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BALLISTIC IMPACT RIG OPERATIONS MANUAL

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AFRL/RXCC

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AFIT/ENY

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Manual

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To date, no Operations Manual has ever been written for AFIT's home built Ballistic Impact Rig (BIR). The lack of such a manual makes learning how to use AFIT's BIR a time consuming, drawn out activity. In addition, due to the ballistic nature and high pressures within the system, the device can potentially be very dangerous to use. To overcome these training and retention difficulties and to assure the effective and safe operation of this intensively modified apparatus, this Operations Manual has been written. This Operations Manual clearly explains the functions and fundamentals behind each of the BIR's subcomponents. It also systematically documents the "XXX" operational sequence steps and their associated "XX" usage warnings required to use it safely and effectively for a typical experimental run.

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1 SUMMARY

To date no Operations Manual has ever been written for Air Force Institute Of Technologies' (AFIT) home built Ballistic Impact Rig (BIR). The lack of such a manual makes learning how to use AFIT's BIR a time consuming, drawn out activity. In addition, due to the ballistic nature and high pressures within the system, the device can potentially be very dangerous to use. To overcome these training and retention difficulties and to assure the effective and safe operation of this intensively modified apparatus, this Operations Manual has been written. This Operations Manual clearly explains the functions and fundamentals behind each of the BIR's subcomponents. It also systematically documents the "XXX" operational sequence steps and their associated "XX" usage warnings required to use it safely and effectively for a typical experimental run.

2 INTRODUCTION

Ballistic testing of materials is necessary to study residual mechanical performance in certain scenarios. The core problem with using home built apparatuses like the AFIT Ballistic Impact rig is that they are laden with quirks, are temperamental and require numerous detailed specific steps to effectively and safely operate. Their operational procedures are always long, complicated, convoluted and are never clearly or formally documented into an Operations Manual. The lack of such a manual makes learning how to use them a time consuming, drawn out activity, typically resulting in the breaking of the apparatus by the learner during training. Lack of an Operations Manual also makes it difficult to remember over time the numerous detailed, specific steps needed to effectively and safely operate such an apparatus.

To overcome these training and retention difficulties and to assure the effective and safe operation of an extensively modified apparatus, it is imperative that an Operations Manual be written for its use. An Operations Manual needs to clearly and briefly explain the functions of the apparatus' subcomponents. It must systematically document the operational steps and their required sequence for a typical use, along with a summarization of these steps into a usable check list.

AFIT's Ballistic Impact Rig is just such an example of an extensively modified apparatus. It was originally designed to test ballistics in simple scenarios. It has been exhaustively modified to accept new materials for testing, as well as a multitude of types of ballistic impactor materials.

3 EQUIPMENT AND SUBSYSTEMS

THROUGHOUT THIS MANUEL ITEMS IN RED DENOTE CRITICAL SAFETY OR EQUIPMENT USAGE ACTIVITIES WHICH THE USER MUST ADHERE TO OR POTENTIALLY SUFFER INJURY OR CAUSE DAMAGE TO THE BALLISTIC IMPACT RIG.

The Ballistic Impact Rig (BIR) consists of three sections. They are the Impact Section, Gas Gun Section and Control Section depicted in figure 1.

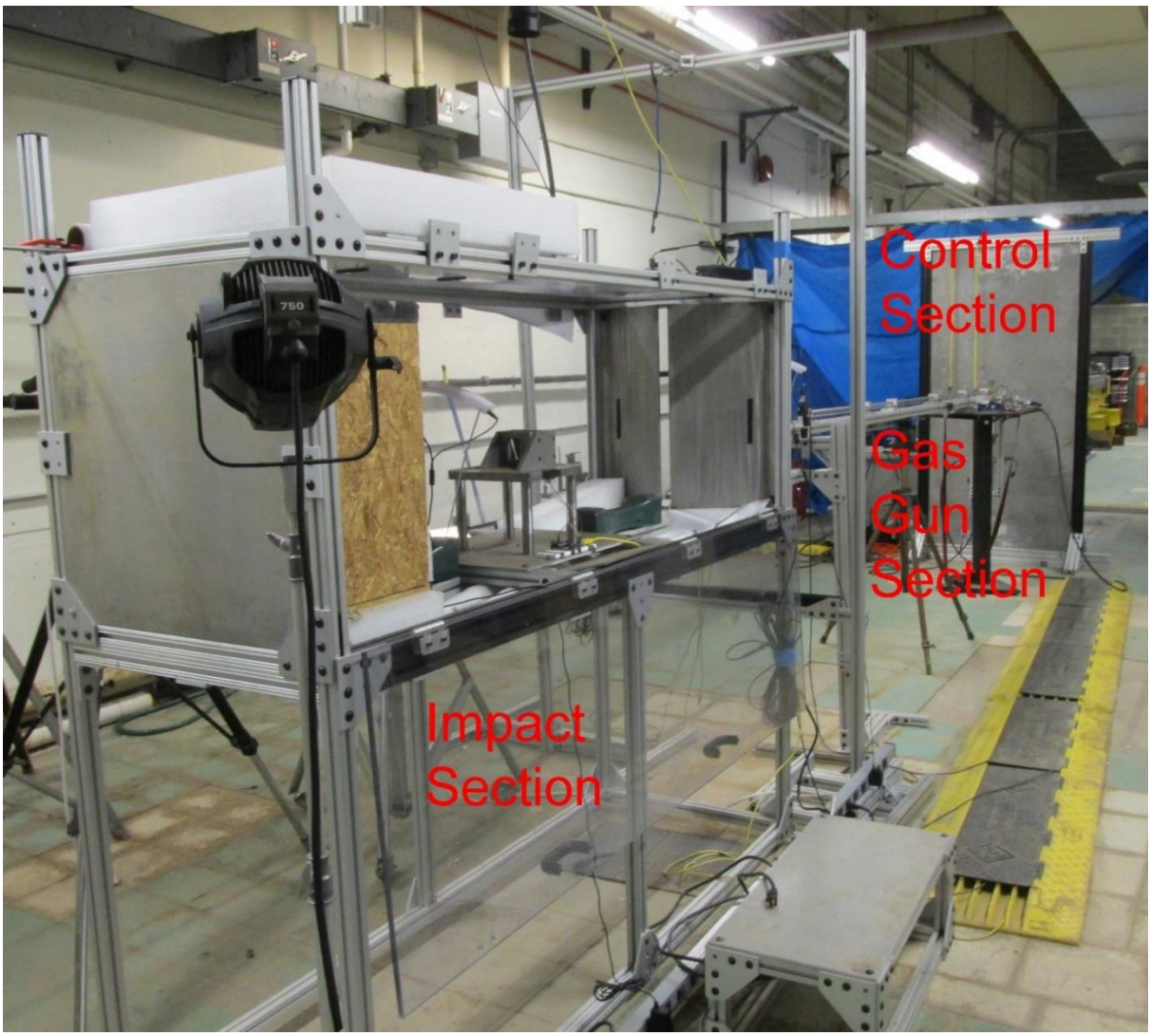


Figure 1: Ballistic Impact Rig.

3.1 Impact Section

The first section of the BIR is where a sample is impacted. It consists of the impacted sample holder, projectile catch trap, shrapnel-debris ballistic shield enclosure and projectile speed

acquisition camera. The impacted sample holder, projectile catch trap and shrapnel-debris ballistic shield enclosure are depicted in figure 2. Acquisition of the projectile's speed is accomplished with the high speed "Phantom" digital image camera, depicted in figure 3 after the surface of the specimen to be impacted is illuminated with the high intensity studio lighting depicted in figure 4. The digital image camera and the studio lights have their own support structures independent from the ballistic shield enclosure structure.

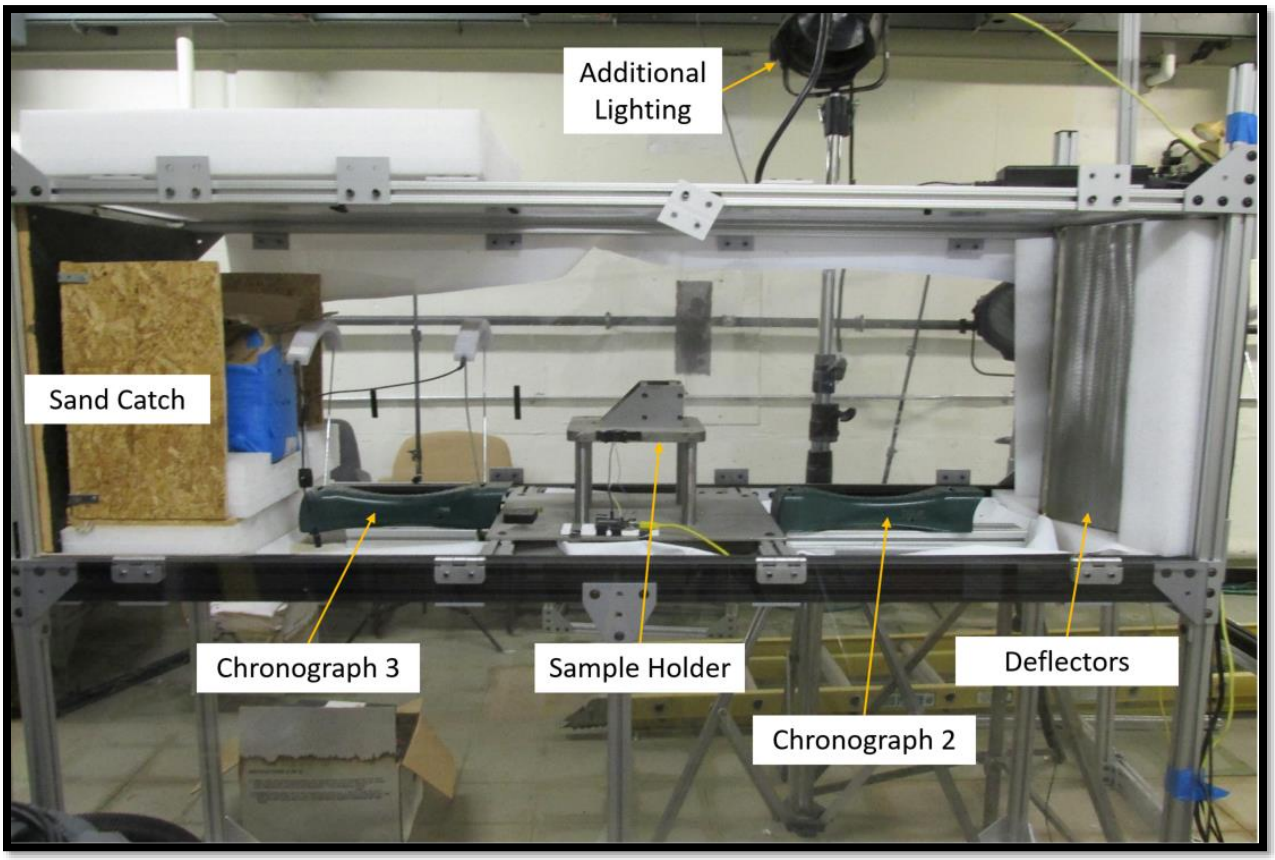


Figure 2: Impact Section.

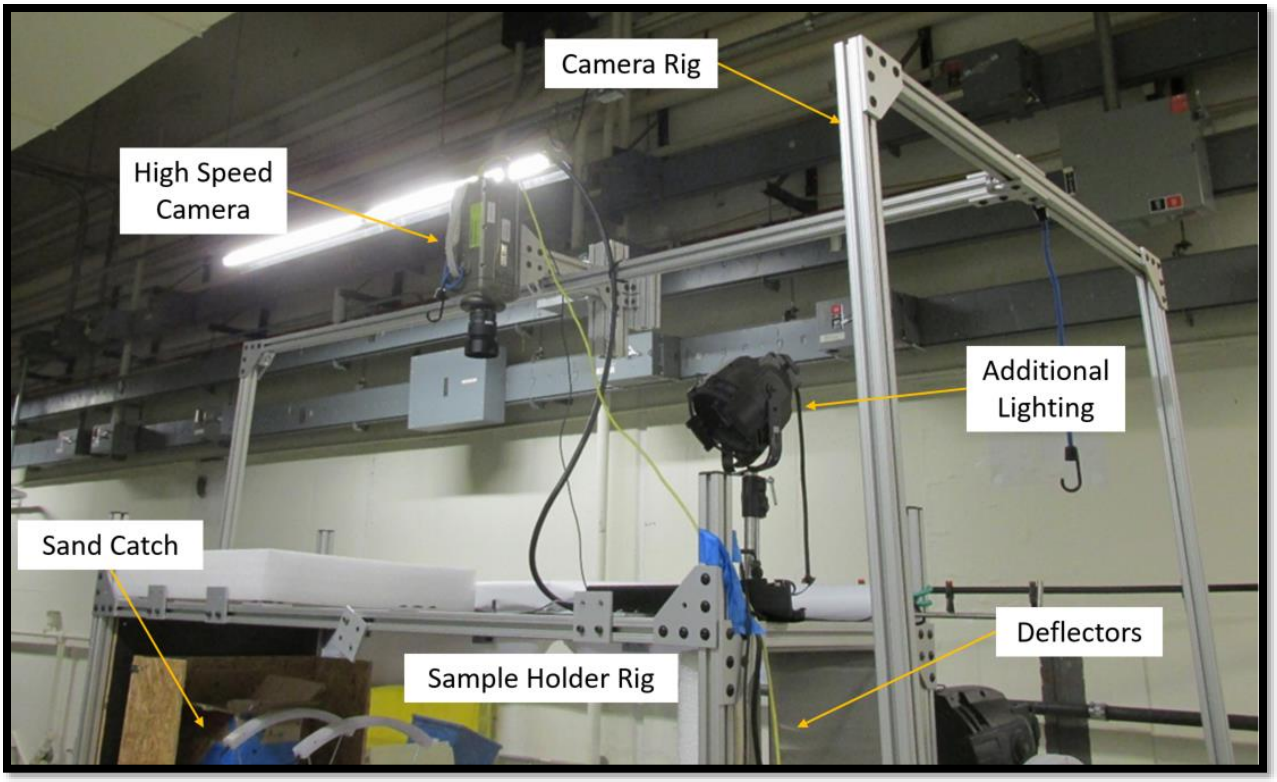


Figure 3: High Speed "Phantom" Digital Image Camera.

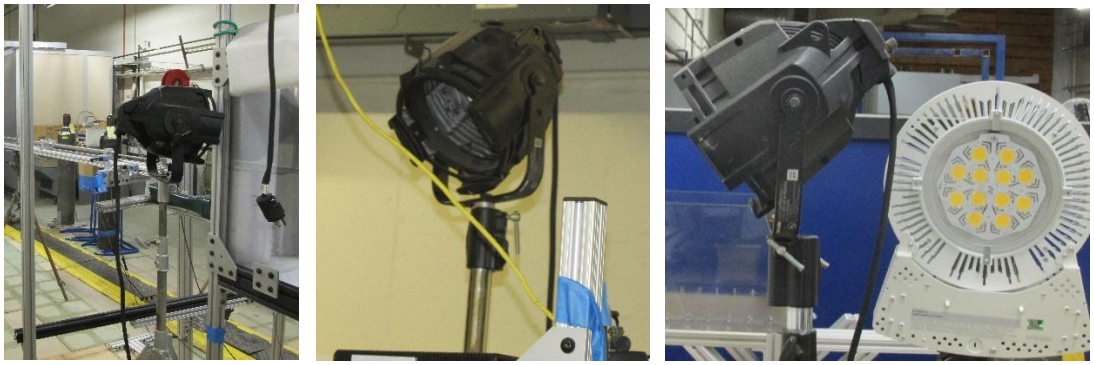


Figure 4: High Intensity Studio Lighting.

3.1.1 Sample Holder

Users should ensure the sample to be impacted is well mounted both to prevent hazardous debris and also to ensure data is properly recorded by the high speed camera as movement of the target material can negatively affect the accuracy of the recorded data. The Sample Holder can be changed to meet the needs of the test sample to be impacted.

3.1.2 **Projectile Catch Trap**

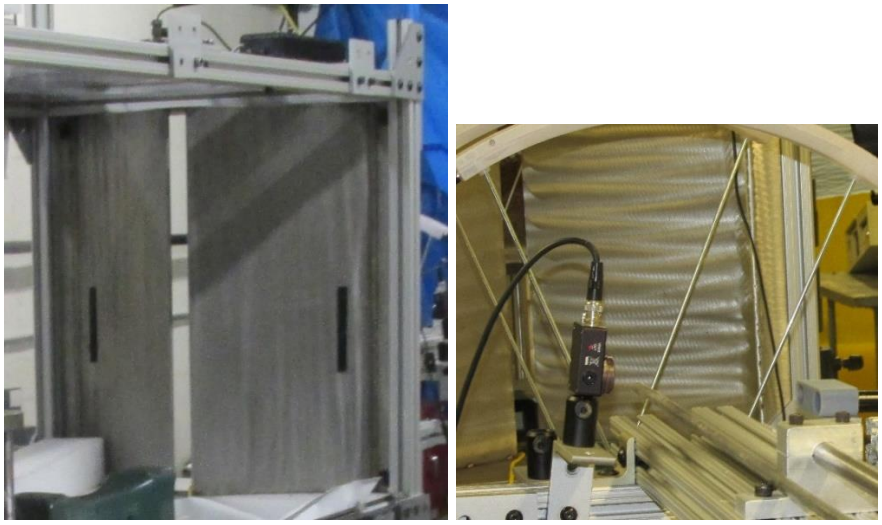
The projectile catch trap prevents the projectile from exiting out the back of the Impact Section should it penetrate the test specimen. This sub component is a blue tape covered, card board box filled with sand. Projectiles, which penetrate the specimen being tested, will punch holes in the blue covering tape. Because tape retains the sand as new holes appear, operators should tape over any hole in the Sand Catch box as soon as possible after the device is fired.

3.1.3 **Shrapnel-Debris Ballistic Shield Enclosure**

The entire impacting zone of the system is encased in clear ballistic rated acrylic to catch debris. If a sample is too large to close the ballistic shields, the user should use tarps and proper risk assessment to ensure safety before proceeding.

The front steel deflector plates, depicted in figure 5a, are angled to prevent a direct splash back onto the gas gun and control sections of the BIR should they be impacted. Only a small slit is open for the projectile to travel through. Users should ensure the barrel is lined up to fire into the sample holder without impacting the deflectors.

A rear steel deflector plate, depicted in figure 5b, is affixed to the back of the Shrapnel-Debris Ballistic Shield Enclosure to prevent any errant projectile from exiting the back of the Shrapnel-Debris Ballistic Shield Enclosure.



a: Front

b: Rear

Figure 5: Steel Deflector Plates.

3.1.4 Projectile Speed Acquisition

The speed of the impacting projectile is measured with the high speed "Phantom" digital image camera depicted in figure 3. This camera is mounted on a separate structure and hangs over the Shrapnel-Debris Ballistic Shield Enclosure with the camera focused downwards into the enclosure. The camera is manually focused and needs to be focused with each projectile's firing.

A commercial chronometer, typically used by rifle and pistol shooters to estimate a bullet's speed, is also available to provide an immediate rough estimate of the projectile's speed. As depicted in figures 5 thru 7 it is located between the front end of the Shrapnel-Debris Ballistic Shield Enclosure and the muzzle of the gas gun.

A sufficient number of the high intensity studio lights, depicted in figure 4, need to be directed onto the surface of the specimen to be impacted, so as to assure that there are no shadows on that surface. The studio lights have their own support structure independent from both the Shrapnel-Debris Ballistic Shield Enclosure and the digital image camera support structure.

3.2 Gas Gun Section

The second section of the BIR is where the projectile is accelerated up to a desired speed. It consists of the gas gun barrel, projectile loading rod and its loading into the gas gun barrel, its supporting and clamping structure, laser barrel alignment and the nitrogen gas projectile propulsion pressurization and fast release valves. The overall Gas Gun Section is depicted in figure 6.

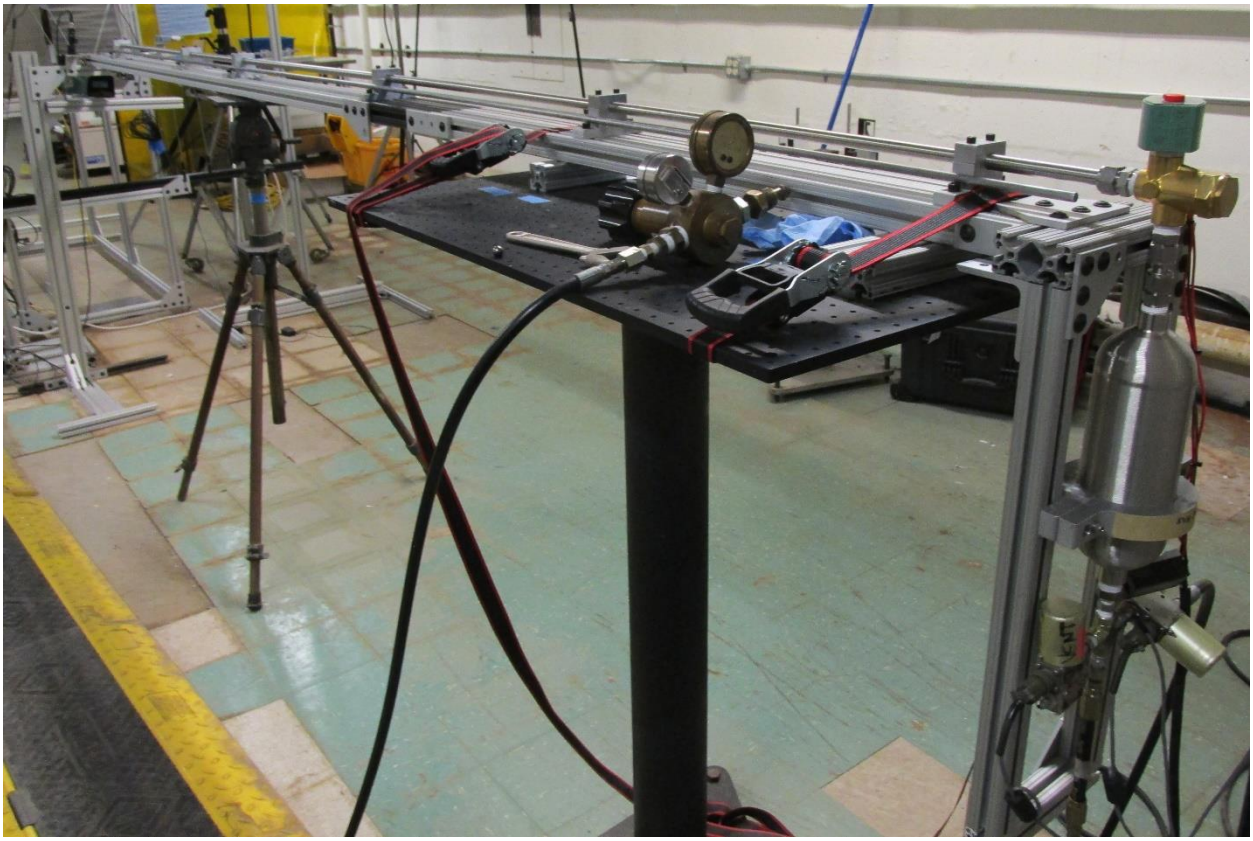


Figure 6: Gas Gun Section.

3.2.1 Gas Gun Barrel and Projectile Loading

3.2.1.1 *Gas Gun Barrel*

The gas gun's barrel consists of the twelve foot long, one half inch inter diameter steel tube depicted in figures 6 and 7. The gas gun's barrel is supported by set height stands and the barrel is kept straight by a series of Clamshell clamps which are bolted down to straight box beams and

spaced along the barrel as depicted in figures 7 and 8. The clamshell clamps are snugged down onto the barrel with the socket head cap screws depicted in figure 8.

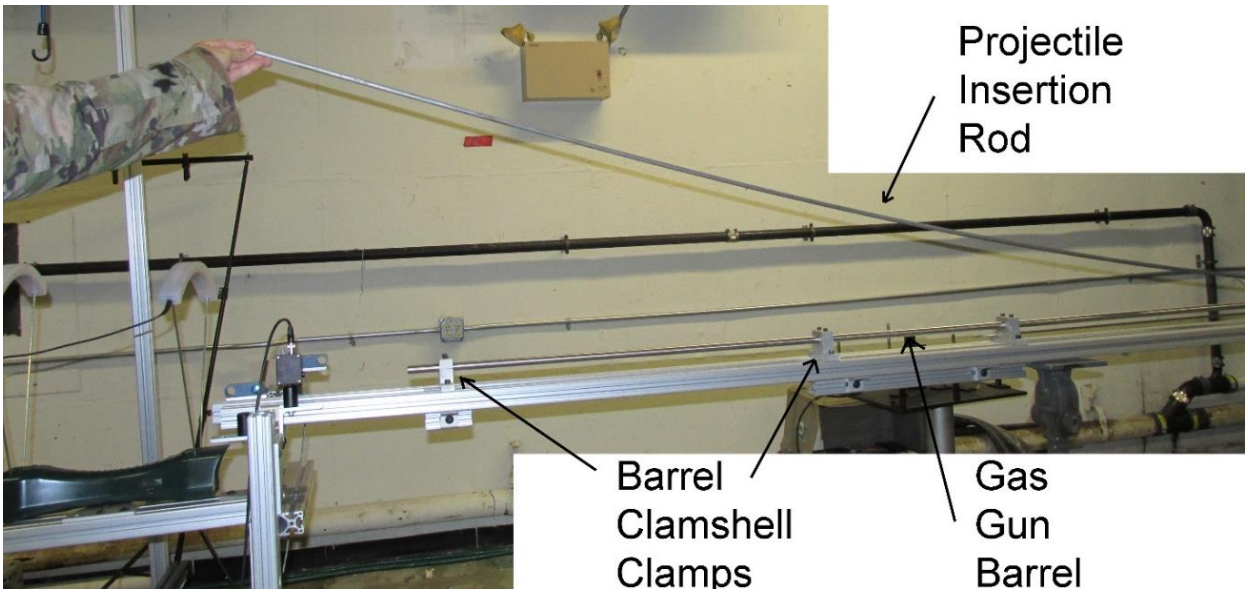


Figure 7: Projectile Insertion Rod And Supporting Structure.

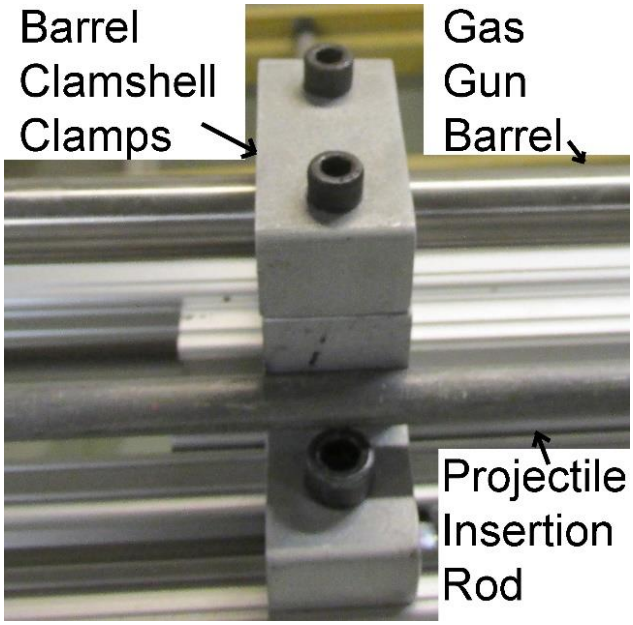


Figure 8: Barrel Clamps.

3.2.1.2 *Projectile And Projectile Preloading Preparation*

The gas gun propels (ie fires) one half inch outer diameter ball bearings depicted in figure 9 up to speeds as high as nine-hundred and fifty feet per second. A preselected projectile is prepared for loading into the gas gun barrel by being swaddled in a wadding patch, as depicted in figure 9,

which has first had a drop of “Hoppes” gun oil, as depicted in figure 10, applied to it. The oiled wadding patch swaddled projectile is then prepositioned near the muzzle of the gas gun for immediate future loading.

Figure 9: Ballistic Impact Ball Baring Swaddled In A Wadding Patch.

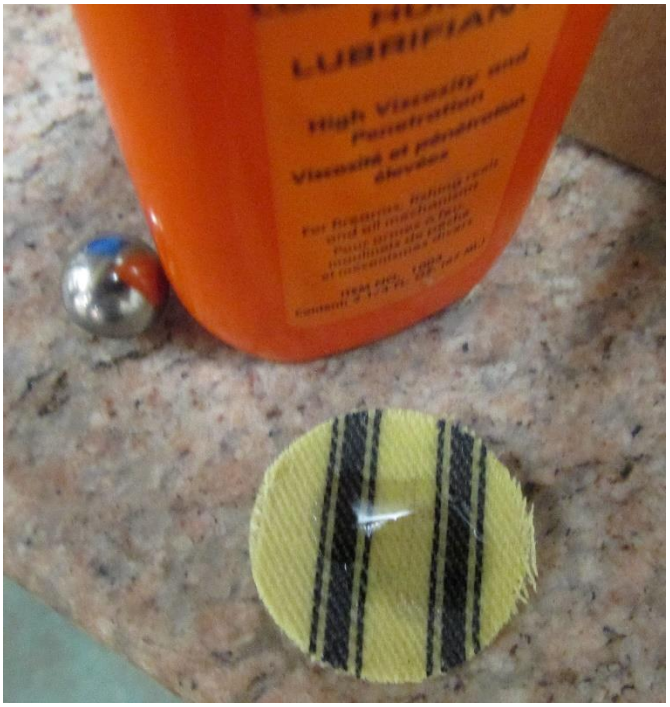


Figure 10: “Hoppes” Oiled adding Patch.

3.2.1.3 *Loading Gas Gun*

Loading the gas gun is accomplished by having the first of the two required BIR operators remove the projectile insertion rod from its storage position alongside the gas gun barrel and placing it alongside the Shrapnel-Debris Ballistic Shield Enclosure. Next the clamshell clamps

depicted in figure 7 are removed by unscrewing the socket head cap screws depicted in figure 8 with an "Allen" wrench and placed on the supporting structure. Using a "Crescent" wrench, the second required BIR operator unscrews the gas gun barrel breach attachment nut depicted in figure 11. The barrel is then lifted off of the supporting structure by the second required BIR operator. The prepositioned oiled wadding patch swaddled projectile is then seated into the muzzle of the gas gun's barrel by the first required BIR operator by being tapped into it, as depicted in figure 12, with a rubber mallet. Once the projectile is seated the first required BIR operator uses the projectile insertion rod to slowly push the oiled wadding patch swaddled projectile down the length of the barrel to a position near the breach of the barrel. The final oiled wadding patch swaddled projectile insertion rod position is achieved when the projectile insertion rod is inserted to the mark on the rod depicted in figure 13. **THE PROJECTILE INSERTION ROD IS THEN EXTRACTED FROM THE GAS GUN'S BARREL** and returned to its storage position on the gas gun support structure as depicted in figure 8. The loaded gas gun barrel is then returned to its' original position on the support structure. **THE GAS GUN BARREL BREACH ATTACHMENT NUT IS THEN SECURELY TIGHTENED WITH A "CRESCENT" WRENCH TO THE QUICK RELEASE VALVE** as depicted in figure 11. Next the clamshell clamps depicted in figure 7 are reattached to the supporting structure by screwing the socket head cap screws depicted in figure 8 down with a final gentle snugging with an "Allen" wrench.

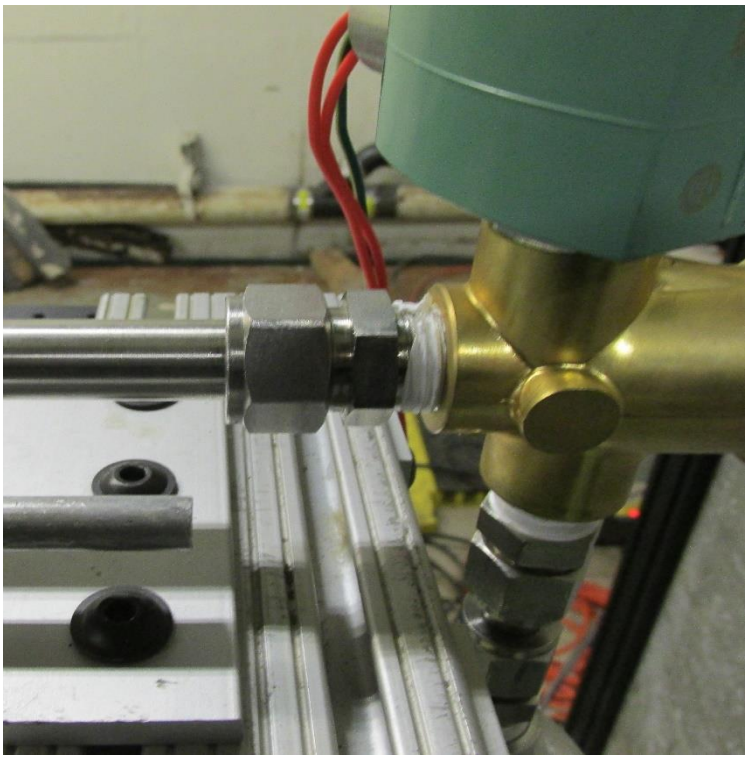


Figure 11: Gas Gun Barrel Breach To Quick Release Valve Attachment Nut.

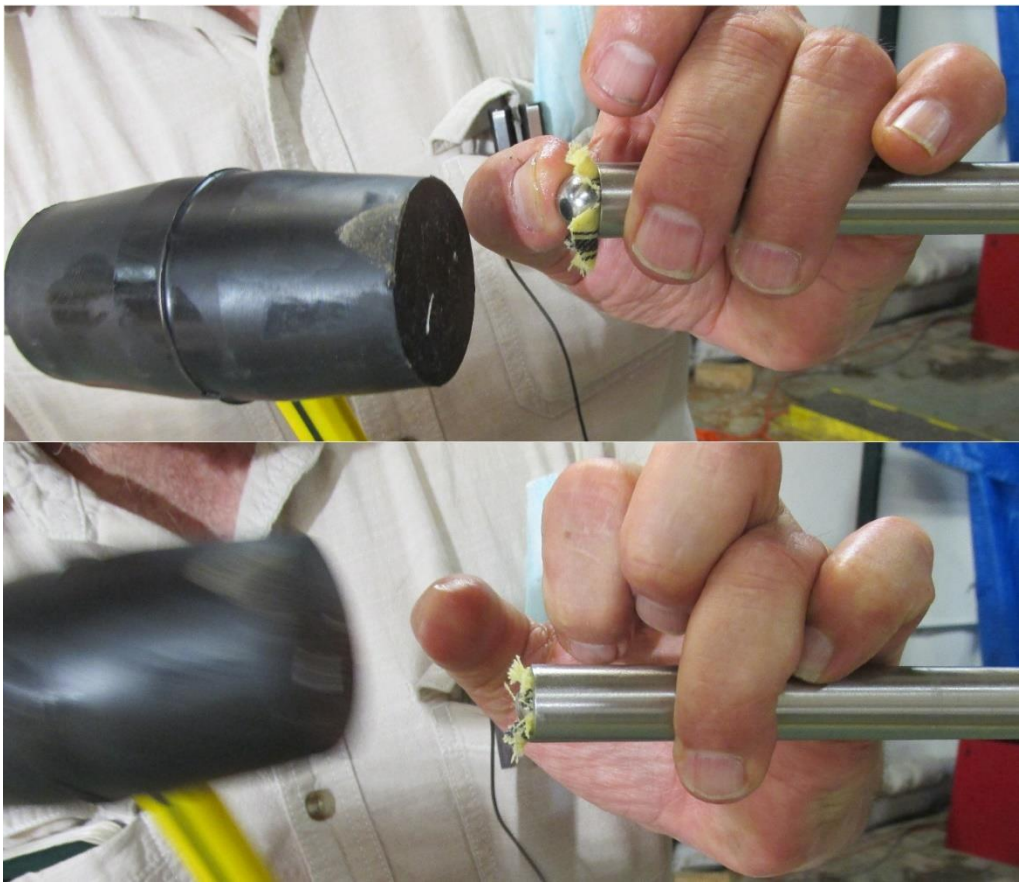


Figure 12: Seating An Oiled Wadding Patch Swaddled Projectile.

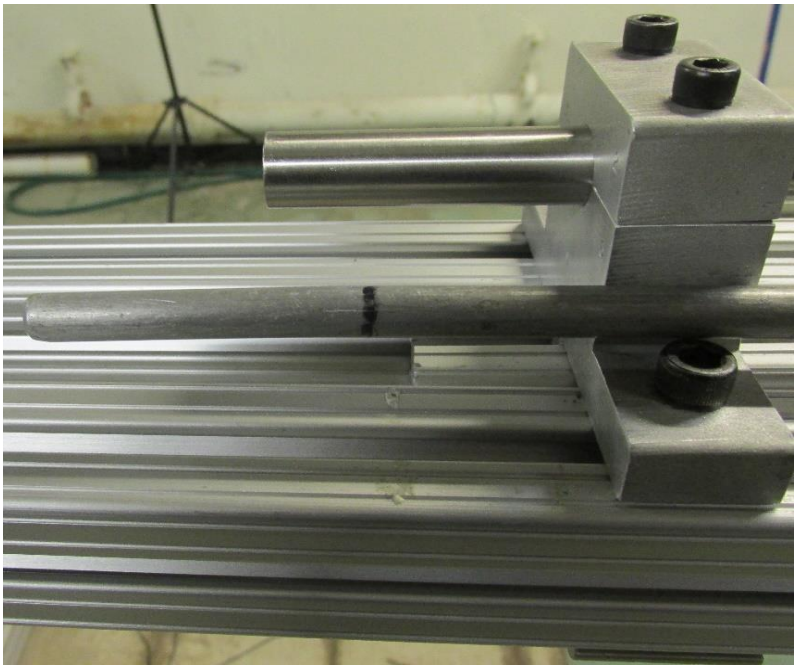


Figure 13: Maximum Projectile Insertion Mark.

3.2.2 **Laser Barrel Alignment**

A laser bore sight, depicted in figure 14, is used to check the probable fight path of a projectile before it is expelled (ie fired) from the muzzle of the gas gun's barrel. The bore sight is held against the muzzle of the gas gun and a piece of white paper is held against the front deflector shield of the Shrapnel-Debris Ballistic Shield Enclosure. If the beam is within a projectile's diameter of the edges of the deflector shield's entrance slit then do not fire the projectile as the gas gun barrel and support assembly needs to be realigned to assure that the fired projectile does not impact the front deflector shield.

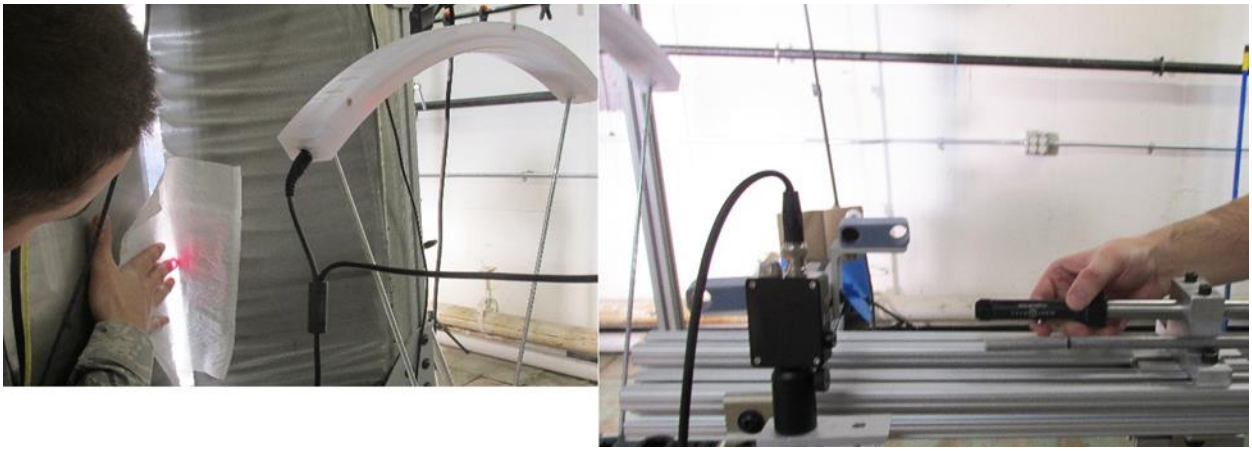


Figure 14: Laser Barrel Alignment.

3.2.3 **Gas Gun Pressurization And Fast Release Valve**

The projectile is propelled up to speed by the rapid release of pressurized nitrogen gas. The gas is first transferred from a nitrogen gas cylinder thru a pressure regulator to a single shot pressure chamber which is released into the breach of the gas gun's barrel with a firing command to the quick release valve sent from the control section of the BIR. These are depicted in figure 15.

The gas gun initial pressurization sequence consists of the following steps. The first step consists of removing the cap from the nitrogen gas cylinder. **BEFORE PROCEEDING MAKE SURE THAT THE VALVE ON THE REGULATOR IS CLOSED**. The second step consists of attaching the pressure regulator to the nitrogen gas cylinder. The regulator is attached to the nitrogen gas cylinder by a threaded nut. **THIS NUT MUST BE SECURELY TIGHTENED WITH A "CRESENT" WRENCH BEFORE GAS IS RELEASED FROM THE NITROGEN GAS CYLINDER.** The third step consists of releasing gas from the nitrogen gas cylinder. The first gage on the regulator reads the pressure of the gas in the nitrogen gas cylinder. The gas gun's pressure chamber is pressurized by opening the valve on the regulator. The second gauge on the regulator reads the pressure of the gas in the gas gun's pressure chamber. Once the gas gun's pressure chamber is pressurized close off the valve on the regulator.

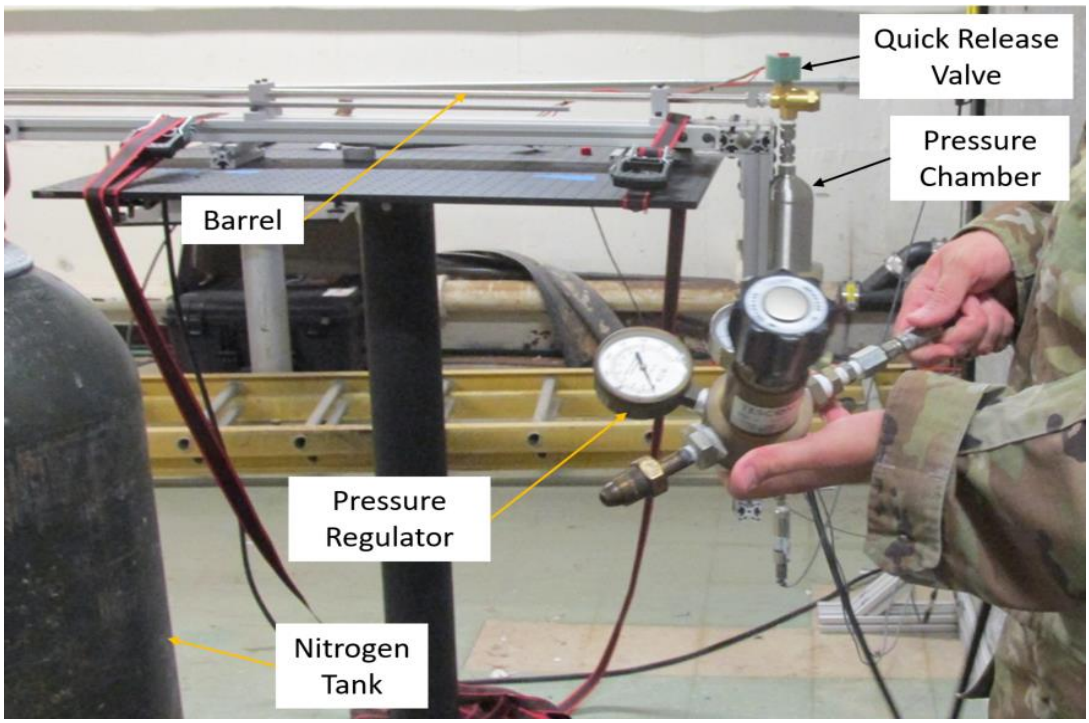


Figure 15: Gas Gun Pressurization System.

3.3 Control Section

The third section of the BIR is the Control Section. It consists of a laptop PC running the projectile speed data collection program; the same laptop PC also runs a gas gun pressure chamber pressure gauge program and a gas gun pressure chamber rapid gas dump control box triggering the firing of a loaded projectile. This controlling and data collection equipment is located behind a steel blast shield separating it from the Impact Section and the Gas Gun Section. The Control Section is depicted in figure 16.

Figure 16: Control Section.

3.3.1 Laptop PC

Access to the Laptop PC's contents is under the "USER" account, with the password "USER". The PC runs the sole program required to obtain the raw data required to determine the speed of the impacting projectile. This program goes under the moniker "PCC" and is brought onto the screen by clicking the purple and white human face icon on the tool bar at the bottom of the screen as depicted in figure 17. At the beginning of a testing session the "PCC" program will need to be set up to collect data from the "Phantom" digital image camera. Figure 18 depicts the initial unset up "PCC" screen. The laptop data collection operator will need to select the "Phantom" camera, designated "9575" in the grey bar in the "Live" drop down. The laptop data collection operator will also need to select the desired Resolution, Sample Rate, Exposure Time and other camera related features. These are also found in the "Live" drop down. When using the "PCC" program, the "Play" drop down depicted in figure 19 allows the user to access and manipulate videos of previously acquired projectile motions and impacts. Also when using the "PCC" program, the "Live" drop down depicted in figure 20 allows the user to access and manipulate the image that the "Phantom" digital image camera is detecting in real time.

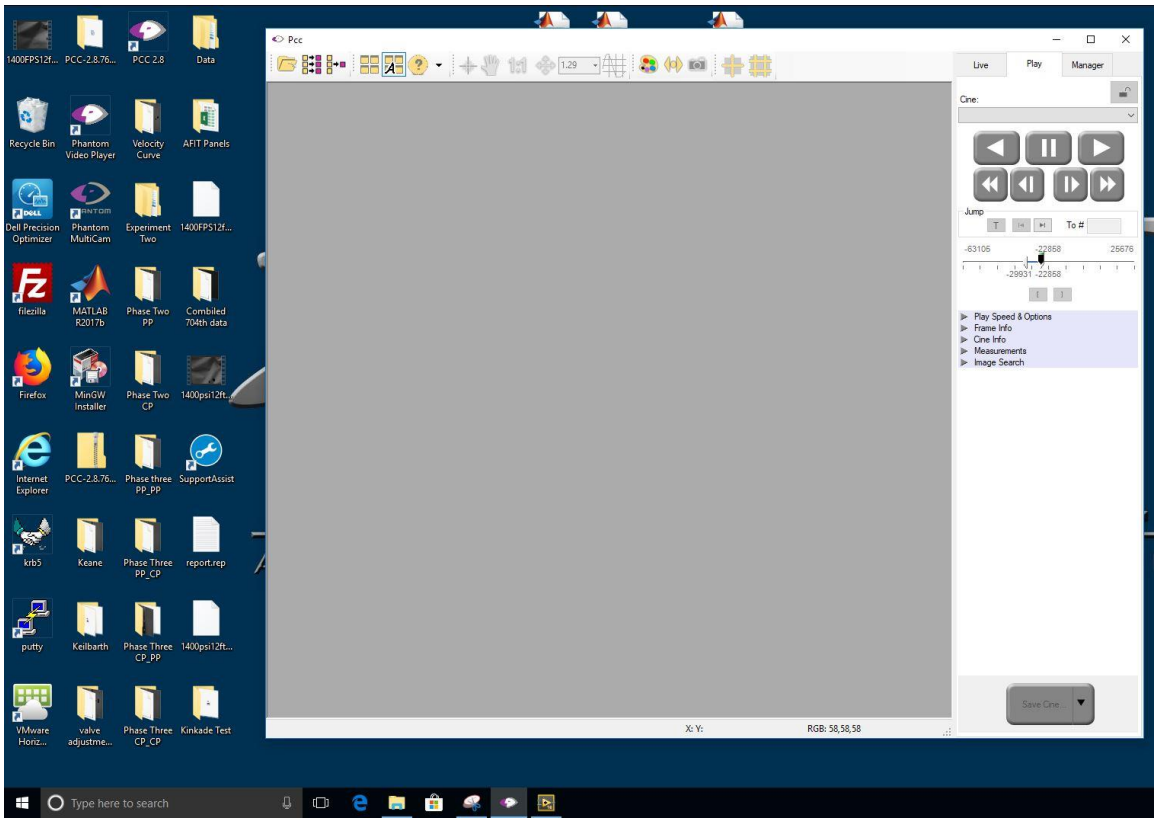


Figure 17: Laptop PC Starting Screen With Phantom Digital Image Capture Program.

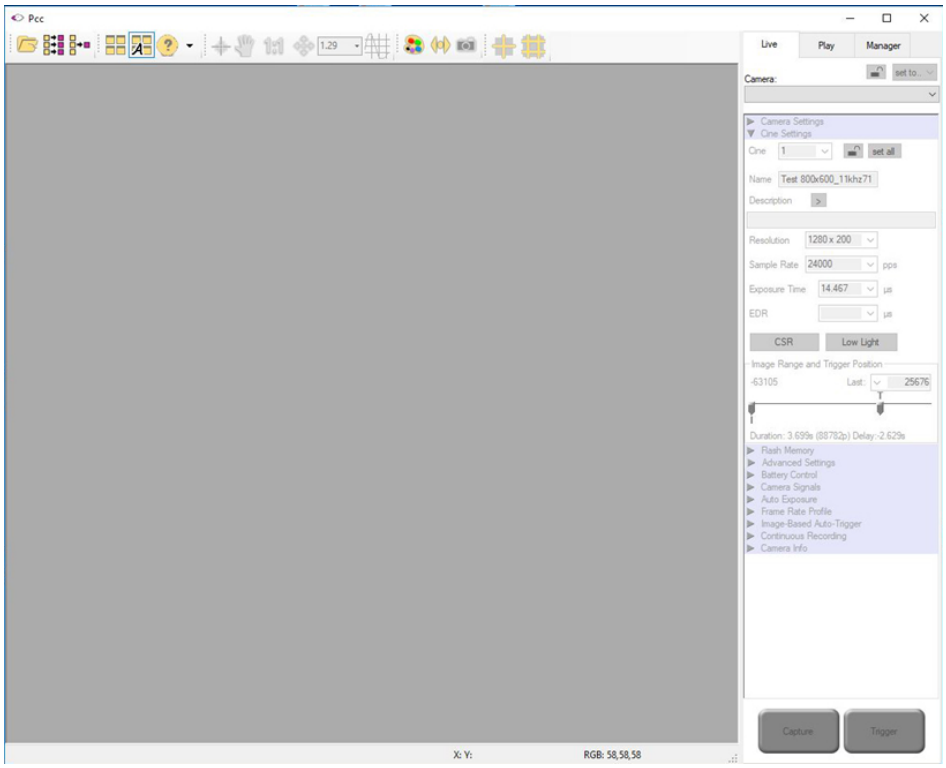


Figure 18: Initial Unset Up "PCC" Screen.

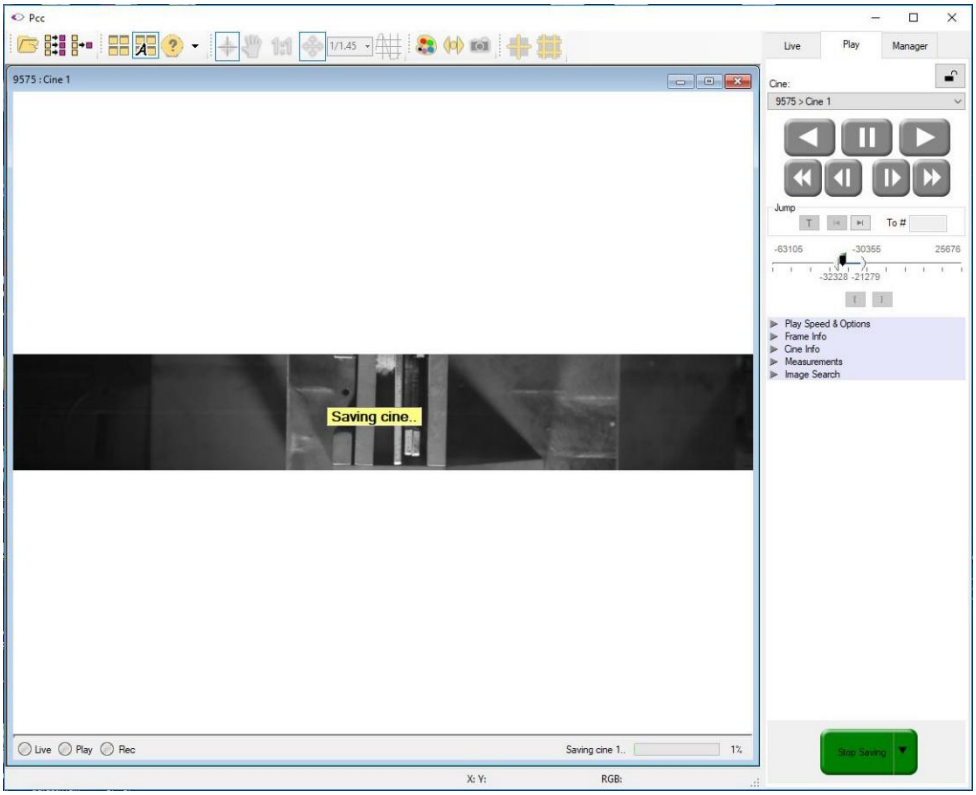


Figure 19: "PCC" program "Play" Screen.

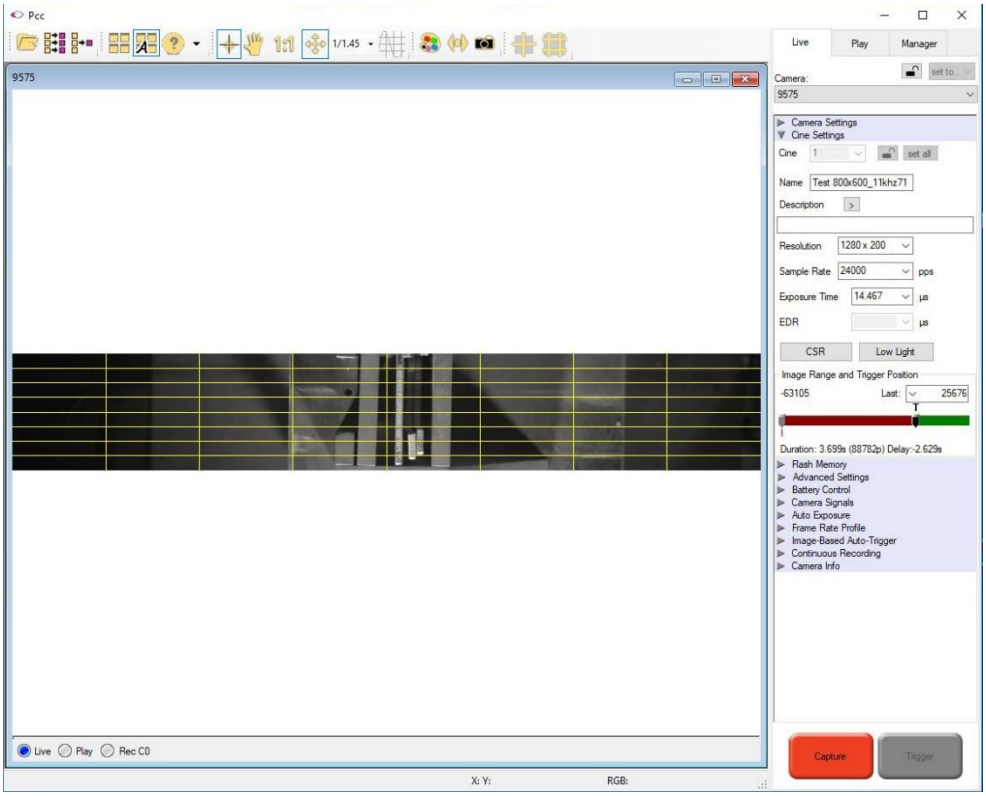


Figure 20: "PCC" program "Live" Screen.

The Laptop PC also runs a pressure transducer display screen depicted in figure 21. This program goes under the moniker "PressTransdmean" and is brought onto the screen by clicking the yellow triangle with red dot icon on the tool bar at the bottom of the screen as depicted in figure 17. The pressure transducer display screen provides a read out of the pressure in the gas gun's pressure chamber.

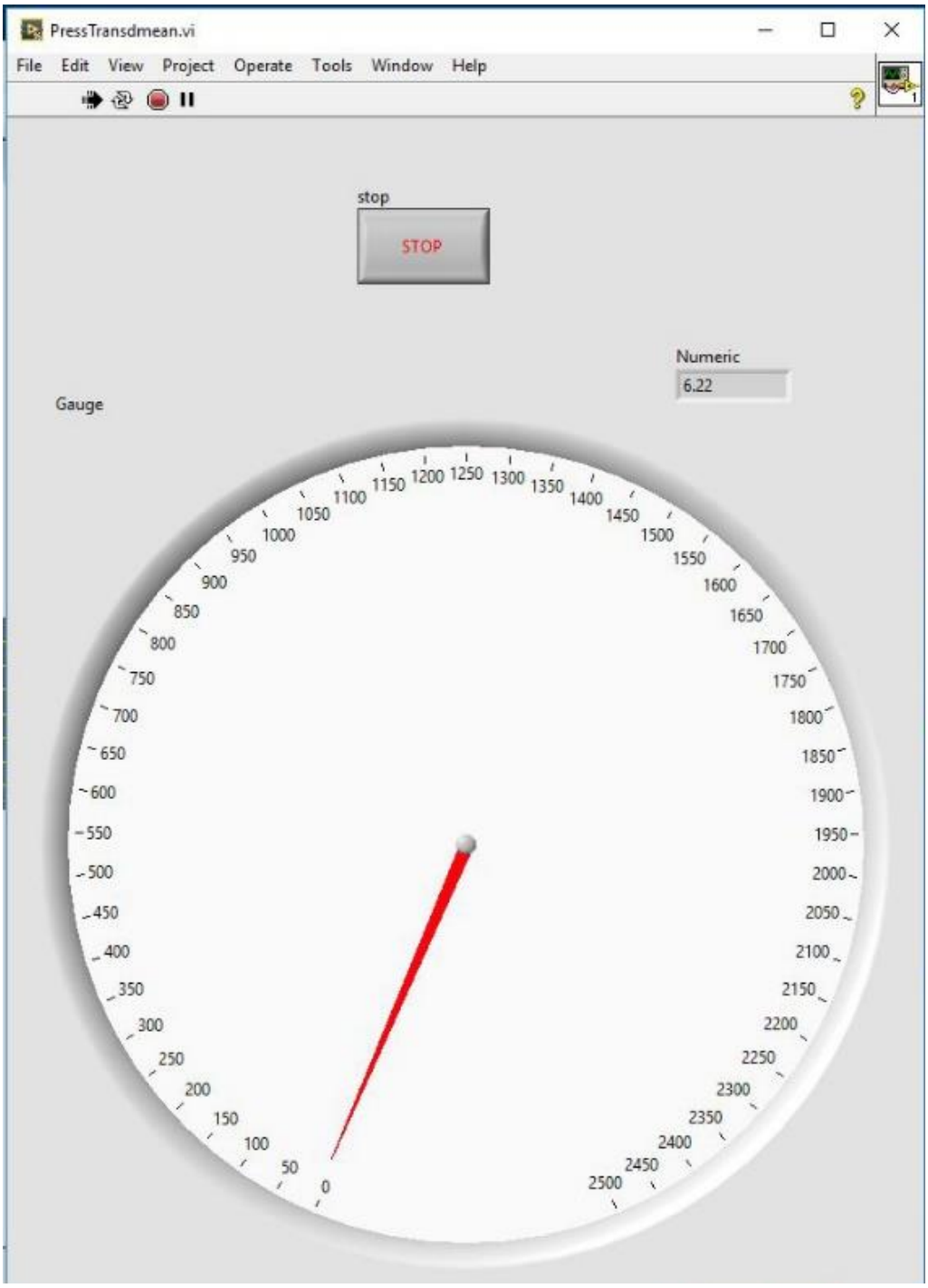


Figure 21: Gas Gun's Pressure Chamber Pressure Transducer Display Screen.

3.3.2 **Steel Blast Shield**

All of the Control Section's data collection and projectile firing control equipment is located behind the steel blast shield depicted in figure 22**. ALL PERSONEL IN THE BALLISTIC IMPACT RIG AREA MUST BE BEHIND THIS STEEL BLAST SHIELD DURING THE FIRING OF ANY PROJECTILE!** This shield separates any portion of the BIR which can be expected to have moving projectiles or debris from any personnel operating the BIR.

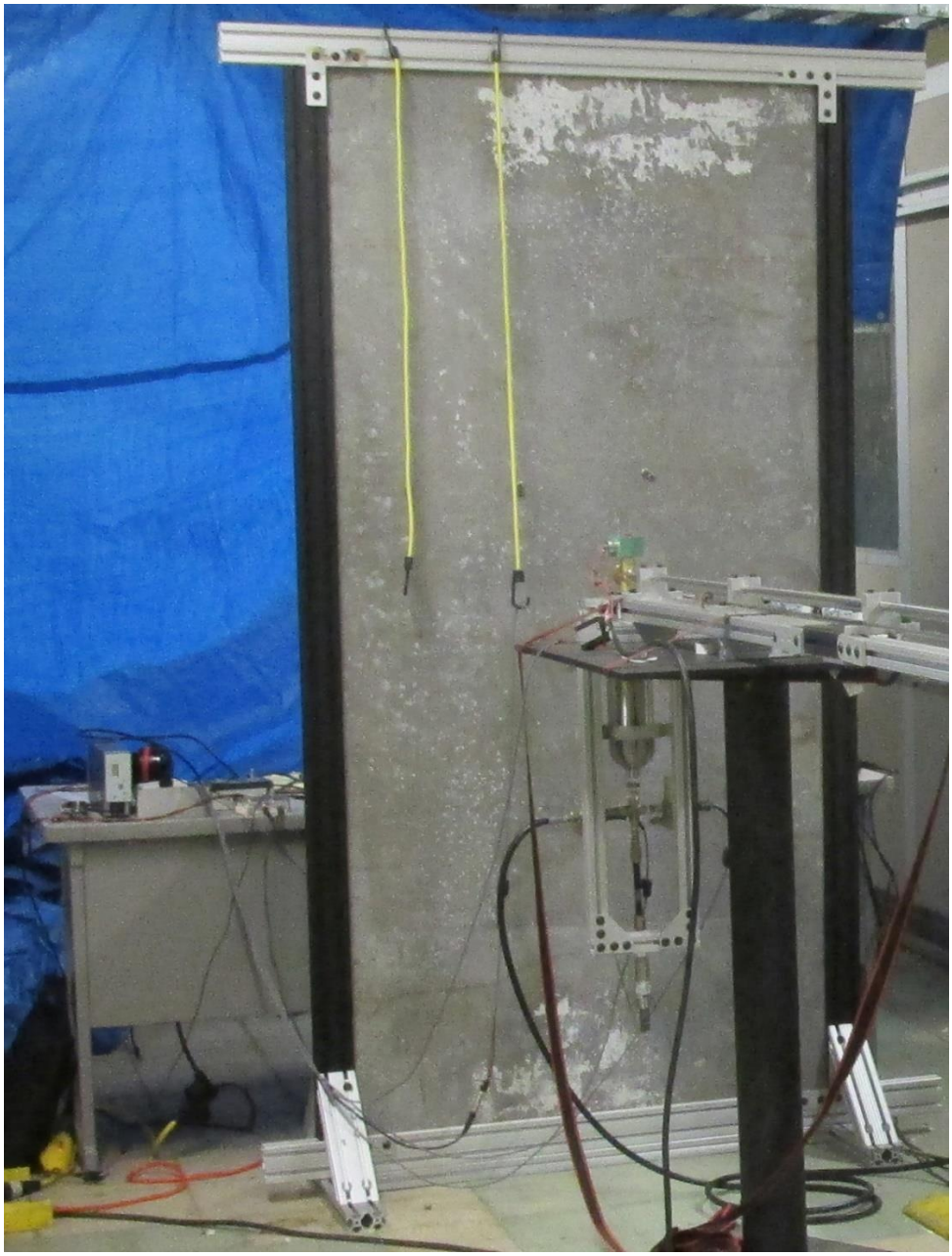


Figure 22: Control Section Steel Blast Shield.

3.3.3 **Gas Gun Firing "Trigger" Console**

The firing of a projectile is controlled with the toggles and buttons of the Gas Gun Firing "Trigger" console depicted in figure 23. From this console the pressure in the gas gun's pressure chamber can be increased by pressing the "PRESS" button or decreased by pressing the "VENT" button. It and the gas gun's quick release pressure chamber gas dump valve are powered by the power box depicted to the right of figure 24. This console is powered up by toggling the black switch at the bottom of the small box depicted on the right hand side of figure 24.

THE TOGGLE LABELED BOTH "ARM" AND "SAFE".
MUST ALWAYS BE SWITCHED TO "SAFE" AT ALL TIMES, EXCEPT FOR WHEN ALL OF THE FOLLOWING ARE MET:

1. **ALL PERSONEL ARE BEHIND THE CONTROL SECTION'S BLAST SHIELD! and**
2. **ALL PERSONEL ARE WEARING HEARING PROTECTION!**

Only when the above conditions are met can the TOGGLE LABELED BOTH "ARM" AND "SAFE" be switched to "ARM" and the button labeled "FIRE" be pressed.

A loaded projectile can only be fired after the toggle labeled both "ARM" and "SAFE" is first switched from "SAFE" to "ARM" and then only after the "FIRE" button is pressed.

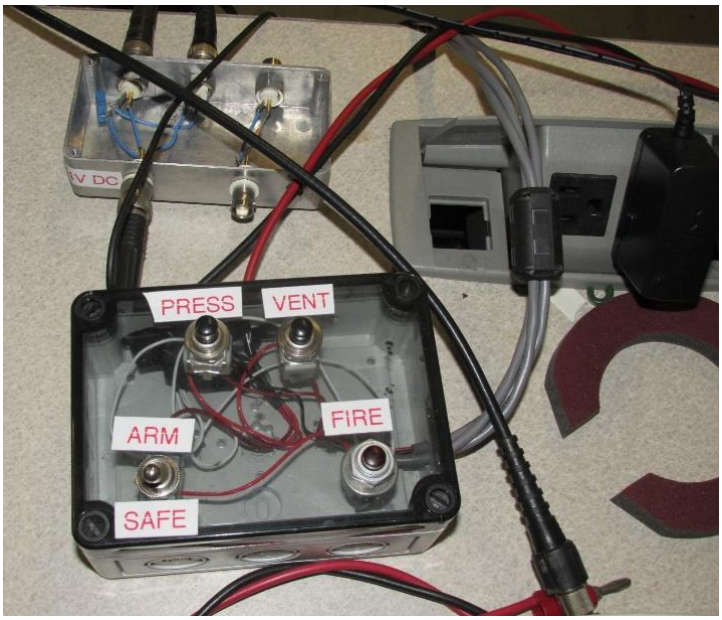


Figure 23: Gas Gun Firing Console

Figure 24: Gas Gun Firing Control.

3.3.4 Gas Gun Projectile Digital Image Capture Data Collection

3.3.4.1 *Data Collection Initialization*

To determine the speed of a projectile about to impact a specimen or sample digital images of the projectile are captured by the "Phantom" digital image camera as video (ie RAM) by the "PCC" program on the laptop. Additionally, the pressure in the gas gun's pressure chamber at the moment of the projectile's firing is also captured by the "PressTransdmean" program on the laptop. But before any specific projectile test firing can accurately occur both of these programs need to be cleared of the results of prior test firings.

Before capturing digital images with the "PCC" program, make certain that the video from any previous activity, is removed from the program. The "PCC" program uses the word "RAM" to describe these videos. To remove these videos ie RAMs first click the "Capture" button depicted at the bottom right of figure 20 while in the "Live" screen and then accept the remove all RAM request by clicking "Yes" and then click the "abort recording" button depicted at the bottom right of figure 25 when that screen appears.

Additionally any previous gas gun's pressure chamber reading on the "PressTransdmean" program screen on the laptop needs to be removed and the reading re-zeroed. This is accomplished by clicking on the arrow depicted immediately below the "Edit" and "View" tabs in figure 21. The screen will change the "Stop" button to an "Abort" button. By then clicking the "Abort" button the "PressTransdmean" program re-zeros its readings.

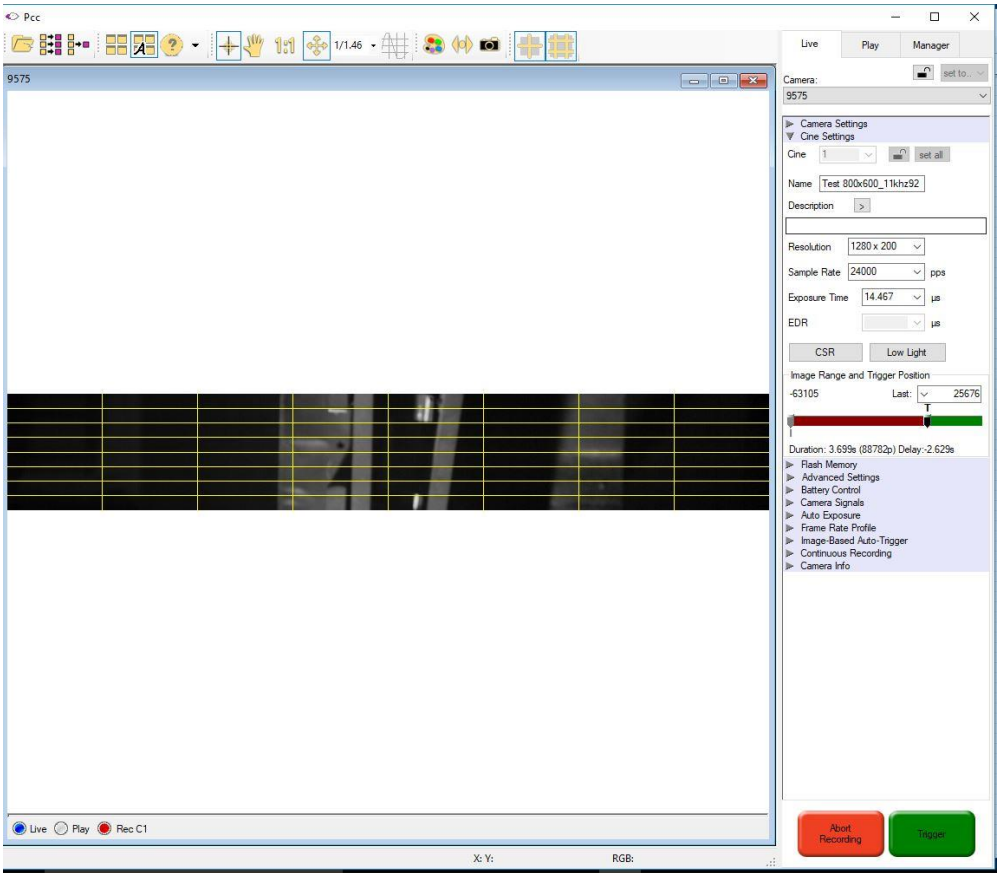


Figure 25: Abort Recording "PCC" Screen.

3.3.4.2 *Projectile Speed Digital Image Data Collection*

To capture the speed of a projectile about to impact a specimen or sample the following series of steps are to be taken. First one of the two required BIR operators clicks the "PCC" program to present the "Live" screen depicted in figure 20. The image shown in the main sub-screen of figure 20 is that now being taken by the "Phantom" digital image camera. It should be an image of the test sample/specimen in the holder. If it is out of focus the "Phantom" digital image camera will need to be manually focused. To begin capturing a video of an about to be fired projectile the first BIR operator clicks the "Capture" button at the bottom of the "Live" drop down in the "PCC" program. Since the "Capture" has a small amount of startup, it is best to start the camera recording at least two seconds prior to firing the projectile. This action begins capturing the images taken by the camera in video form. After a few seconds, the second BIR operators presses the "fire" button on the Trigger Console and fires the projectile. After another second or once the projectile has finished impacting the specimen, the first BIR operator clicks the "Trigger" button as depicted in figure 25 at the bottom of the "Live" drop down in the "PCC" program. The clicking of the "Trigger" button causes the "PCC" program to pause and stop collecting images coming from the "Phantom" digital image camera.

The collected digital images now need to be saved in some file form of the BIR operators choice. This is accomplished by the first BIR operator clicking the "Play" drop down in the "PCC" program. When the "Play" drop down in the "PCC" program is clicked the "PCC" screen will

change to that depicted in figure 26. The size of the videos captured by the "PCC" program is extremely large, but only that brief portion of the video in which an image of the projectile about to impact a specimen or sample is of use to calculate the speed of the projectile as it impacts the specimen or sample. The first BIR operator finds this brief portion of the video by clicking on the specific video frame pointer " ▼ " and slowly moving it along the slider bar under the "Play" drop down in the "PCC" program until an image of the projectile, typically that depicted in figure 9, is located. The first BIR operator then clips the size of the video by moving the end of video pointers " ◁ ▷ " to a length immediately surrounding the specific video frame pointer " ▼ " as depicted in figure 27. The clipped video can now be saved by clicking the "Save Cine" button at the bottom of the "Play" screen of figure 27 and saved in a file of the operator's video format of choice.

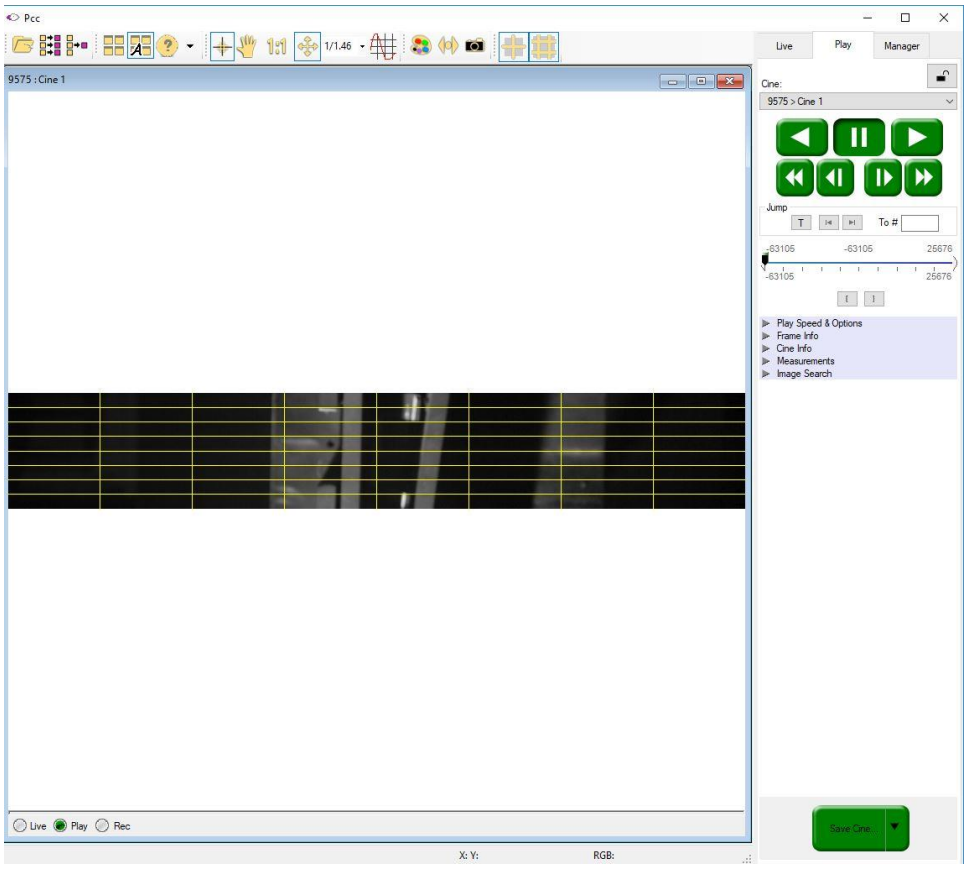


Figure 26: Play "PCC" Screen From Which Video Can Be Saved.

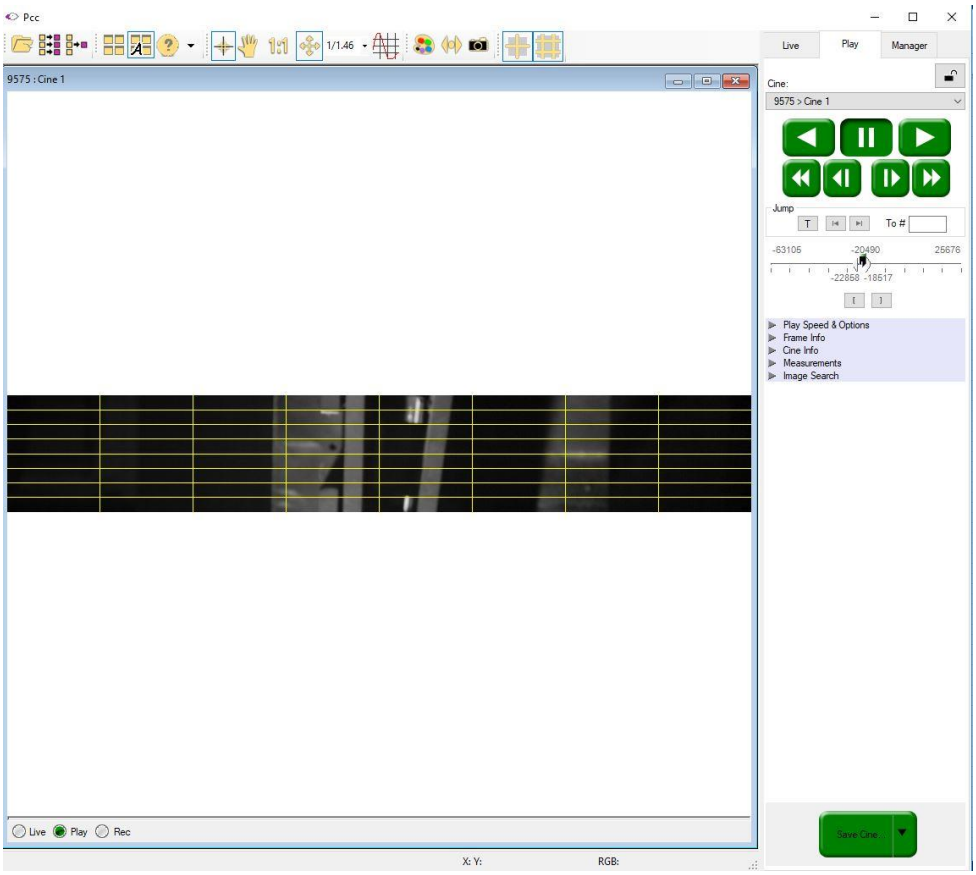


Figure 27: Found Projectile Frame and Clipped Video To Be Saved.

3.3.5 Choreographing Projectile Image Collection And Firing "Trigger" Console

Collecting digital image data from the "Phantom" digital image camera to determine the projectile's speed at impact with the test specimen or sample on the laptop and firing the projectile from the gas gun requires two BIR operators. The first BIR operator executes commands primarily on the "PCC" and also the "PressTransdmean" programs to collect needed speed determination data. The second BIR operator executes commands on the "Trigger Console" to fire the projectile. The actions of both of these operators need to be choreographed so as to effectively acquire accurate fired projectile speed data. A recommended approach to achieve this is with the five, four, etc, zero countdown sequence listed in table 1.

Table 1: Recommended Data Collection and Firing Sequence

Count	Action
5	Operators In Place And ready
4	In "Live" screen of the "PCC" laptop operator clicks the "Capture" button at the bottom of the screen
3	Trigger Console Operator Makes Final Pressure Chamber Adjustments
2	Trigger Console Operator Makes Final Pressure Chamber Adjustments
1	From Trigger Console the "fire" button is depressed and the projectile is launched
0	In "Live" screen of the "PCC" laptop operator clicks the "Trigger" button at the bottom of the screen

4 OPERATIONS

4.1 Pre-Testing Arrival Preparations

Before going to the BIR it is important that the operators take with them the items listed in Table 1.

Table 2: Pre Experimental Testing Arrival Preparations

A portable hard drive to download the impact image videos.
A mouse to ease access and control of the various data collection programs on the laptop.
All specimens to be tested.
Any special sample holder jigging.
Any special projectiles.
"Hoppes" gun oil.
Projectile wadding patches.

4.2 Operational Sequence

The BIR should always be found Shutdown and only be in Operational Mode during experimental runs with a minimum of two people present.

ONLY CONDUCT TESTS WITH TWO OR MORE PERSONS PRESENT.

4.2.1 Experimental Run

To safely and effectively conduct an experimental run using the BIR the user must rigorously and methodically follow in sequence the "***Step: (#),*** Action" Operational ***Steps*** detailed in Tables 3 through 5 while meticulously heeding the associated "**WARNING: (#),** Action" Operational Use **WARNINGs** also detailed in Tables 3 through 5. The "***Note:*** Activity***",*** denotes suggestions to make the BIR operations go easier for the users.

Table 3: BIR INITIALIZATION Sequence

WARNING I1	**Ensure BIR was properly put into Shutdown before beginning use. If not follow the checklist in SHUTDOWN.**
WARNING: I2.	**ONLY CONDUCT TESTS WITH TWO OR MORE PERSONS PRESENT.**
WARNING: I3.	**Ensure Arming Device remains on SAFE until all personnel are safely behind the Control Section's Ballistic Shield.**
Step: I1	Ensure all materials are present for an experimental run. (projectiles, wadding, test samples, sample holding fixtures, sufficient Nitrogen Gas, etc)
WARNING: I4	**Assure that all sample holding jigging is firmly affixed to the ballistic shield enclosure structure.**
Step: I2	If required install any unique sample holding jigging and assure that it is firmly affixed to the ballistic shield enclosure structure.
WARNING: I5	**Assure that any sample is firmly affixed to the sample holding jigging.**
Step: I3	Put a test sample in the Sample Holder and assure that the sample is firmly affixed to the sample holding jigging.
Step: I4	Ensure the Sand Catch has a proper amount of sand and is taped. Replace box as it becomes necessary.
Step: I5.	Locate High Speed "Phantom" digital image Camera directly over sample, connect and power it on.
WARNING: I6	**Flood Lighting can become hot, use with caution to prevent burns.**
Step: I6	Plug in to power up Flood Lighting, locate in position for best digital image Camera Results (may take trial and error depending on Sample)
Step: I7	Turn on Chronographs and ensure units are set according to test needs (m/s or fps)
Step: I8	Power up Laptop, log in and start up the "PCC" and "PressTransdmean" programs.
Step: I9	Review High Speed "Phantom" digital image Camera video quality and adjust its' focus and the flood lighting position as necessary.
Step: I10	**.** Connect Pressure system to include Nitrogen Tank, Pressure regulator, and Pressure Chamber
WARNING: I7	**Make Sure the tank valve is tightly closed before proceeding.**

Table 4: BIR EXPERIMENTAL TEST RUN Sequence

Note: Repeat steps T1-T22 for each Sample

Step: T1	Put a sample to be impacted into the sample holder.
WARNING: T1	**Assure that any sample is firmly affixed to the sample holding jigging.** The impact event is violent and any improperly secured sample will be tossed about the interior of the ballistic shield enclosure structure damaging instrumentation contained within it.
Step: T2	**SECURE THE SAMPLE IN THE SAMPLE HOLDER.**
Step: T3	Close up and secure the ballistic shield enclosure structure's doors. If the sample is larger than the enclosure then drape tarps over the open areas.
WARNING: T2	**Loading a projectile into the barrel is a complicated process REQUIRING AT LEAST TWO PERSONNEL.**
Step: T4	Load a projectile into the gas gun.
Step: T5	Use laser bore sight to ensure the barrel is properly aimed at the sample and will not impact the walls.
Step: T6	Pressurize the small firing pressure chamber by opening the regulator to the anticipated correct pressure setting.
Step: T7	Locate all persons behind the ballistic shield to preparing for FIRING.
WARNING: T3	**No personnel should be downrange once the Firing process has begun.**
Step: T8	Second BIR operator pressurizes the gas gun with the ARMING device. Vent as necessary to achieve desired pressure.
Step: T9	First BIR operator prepares "PCC" program to begin Data Acquisition.
Step: T10	Announce "FIRING" prior to using device.
Step: T11	Set ARMING device to ARMED.
Step: T12.	On the count of 5 Operators In Place And ready
Step: T13	On the count of 4 In "Live" screen of the "PCC" click the "Capture" button.
Step: T14	On the count of 3 "Trigger Console" Operator Makes Final Pressure Chamber Adjustments.
Step: T15	On the count of 2 "Trigger Console" Operator Makes Final Pressure Chamber Adjustments.
Step: T16	On the count of 1 "Trigger Console" Operator presses the "fire" button launching projectile.
Step: T17	On the count of 0 In "Live" screen of the "PCC" click the "Trigger" button.
Step: T18	Vent any remaining gas and return ARMING device to safe.
Step: T19	Save Collected Projectile Speed Data.
Step: T20	Go down range open ballistic shield, remove sample and inspect sample.
Step: T21	If Sand Catch is penetrated, tape hole.
Step: T22	Prepare New Specimen And Sample Holder for next test.

Table 5: BIR SHUTDOWN Sequence

Note: If the testing session is completed, shutdown the BIR with the following steps.

Step: S1	Ensure the Device is on SAFE and NO cartridge is loaded.
Step: S2	Bleed off and excess gas throughout the Pressure System, including: Pressure Chamber, Pressure Regulator, any additional valves and lines
Step: S3	Shut off the Nitrogen Gas
Step: S4	Remove the Pressure Regulator from the Nitrogen Tank and Cap the tank
Step: S5	Drop Ballistic Shield to access Sample Holder, leave down.
Step: S6	Remove any remaining Sample and debris.
Step: S7	Tape over any remaining holes in the Sand Catch and clean Sample Holder area
Step: S8	Remove any special sample holding jigs
Step: S9	Turn off all Chronographs
Step: S10	Disconnect/Turn off all Flood Lights for the High Speed Camera
Step: S11	Turn off High Speed Camera
Step: S12	Log off and Power Down Laptops
Step: S13	Clean up excess materials (Samples, Ballistic Wadding, Ball Bearings, etc)
Step: S14	Ensure all other electrical devices are powered down
Step: S15.	Turn off lights and lock door when exiting

4.2.2 **Shutdown**

The Shutdown status puts the BIR into a safe, sealed, not being used, condition for long periods of time. All pressured components should be both depressurized and disconnected from one another (with the exception that the Nitrogen Tank itself is not depressurized). The Barrel is empty of all foreign objects or loadings. The firing mechanism is on safe, and fully vented. The Sand Catch is filled and taped. All electrical equipment including lights, cameras, chronographs, laptops, and lasers are turned off, unplugged or powered down. The process of putting the BIR into Shutdown state ensures that the system is safe when another user conducts testing with it and none of the electronics/batteries degrade while the system goes unused.

5 CONCLUSION

This Operations Manual clearly and briefly explains the functions of AFIT's Ballistic Impact Rig and its subcomponents. It systematically documents the operational steps and their required sequence for the typical and safe use of the Ballistic Impact Rig . Additionally it summarizes these steps into a usable check list.

APPENDIX A: Pre-Testing Arrival Preparations Check List

A portable hard drive to download the impact image videos.
A mouse to ease access and control of the various data collection programs on the laptop.
All specimens to be tested.
Any special sample holder jigging.
Any special projectiles.
“Hoppes” gun oil.
Projectile wadding patches.

APPENDIX B: BIR INITIALIZATION Sequence Check List

WARNING: I1.	**Ensure BIR was properly put into Shutdown before beginning use. If not follow the checklist in SHUTDOWN.**
WARNING: I2.	**ONLY CONDUCT TESTS WITH TWO OR MORE PERSONS PRESENT.**
WARNING: I3.	**Ensure Arming Device remains on SAFE until all personnel are safely behind the Control Section's Ballistic Shield.**
Step: I1	Ensure all materials are present for an experimental run. (projectiles, wadding, test samples, sample holding fixtures, sufficient Nitrogen Gas, etc)
WARNING: I4	**Assure that all sample holding jigging is firmly affixed to the ballistic shield enclosure structure**.
Step: I2	If required install any unique sample holding jigging and assure that it is firmly affixed to the ballistic shield enclosure structure.
WARNING: I5	**Assure that any sample is firmly affixed to the sample holding jigging.**
Step: I3	Put a test sample in the Sample Holder and assure that the sample is firmly affixed to the sample holding jigging.
Step: I4	Ensure the Sand Catch has a proper amount of sand and is taped. Replace box as it becomes necessary.
Step: I5	Locate High Speed "Phantom" digital image Camera directly over sample, connect and power it on.
WARNING: I6.	**Flood Lighting can become hot, use with caution to prevent burns.**
Step: I6	Plug in to power up Flood Lighting, locate in position for best digital image Camera Results (may take trial and error depending on Sample).
Step: I7.	Turn on Chronographs and ensure units are set according to test needs (m/s or fps)
Step: I8	Power up Laptop, log in and start up the "PCC" and "PressTransdmean" programs.
Step: I9	Review High Speed "Phantom" digital image Camera video quality and adjust its' focus and the flood lighting position as necessary.
Step: I10	Connect Pressure system to include Nitrogen Tank, Pressure regulator, and Pressure Chamber.

APPENDIX C: BIR EXPERIMENTAL TEST RUN Sequence Check List
Note: Repeat steps T1-T22 for each Sample

Step: T1	Put a sample to be impacted into the sample holder.
WARNING: T1	Assure that any sample is firmly affixed to the sample holding jigging. The impact event is violent and any improperly secured sample will be tossed about the interior of the ballistic shield enclosure structure damaging instrumentation contained within it.
Step: T2	**SECURE THE SAMPLE IN THE SAMPLE HOLDER.**
Step: T3	Close up and secure the ballistic shield enclosure structure's doors. If the sample is larger than the enclosure then drape tarps over the open areas.
WARNING: T2	**Loading a projectile into the barrel is a complicated process REQUIRING AT LEAST TWO PERSONNEL.**
Step: T4	Load a projectile into the gas gun.
Step: T5.	Use laser bore sight to ensure the barrel is properly aimed at the sample and will not impact the walls.
Step: T6	Pressurize the small firing pressure chamber by opening the regulator to the anticipated correct pressure setting.
Step: T7	Locate all persons behind the ballistic shield to preparing for FIRING.
WARNING: T3	**No personnel should be downrange once the Firing process has begun.**
Step: T8	Second BIR operator pressurizes the gas gun with the ARMING device. Vent as necessary to achieve desired pressure.
Step: T9	First BIR operator prepares "PCC" program to begin Data Acquisition.
Step: T10	Announce "FIRING" prior to using device.
Step: T11	Set ARMING device to ARMED.
Step: T12	On the count of 5 Operators In Place And ready
Step: T13	On the count of 4 In "Live" screen of the "PCC" click the "Capture" button.
Step: T14	On the count of 3 "Trigger Console" Operator Makes Final Pressure Chamber Adjustments.
Step: T15.	On the count of 2 "Trigger Console" Operator Makes Final Pressure Chamber Adjustments.
Step: T16	On the count of 1 "Trigger Console" Operator presses the "fire" button launching projectile.
Step: T17	On the count of 0 In "Live" screen of the "PCC" click the "Trigger" button.
Step: T18	Vent any remaining gas and return ARMING device to safe.
Step: T19	Save Collected Projectile Speed Data.
Step: T20	Go down range open ballistic shield, remove sample and inspect sample.
Step: T21	If Sand Catch is penetrated, tape hole.
Step: T22	Prepare New Specimen And Sample Holder for next test.

APPENDIX D: BIR SHUTDOWN Sequence Check List

Note: If the testing session is completed, shutdown the BIR with the following steps.

Step: S1	Ensure the Device is on SAFE and NO cartridge is loaded.
Step: S2	Bleed off and excess gas throughout the Pressure System, including: Pressure Chamber, Pressure Regulator, any additional valves and lines
Step: S3	Shut off the Nitrogen Gas
Step: S4	Remove the Pressure Regulator from the Nitrogen Tank and Cap the tank
Step: S5	Drop Ballistic Shield to access Sample Holder, leave down.
Step: S6	Remove any remaining Sample and debris.
Step: S7	Tape over any remaining holes in the Sand Catch and clean Sample Holder area
Step: S8	Remove any special sample holding jigs
Step: S9	Turn off all Chronographs
Step: S10	Disconnect/Turn off all Flood Lights for the High Speed Camera
Step: S11	Turn off High Speed Camera
Step: S12	Log off and Power Down Laptops
Step: S13	Clean up excess materials (Samples, Ballistic Wadding, Ball Bearings, etc)
Step: S14	Ensure all other electrical devices are powered down
Step: S15.	Turn off lights and lock door when exiting

LIST OF SYMBOLS, ABREVIATIONS AND ACRONYMS

◁▷	End Of Video Pointers
▮	Specific Video Frame Pointer
AFIT	Air Force Institute of Technology
AFRL	Air Force Research Laboratory
BIR	Ballistic Impact Rig
ENY	Department of Aeronautics and Astronautics
RX	Material And Manufacturing Directorate
RXC	Structural Materials Division
RXCC	Composites Branch
WPAFB	Wright-Patterson Air Force Base