).

4.6.11. **Set** the delay in accordance with HIG spreadsheet calculations (Figure 7.3-5).

4.6.12. **Ensure** that the trigger is working properly by breaking the laser beam and observing the oscilloscope to ensure this interference was received.

CAUTION: Do not look into the laser light.

WARNING: AT THIS TIME, DON HEARING PROTECTION. STAND TO THE SIDE OF THE HIG NEAR THE TARGET CHAMBER.

WARNING

4.6.13. **Turn off** the vacuum pump valve by pressing the pump valve switch (Figure 4.6-5)

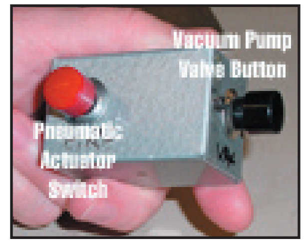


Figure 4.6-5.
Vacuum pump valve button and pneumatic actuator switch

4.6.14. **Ensure** that a good drop forms.

4.6.15. On the camera remote control, **push** the **RECORD READY** button.

4.6.16. Just before the drop falls, **fire** the HIG by pressing the pneumatic actuator switch (Figure 4.6-5). **Yell** "FIRE."

4.7 Misfire Procedure

In the event of a misfire, personnel **shall wait** 5 minutes, **don** face shields, and **perform** the following steps:

4.7.1. **Determine** if the armature on the firing pin solenoid is still is pulled back.

4.7.1.1. *If the armature is still pulled back,*

- **Ensure** that the BNC connector is securely attached to the solenoid.
- **Ensure** that the triggering mechanism is functioning by waving an object across the laser path. **Watch** the oscilloscope to make sure the drop is actually triggering the system. *If not,* slightly **adjust** the trigger controls until this action triggers the scope. **Repeat** firing sequence starting at step 4.6.13. After three unsuccessful firing attempts, **disconnect** the BNC, **manually slide** armature in, **slide** metal sleeve to breech, **remove** the solenoid, **safe** the system, and **discard** the powder by the approved procedure.

4.7.1.2. *If the armature has been released,* **disconnect** BNC, **slide** metal sleeve back to breech section, and **remove** solenoid.

4.7.2. **Determine** whether the armature has impacted the .38 cartridge primer.

4.7.2.1. *If the armature has **not** impacted the .38 cartridge primer,* **reconnect** BNC, and **reposition** metal sleeve. **repeat** the firing sequence starting at step 4.6.13 or (4.6.12, depending on the vacuum pressure).

Note: The vacuum pressure must be approximately 200 millitorr or drops may be distorted.

4.7.2.2. *If the armature has impacted the .38 cartridge primer,* **inspect** the cartridge from a safe distance to determine if impact caused the .38 cartridge to actually fire. The smell of burnt powder is a certain indication of a firing. Proceed to step 4.7.3.

4.7.2.3. *If it cannot be determined from the above steps whether the cartridge has fired,* **repeat** the firing procedure from step 4.6.12 or 4.6.13.

4.7.3. *If the armature has impacted the .38 cartridge and it is obvious that the gun has fired without launching the sabot,* **proceed** as follows:

4.7.3.1. **Disconnect** the BNC from the firing pin solenoid.

4.7.3.2. **Remove** the protective metal sleeve.

4.7.3.3. **Ensure** that the vacuum pump is isolated from the system.

4.7.3.4. **Bleed** in helium to bring back the HIG to atmosphere.

4.7.3.5. **Remove** the solenoid.

4.7.3.6. **Remove** the breech.

4.7.3.7. **Discard** the remaining powder into the canister designated for shot powder. (**Refer** to MWI 8715.10.)

4.7.3.8. **Remove** the cartridge, and **discard** it in the container designated for used cartridges.

4.7.3.9. **Clean** the breech thoroughly. **Refer** to section 4.10.

4.7.3.10. **Reload** the breech, step 4.5.5, and **repeat** the firing procedure.

4.8 System Safing

4.8.1. **Disconnect** the BNC from the firing pin solenoid.

4.8.2. **Remove** the protective metal sleeve.

4.8.3. **Remove** the firing pin solenoid with the special wrench.

4.8.4. **Remove** the breach assembly from the barrel.

4.8.5. **Discard** the .38 cartridge into the proper container. **Discard** any unburned powder in the canister designated for unburned powder.

4.9 Shutdown Procedure

4.9.1. **Turn off** the warning beacon.

4.9.2. **Turn off** the helium K bottle.

4.9.3. **Review** the high-speed video film.

4.9.4. **Record** velocity on the shot sheet.

4.9.5. **Disassemble** the HIG brake tube (and catch tube, *if necessary*), and **retrieve** the sabot.

4.9.6. **Photograph** the recovered sabot assembly at the end of the of test series.

4.9.7. **Photograph** the sample**.**

4.9.8. **Record** any comments on the shot sheet.

4.9.9. **Clean** the HIG as described in section 4.10.

4.10 System Cleaning

The HIG **shall be cleaned** after each shot. Personnel **shall clean** the HIG as follows:

4.10.1. **Don** safety glasses and gloves.

4.10.2. **Clean** the launch tube using a rod to run three to five rags saturated with alcohol through the breech end to the impact chamber to remove polyethylene.

Note: **Remove** the rags from the slotted region of the impact chamber using needle nose pliers.

4.10.3. *If necessary,* **hone** the launch tube using the honing device and a drill until all debris from the inside surface is removed, usually three to four times.

4.10.3.1. **Inspect** the honing stones before use to ensure they are not excessively worn. Worn stones can scratch the inside surface of the launch tube .

4.10.3.2. **Insert** the honing stones and rod in the launch tube.

4.10.3.3. **Attach** the drill, and **switch** it for clockwise rotation.

4.10.3.4. **Slowly move** the honing rod through the launch tube to the stop piece on the rod.

4.10.3.5. **Reverse** the drill direction to counter clockwise, and **retract** the honing rod.

4.10.3.6. Lightly **clean** the honing stones with fine grit sand paper between each insertion.

4.10.4. **Clean** the entire brake tube length by running a series of rags saturated alcohol from the launch tube through the target chamber to the recovery end.

4.10.4.1. **Place** the plunger end of the holding cylinder in the breech end of the gun, and **unwrap** approximately 50 feet of slack.

4.10.4.2. **Use** compressed air to blow the plunger through the entire gun.

4.10.4.3. **Pull** (1) alcohol-wetted shop cloth rags, (2) a two-ended bristle brush, (3) lint-free rags, and (4) a dry lint-free rag through launch tube, impact chamber, and brake tube.

4.10.4.4. **Visually inspect** the brake tube for cleanliness, and **repeat** step 4.10.3.3 *if necessary.*

Note: Compressed air can be blown down the gun to remove any remaining particulate.

4.10.5. **Vacuum** and **wipe** with alcohol the two sections of the impact chamber, *if debris is present.*

4.10.5.1. **Remove** the lid from the smaller chamber end, and **vacuum** each valve port and all walls.

4.10.5.2. Lightly **wet** a shop cloth rag with alcohol, and **clean** all walls, the insides of the port, and the lid.

4.10.5.3. **Remove** the lid from the impact chamber. **Vacuum** the chamber and the slots within the chamber. **Clean** these with generous amounts of alcohol, rags, and Q-tips.

Note: Turn on the stage light to assist in locating particulate matter between the slots of the target chamber.

Note: **Remove** the rags from the target chamber's slotted region using needle nose pliers.

4.10.4.4. Thoroughly **douse** the chamber and slots with alcohol, and **wipe** dry with rags and Q-tips.

4.10.4.5. **Reinstall** the impact chamber lids.

4.11 Data Recording and Reduction; Post-Test Photography

All test data **shall be recorded** in appropriate laboratory notebook or on test specific shot sheets (Figure 7.3-5). Reports documenting test results **shall be written, provided, and maintained** in accordance with EM50-OWI-003, *Control of Records*. All forms (section 7) **shall be included** with a memo to the requesting office. The report of results from each test **shall include t**he following:

- Specimen shot data including calibration shots, with photos before and after the shot
- Impact velocity
- Water drop diameter
- Instrumentation data (spreadsheet, photos, video), as applicable
- Plans for further testing, if applicable
- A statement of any other relevant items that might be deemed important.

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5.0 Notes

Custodians for EM50-OWI-037	
Master List and Document Control	EM50 Branch ISO Representative
Alternate Document Control	EM50 Branch ISO Representative
Records	Environmental Effects Branch ISO Representative
Calibration	Environmental Effects Branch Calibration Contact
Memoranda	Environmental Effects Branch ISO Representative

6.0 Safety Precautions and Warning Notes

Warning
Death, severe personal injury, or loss of major equipment may result if maintenance or operating procedures, techniques, restrictions, etc., are not followed exactly.

6.1 Hazards

The nature of operating the HIG involves several potential hazards, including:

- Storage, transportation, and handling of smokeless propellant
- Preparation and loading of explosive charges
- Flammability risks from powder
- Potential damage to eyesight from laser systems.

6.2 Safety Precautions

Proper safety procedures **shall be followed** for all operations.

6.2.1. Preparation and firing of the HIG **shall be supervised** by a Range Operator in accordance with this OWI. **The Range Operator's authority includes the right to order off the range anyone who interferes with or contravenes safety precautions.** The Range Operator **shall also be permitte**d to postpone or cancel any firing in the interest of safety.

6.2.2. HIG system setup, testing, and shutdown **shall be planned** so that at least one certified Range Operator and one explosive-certified person are in attendance during HIG loading and firing operations.

6.2.4. No more than 2 trainees at a time shall participate in firing the HIG.

6.2.5. In accordance with Occupational Safety and Health Administration requirements, all personnel involved in HIG operations shall **read** the Materials Safety Data Sheets (MSDSs) for all chemicals used or encountered during testing and shall **read the test material's MSDS to ensure familiarity with all safety precautions associated with the material.**

6.2.6. The Ranger Operator **shall ensure** that all personnel understand Safety information.

6.2.7. **Smoking shall not be permitted** in Building 4571.

6.2.8. Personnel **shall wear** safety apparel appropriate for HIG operations:
- Face shields when preparing and loading a charge
- Face shields, long sleeves, and gloves during LN_2 loading.
- Safety glasses during cleaning operations with solvents or liquids
- Proper gloves and laboratory coats during cleaning operations
- Wrist stats connected to ground when preparing and loading a charge

6.2.9. Personnel **shall always stand to the side** of the HIG breech and **shall never walk or stand behind the breech.**

6.2.10. The projectile **shall not be loaded** into the barrel until the bore has been visually inspected to ensure there are no obstructions.

6.2.11. The outside flashing red light (Figure 6.2) **shall be turned on** just before preparing the powder and loading the breech. The warning signal **shall remain** on until the firing has been completed and the range area is clear to all personnel, as determined by the Range Operator.

Figure 6.2.
Building 4571 signage and flashing warning light

6.2.12. *If, during firing, a range structure sustains damage or some other anomaly occurs,* no further firing **shall be carried out** until the damage is repaired or the proper corrective action has been taken. The Range Operator **shall permit** further operations only when satisfied that personnel or equipment are not endangered.

6.2.13. Powder handling operations **are prohibited** when Test Area is under a lightning warning.

6.2.14. The area and this test facility are deemed hazardous operations; therefore, only authorized personnel **shall be allowed** in the facility during test operations.

6.2.15. All warning signs, lights, and sirens **shall be obeyed** at all times.

6.2.16. All mechanical connections for compressed gas **shall be verified** as leak free and properly anchored.

Note: When changing out compressed gas bottles, **bleed** the system by opening the hand valve to the chamber to ensure no pressure remains in the line before disconnecting the bottle.

6.2.17. System electrical cords **shall be inspected** to ensure that all safety requirements are met. Any unacceptable conditions **shall be corrected** immediately.

6.3 Special Hazards Associated with Compressed Gases and Liquids

6.3.1. All operations involving compressed gases and liquids **shall be conducted** with at least two people in visual contact in the facility.

6.3.2. All operating personnel **shall be instructed** on the nature of hazards associated with compressed gases and liquids.

6.3.3. Before removal of any component of the system for servicing, the operator **shall secure** and **inspect** the system to ensure that no unsafe condition exists.

6.3.4. Personnel **shall perform** continuous monitoring, *e.g.,* check operating pressures, look for leaks, listen for unusual noises, during all operations. Personnel **shall ensure** that oxygen leak levels are adequate throughout operations.

6.4 Emergency Shutdown

There is no emergency shutdown required for the HIG.

6.5 Accident Reporting

6.5.1. From a safe location, the Range Operator **shall immediately call 911** and **notify** the EM50 Space Environmental Effects Team Lead and Branch Supervisor.

6.5.2. From a safe location, the notified *EM50 Space Environmental Effects Team Lead* **shall immediately report** the accident to the NASA Safety Monitor and the appropriate supervisor(s).

6.6 Emergency Response Plan

Emergency procedures and plans for Building 4571 are incorporated into the OWIs and are stated in MPG 1040.3G. *MSFC Emergency Plan*. Plans shall be modified if operations change in a significant manner.

6.7 Mishap Reporting

"Each employee is responsible for reporting emergencies, unsafe or potentially unsafe conditions, mishaps and close calls in the workplace.[1]"

Personnel **shall report** all mishaps occurring in Building 4571 to the *Range Operator*, who shall **report** the mishap to the *Branch Supervisor,* who shall **report** the mishap or close call in accordance with MWI 8621.1, *Close Call and Mishap/ Incident Reporting and Investigation Program*.

- For all Type A & B mishaps, *Branch Supervisor* shall immediately (as soon as possible) **initiate** an initial verbal report to the Center Director and S&MA Director.

[1] MWI 8621.1 *Close Call and Mishap/Incident Reporting and Investigation Program.* March 27, 2000. pg. 7.

Note for contractor employees: In the absence of the Range Operator and the Branch Supervisor or other NASA employee, any employee shall be authorized to initiate verbal notification of the Center Director and S&MA Director immediately (as soon as possible).

- For all mishaps and close calls, a flash report is required and **shall be generated** within 4 hours of the mishap occurrence. The *employee reporting the mishap or close call* **shall notify** his/her supervisor immediately. The *employee's immediate supervisor* **will call** 544-4357, Option 0, to generate the flash report. In addition, the *employee's immediate supervisor* **must submit** NASA Form 1627 to S&MA within 6 calendar days. All mishaps **shall be reported** in accordance with MWI 8621.1, *Close Call and Mishap/Incident Reporting and Investigation Program.*

7.0 Attachments, Data, Reports, and Forms

7.1 Attachments

7.1.1. Calculating Calibration Curves

The amount of gun powder needed to propel the sabot at a given velocity is proportional to the sabot's mass (Eq. 1):

$$M_{p1}/M_{S1} \times M_{S2} = M_{p2} \qquad \text{(Eq. 1)}$$

where:

M_{p1}/M_{S1} = ratio of powder mass to sabot mass (commonly written P/M) to attain a desired velocity

M_{S2} = mass of the test sabot

M_{p2} = mass of powder (grams) required to attain test velocity (g)

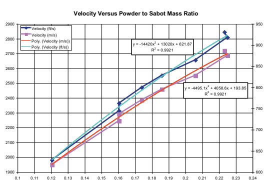

Figure 7.1-1.
Example of P/M calibration curve

P/M calibration curves (Figure 7.1-1) are used to predict appropriate powder/mass ratios for desired velocities.

7.1.1.1. For tests for which P/M calibration curves have been generated, **use** the HIG shot sheet (Figure 7.3-5) to calculate the amount of powder required to attain the requested velocity.

7.1.1.2. For tests that have no P/M calibration curves, curves from previous tests may provide a rough approximation of the powder/mass ratio. **Start** with a powder charge below that required to calculate the maximum velocity encountered in previous tests. **Adjust** the powder charge as necessary to attain required velocity. Calibration is complete when the powder/mass curve is determined.

Note: This powder-to-sabot-mass plot can be generated as tests are performed. Velocity should be increased in small increments using previous P/M plots as a general guide.

7.1.2. Determining Water Drop Size and Drop Rate

The HIG high-speed camera system is supported by a laptop computer outfitted with Photron FASTCAM Viewer; this software enables selection of the playback rate and one-frame-at-a-time review of the video. Use these features to calculate water drop size and drop rate (velocity).

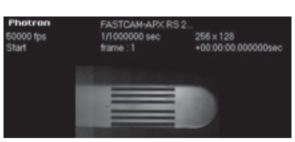

Figure 7.-21.
Grid installed in impact chamber slot

7.1.2.1. **Install** grid in the center of the impact chamber slot so that it is in the plane through which the drop will fall (Figure 7.1-2).

7.1.2.2. **Turn on** the 1000-W flood light, and **align** it and the high-speed camera so that the barrel slot is inside the camera's viewing window.

7.1.2.3. **Take** grid measurements using digital calipers, noting how many calibrated lines (real distance) are being measured.

Note: Ensure calipers are zeroed and set to inches.

7.1.2.4. **Record** these measurements in the log book and shot sheet (Figure 7.3-5).

7.1.2.5. **Divide** the actual distance by the measured screen distance, and **record** this number.

7.1.2.6. **Measure** screen drop diameter just before sabot impact, and **record** this number

7.1.2.7. **Record** sabot first frame time, *i.e.,* when the sabot first enters the barrel slot.

7.1.2.8. **Record** sabot last frame time, *i.e.,* last frame before front of sabot disappears.

7.1.2.9. **Place** scotch tape on the computer screen, and **mark** first frame and last frame. **Measure** and **record** this distance (called the screen delta L).

7.1.2.10. In the HIG shot sheet from any of the runs since March 2006, **enter** the grid width measured (usually 9 mm). **Enter** the measured screen distance in inches. This sets the distance calibration in the spreadsheet.

7.1.2.11. **Enter** the first frame and last frame time for the sabot in seconds.

7.1.2.12. **Enter** the screen delta L in inches.

7.1.2.13. **Enter** the screen drop diameter in inches.

7.1.2.14. Shot velocity and drop diameter are calculated from the spreadsheet.

- Velocity is calculated by taking dividing the real distance traveled by the sabot by the time it took to go that distance, which is the screen delta L multiplied by a constant divided by the difference between the first and last sabot frame times. V = delta L x Const/(first frame time-last frame time) The Const comes from a ratio of the real grid distance to the screen distance.
- Drop size is Const x Screen Distance x conversion factor from in to mm.

7.2 Reports

Testing **shall** be reported in weekly notes. A final test report **shall** be sent to the test requester at the end of the test series, unless otherwise requested. Test results are also contained in a database.

All test data **shall be recorded** in the appropriate laboratory notebook or on test-specific shot sheets.

7.3 Forms

7.3.1. System Initial Preparation Checklist: Figure 7.3-1 shows a representative sample of the System Initial Preparation Checklist. This checklist does not require archiving.

7.3.2. Pre-Load Checklist: Figure 7.3-2 shows a representative sample of the Pre-Load Checklist. This checklist does not require archiving.

7.3.3. HIG Firing Procedure Checklist: Figure 7.3-3 shows a representative sample of the HIG Firing Procedure Checklist. This checklist does not require archiving.

7.3.4. System Cleaning Checklist: Figure 7.3-4 shows a representative sample of the System Cleaning Checklist. This checklist does not require archiving.

7.3.5. HIG Shot Sheet: Figure 7.3-5 shows a representative shot sheet, which **shall be generated, tracked,** and **documented**. HIG Shot Sheets **shall** be maintained as records.

Figure 7.3-1.
System Initial Preparation Checklist (sample)

System Initial Preparation Checklist

________ 1. Brake tube packed
________ 2. Brake tube sealed with disk and prophylactics
________ 3. Catch tube foam replenished
________ 4. Metal end cap installed on catch tube
________ 5. Catch tube properly positioned around brake tube
________ 6. Breech end of HIG plugged with rubbert stopper
________ 7. Target chamber lids secured
________ 8. Vacuum pump turned on
________ 9. Vacuum of 200 millitorr obtained
________ 10. LN_2 trap filled
________ 11. Vacuum on target chamber <200 millitorr

Note: Representative checklist.

Figure 7.3-2.
Pre-Load Checklist (sample)

Pre-Load Checklist

Shot Number				Step Number	Step Description
Water Solution Preparation					
				1	Large syringe filled with ethylene glycol and deionized water
				2	Filter tip screwed on end of syringe, replaced as necessary
				3	Solution filtered into a clean flask
				4	Flask and solution brought to boil on a hotplate
				5	Rubber stopper pressed firmly into the flask (air tight)
				6	Flask placed in beaker of water at room temperature
				7	After returning to room temperature, flask placed in second beaker of boiling water for ~1 minute
				8	Stopper firmly secured
				9	Flask set aside until cool
				10	Appropriate syringe filled with the degasified mixture
				11	Log the syringe size logged on the shot sheet
Sabot Preparation					
				1	Sample installed onto plastic insert,
				2	Sample/insert placed into top piece of sabot
				3	Attach the bottom of sabot attached
				4	Sabot fin undamaged
				5	Holes drilled for nylong string
				6	Nylon string inserted into assembly holes
				7	Excess string shaved; string flush with sabot surface
				8	Mass of sabot assembly measured and recorded on shot sheet

Note: Representative checklist.

Figure 7.3-3.
HIG Firing Procedure Checklist (sample)

HIG Firing Procedure Checklist

Shot Number				Step Number	Step Description
					Breech Loading
				1	Shot velocity calibrated
				2	Powder charge determined
				3	Building warning beacon activated
				4	Exit doors closed and secure
				5	All personnel in HIG area authorized by Range Operator
				6	Breech loaded:
				7	Charge preparation performed on the grounded, non-sparking table
				8	All jewelry, wrist watches, keys, etc., removed
				9	New primer pressed into the cartridge
				10	Face shields and wrist stats donned.
				11	Wrist straps tested with a calibrated meter
				12	Appropriate powder container secured from magazine
				13	Wrist stats connected to ground
				14	Scales zeroed out
				15	Required weight for total charge measured/recorded on shot sheet
				16	Weighed powder poured into cartridge shell
				17	Cartridge inserted into breech
				18	Electrical tape placed over the cartridge/primer
				19	Breech set upright on the grounded, non-sparking table atop copper O-ring
				20	Remaining powder poured into center of breech
				21	Foam plug pressed down over the powder charge
				22	Breech press assembly installed over press tube/plug, screwed down until voltmeter reads 15 mV
				23	Assembly settled until ready to shoot
				24	Powder container returned to magazine
					Firing
				25	Target chamber and lauch tube backfilled with helium
				26	Sabot inserted in launch tube
				27	Breech press and elecrical tape removed
				28	Breech assembly installed
				28	Firing pin soleoid attached to breech assembly; armature touching base
				29	Metal sleeve placed over launch tube/breech/solenoid
				30	BNC connector attached
				31	Armature pulled back
				32	Syringe inserted into liquid drop dispenser
				33	Pump valve switched on; vacuum at <200 millitorr
				34	Helium valve closed
				35	Vacuum valve opened; HIG pumped to 200 millitorr
				36	Camera and backlight set up
				37	Laser aligned with falling drop
				38	Drop size and drop fall rate confirmed and recorded
				39	Delay set
				40	Trigger functioning
				41	Vacuum pump valve turned off
				42	Good drop formed
				43	RECORD READY button pushed
				44	Pneumatic acuator switch pressed.
				45	Operator yells “FIRE”

Note: Representative Checklist For Illustration only.

System Cleaning Checklist

- _____ 1 Safety glasses and gloves donned
- _____ 2 Launch tube cleaned with rags saturated with alcohol
- _____ 3 Launch tube honed; all debris on inside surface removed
- _____ 4 Target chamber and brake tube cleaned with rags saturated in alcohol
- _____ 5 Alcohol-wetted shop cloth rags, two-ended bristle brush, lint-free rags, run thorugh launch tube, target chamber, brake tube.
- _____ 6 Brake tube inspected visually for cleanliness
- _____ 7 Impact chamber vacuumed and wiped with alcohol
- _____ 8 Each valve port and all walls of target chamber vacuumed
- _____ 9 All walls, insides of port, and lid cleaned with alcohol and shop rag
- _____ 10 Vacuum the Impact chamber and slots vacuumed, wiped with alcohol
- _____ 11 Impact chamber/slots thoroughly doused with alcohol and wiped dry

Note: Representative Checklist For Illustration only..

Figure 7.3-4.
System Cleaning Checklist (sample)


shot sheet example.xls

MSFC RAIN GUN

Date:
Job No.:
SHOT No.
Reference No.
SPECIMEN No.
Material Type
PARTICLE
Expected Velocity (ft/s)
Expected Velocity (m/s)
Impact Angle

RECOVERY TUBE
Breach
End

PACKING (ft from barrel end)

CATCHER
Coffin:foam, CB
Suspended catcher: CB, rubber

COMMENTS:

SABOT CONSTRUCTION
Fin Type
Fin Diameter in.
Nose Type
Nose Diameter in.
No. of Pins

Sabot Length, L: in.
Sabot Mass: g
P/M ratio

Powder Estimate based on P/M ratio
Est Main Charge g
Primer Charge g
Est Total Charge g
Actual Total g
Actual P/M

TIMING (ms)
Total Time to first frame (ms)
Delay Box (ms)
Drop Fall Time Center of slot (s)
Corrected Delay at same velocity
Transit time trig to first frame (ms)

High Speed Camera Settings
Frame rate per second
Shutter speed per second
Trigger

RESULTS
Shot Vacuum (mtorr)
Time of first frame (s)
Time Time of last frame (s)
Screen Delta L (in)
Screen to grid Width (in)
Screen Drop Diameter (in)
Sabot Velocity
Real Delta L (in)
Velocity (ft/s, Frames method)
Velocity (m/s, Frames method)
Delta T (ms)
True Drop Size (mm)

RECOVERY
Sabot:
Specimen:

IMPACT:

Note: Representative Shot Sheet. Refer to Forms Master List for current version.

Figure 7.3-5.
HIG Shot Sheet (sample)

8.0 Records

8.1 Memoranda

Memoranda containing test results **shall be retained** for a minimum of 5 years by EM50.

8.2 Calibration Records

All HIG equipment requiring calibration **shall be** in current calibration. Calibration records **shall be maintained** on site for a minimum of 1 year.

8.3 Maintenance of Records

All test data **shall be recorded** in an appropriate laboratory notebook or computer or on test specific shot sheets.

Records required to support testing per this OWI and records of test results **shall be maintained** in accordance with EM50-OWI-003, *Control of Records.*

9.0 Tools, Equipment, and Materials

9.1 Standard Configuration

The Hydrometeor Impact Gun provides the ability to test materials against a single water drop impact. The sample can have a velocity from 300 ft/sec to ~3300 ft/sec (Mach 3), and the drop diameter can be up to 5 mm. The sample size can be up to 20 mm in diameter with impact angles from 30 ° to 90 °.

The system (Figure 9.1) consists of the following components:

- 30-mm cannon (launch tube): ~8 ft long; contains the sabot and breech (holds powder charge)
- Impact chamber: about 1 ft square and 3 ft long, made of steel and Lexan. On top of the chamber is a syringe that drops a steady stream of water drops into test chamber. A set of lasers coordinates firing sequence timing, valve opening, photography, and sample velocity measurement.
- Brake tube: ~ 40-ft long, allows safe braking and recovery of the sample vehicle without doing damage to the sample following the impact event.
- Vacuum pump: the cannon section and impact chamber are pumped down to <200 millitorr, and the system is backfilled with helium before firing
- Aluminum catch tube; filled with foam as a final catch box for the sabot.

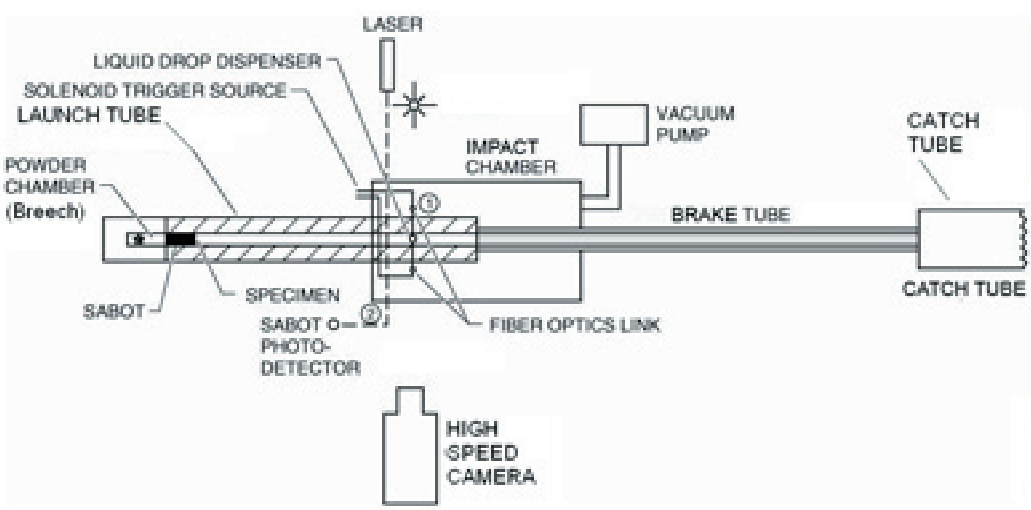

Figure 9.1.
HIG Schematic

9.2 Procedure for Deviations

Deviations to the baselined Hydrometeor Impact Gun configuration require NASA written approval. The Range Operator **shall obtain** the written approval. After written approval is received, the change **shall be added** to the appropriate *Hydrometeor Impact Gun Control Book.*

9.3 Required Maintenance

The standard maintenance program for the Hydrometeor Impact Gun and related control equipment involves a maintenance log, calibration, and a required spare parts inventory. The vacuum pump oil **shall be checked** and **changed** monthly. The helium regulator shall be certified yearly. The breech section shall be inspected every 5 years using nondestructive evaluation techniques.

9.4 Calibration

Calibration **shall be maintained** on critical instrumentation in accordance with MPR 8730.5, *Control of Inspection, Measuring, and Test Equipment.* All instrumentation associated with the test system that requires calibration **shall have** current calibration stickers. *If any instrument calibration is out of date,* personnel **shall refer to** MPR 8730.5 on how to deal with out-of-calibration equipment. Building grounding shall be checked yearly.

Calibrated equipment lists of all categories for this OWI **shall be kept** by the Range Operator and **shall include** the multimeter, regulator, and balance.

9.5 Required Spare Parts Inventory

Not applicable.

10.0 Personnel Training and Certification

The nature of work that occurs in the Impact Testing Facility, Building 4571, is complex and involves potential hazards; therefore, all activities covered by this OWI shall be performed only by certified HIG personnel or under the direct supervision of personnel certified to do this work.

The Range Operator is responsible for the training and certification of HIG operators. Individuals shall train under certified operators. No more than two trainees shall participate in firing of the HIG. Training **shall** be overseen by the EM50 Management Support Assistant. The Range Operator may withdraw an operator's certification at any time.

10.1 Range and HIG Operator Certification

Certification as a Range or HIG Operator requires that the candidate:

- Successfully complete requirements for the following certification specialities as defined by MWI 3401.1, current revision:
  - Laser Safety
  - Propellant and Explosive User/ESD (NSS 1740.12)
- Successfully complete training in the following subjects**:
  - Use of Personal Protective Equipment
  - Operation of the HIG range
  - Cryogen Handler
  - High-Pressure Systems (>150 psig)
- Read this OWI thoroughly, and sign a statement of reading and understanding the OWI. Each candidate **shall have access** to a current version of the OWI.
- Demonstrate proficiency in:
  - Preparing the HIG system for firing
  - Preparing and loading charges
  - Performing pre-firing inspections
  - Performing the firing procedure
  - Performing post-firing system safing
  - Cleaning and minor maintenance of the HIG.

The candidate's signed statement and training record shall constitute verification of certification. Certification shall also be documented in a letter from the EM50 supervisor to the Manager of the Materials and Processes Laboratory with a copy to S&MA (QD01).

EMERGENCY PHONE NUMBERS

Emergency.......................... 911

Medical Center.................... 4-2390

Industrial Safety.................. 4-0046

Chemical Spills.................... 4-4357

EM50 Branch Supervisor..... 4-2529

EM01 Laboratory Manager.. 4-7647