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MEMORANDUM REPORT BRL-MR-3399

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A GAS GUN IMPACT TESTER FOR
SOLID GUN PROPELLANTS

Robert J. Lieb
Joseph J. Rocchio

October 1984

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I. INTRODUCTION

During ignition of gun charges, the propellant bed is subject to motion and compaction due to the action of the ignition system. If conditions are unusual, as in igniter malfunctions, the thrust experienced by the propellant within the bed can cause grains to achieve velocities of at least 100 m/s.¹ It is important to know how the grains will respond upon impact with the projectile base or other grains within the bed in order to predict the ballistic performance. If the grains are brittle, significant fracture can occur which will result in the surface area exposed being much greater than that originally programed. Even if only a small percentage of grains are subject to these fracture conditions, large deviations in pressure can result because of the higher mass generation rate from the larger surface area. It would, therefore, be advantageous to know the fracture response of propellant grains under conditions simulating early interior ballistic environments from both the quality control and material development standpoints.

A drop weight mechanical properties tester, which can be used to measure the mechanical properties of gun propellant grains at strain rates and temperatures corresponding to those that may be experienced within the gun, has been valuable in characterizing the propellant mechanical properties and evaluating response changes for various propellant lots.^{2,3} If the scatter in the measured results is to be minimized, however, the specimens tested must be prepared so that the grain ends are flat, parallel, and perpendicular to the longitudinal cylinder axis. These grain modifications have been shown to affect the fracture response of the grain, especially at lower temperatures. Grains that have uniform and regular dimensions show a much greater resistance to fracture damage than unprepared or poorly prepared grains. As a result, when this test is used, the mechanical properties are measured well, but the fracture response of unprepared grains has to be estimated from the mechanical properties measurements or simply left unknown.

A gas gun impact tester was built, therefore, to determine the fracture response of unprepared grains under conditions more like those existing during firing. The gun, using pressurized nitrogen, fires single propellant grains of various diameters against a steel plate. A velocity-temperature test matrix can be created to evaluate the fracture response of the grains at each point. If sudden changes in the fracture response occur at some velocity or

¹W. G. Soper, "Ignition Waves in Gun Chambers," Combustion and Flame, 20, pp 152-162, 1973.

²R. J. Lieb, and J. J. Rocchio, "Standardization of a Drop Weight Mechanical Properties Tester for Gun Propellants," Technical Report ARBRL-TR-02516, USA ARRADCOM Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, July 1983. ADA-132966.

³R. J. Lieb, and J. J. Rocchio, "High Strain Rate Mechanical Properties Testing on Lots of Solid Gun Propellant with Deviant Interior Ballistic Performance," 1982 JANNAF Structures and Mechanical Behavior Subcommittee Meeting, CPIA Publication 368, pp 23-38, October 1982.

temperature, and these conditions are deemed likely to occur during the ballistic cycle, then potential performance or safety problems are exposed without extensive firing programs.

The method of analysis used to interpret the gas gun results is evolving. Presently, a semiquantitative parameter which reflects the visual appearance of the grain is used as a figure of merit. This system has many serious drawbacks but was used in the initial testing of the gas gun. A more quantitative method that evaluates fracture induced surface area is under development. The utility of the gas gun as a device that bridges the highly controlled, mechanical properties measurements to the evaluation of the fracture response of the grains under firing conditions is shown here.

II. EXPERIMENTAL METHOD

A. The Apparatus

The gun fires a single, temperature-conditioned grain, at a selected velocity and known orientation, onto a target; impact causes damage as determined by the kinetic energy of the grain. The pieces are collected after a single impact for later evaluation of damage. The gas gun system and experimental set-up are illustrated in Appendix A and described below. Pressurized nitrogen is used to propel the grain and enters the barrel through a high-volume solenoid valve. The inside diameter of the barrel is selected to accommodate the outside grain diameter so that no sabot is required. The barrels are, therefore, interchangeable and designed to perform several tasks. Copper coils with an outside diameter of 3.18 mm (one-eighth inch) are wrapped around the breech end to provide uniform temperature conditioning, $\pm 0.5^{\circ}\text{C}$, over the length of the grain. A thermocouple is located between the coil and the outside barrel surface, and provides an accurate measurement of the inside barrel temperature. For subambient testing, liquid nitrogen vapor is circulated through the coils. At test temperatures above ambient, the coils are wrapped with an electric heating strip. Near the muzzle, narrow slots serve to exhaust the propelling gas, which results in nearly uniform grain velocity before impact. The slots are also pathways for infrared radiation (IR) which is used in the velocity measurement of the grain. Of course, the barrel serves its usual function of controlling the grain orientation and directing the grain onto the impact plate. To insure that the grain does not tumble significantly after leaving the barrel, the impact plate is placed only a little more than one grain length away from the muzzle. The plate is 6.35-mm thick steel and has a smooth impact region. It is made immobile by being bolted to a rigid frame, so that very little of the kinetic energy of the incident grain is absorbed by the plate. After impact, a soft fabric bag catches the grain and any pieces that may be generated.

B. Velocity Measurement

The propelling pressures are limited by the maximum rating of the regulator that is used on the high pressure tank. The range used thus far has been from 0 to 1.4 MPa. This produces typical velocities of 30 to 120 m/s. This velocity is calculated from the measured time of flight between two pairs

of infrared, emitter-receiver diodes. A schematic diagram of the electronic circuit used to generate square wave pulses as the grain breaks the IR radiation path is shown in Figure A-2, Appendix A. The pulse has a rise time of less than 2 microseconds so the position of the grain is defined within 0.2 mm at 100 m/s. The sensors are typically 10 cm apart, so the error in velocity due to the measuring system is less than 0.2 percent. The time between the beginning of the two pulses is measured by feeding the output of the IR circuits into a Hewlett Packard, Model 5314A, Universal Counter. No significant error is introduced by the counter (± 100 ns). Typical pressure and velocity results are found in Table I. The velocity error is the standard deviation based on five tests at each pressure. The magnitude of the velocity depends on the barrel diameter being used and the mass of the grain, but the standard deviation in velocities remains about 1 percent.

Table I. Typical Gas Gun Velocities

Propellant: JA2 Grain Diameter : 8.9 mm
 Grain Mass: 1.25 gm Barrel Diameter: 9.2 mm

Pressure kPa	Velocity m/s
35	35.9 \pm 0.5
70	42.5 \pm 0.3
140	55.8 \pm 0.6
280	67.9 \pm 0.7
420	77.1 \pm 0.6
560	84.8 \pm 0.8
875	95.2 \pm 0.7

In tests designed to calculate how effective the barrel slots were in venting the propelling gas and stopping grain acceleration, a 3.5-cm plastic plug was fired in the gas gun. Both the outputs from the IR detectors were recorded on a Nicolet two channel digital oscilloscope. By knowing the length of the grain and the distance between detectors, the average speed over the length of the plug at the first and second detector, as well as the average speed over the inter-detector distance could be calculated. The velocity at the second (farthest from breech) detector averaged about 1 percent lower than the velocity at the first. The average velocities calculated between detectors were very close to the average of the first and second detector velocities. These results indicate that the gas is being effectively vented. Also, the higher velocity at the first detector is probably due to acceleration taking place while the rear portion of the plug was still confining the propelling gas. It is indicated that the actual impact velocity deviates from the measured value by no more than 1 or 2 percent.

C. Experimental Procedure

With the equipment arranged as indicated in Appendix A, the distance between the IR detectors is measured in the following way. A grain is loaded and pushed down the barrel until the first IR emitter-receiver pair is activated. This position of the ramrod is recorded. The grain continues to be pushed until the second IR detector is activated. The difference between the two ramrod positions defines the distance over which the time of flight is measured. This distance is used in the velocity calculation.

Grains that are fired at other than ambient temperatures must be temperature conditioned. Propellant grains with lengths and diameters in the range of 10 mm have been instrumented with thermocouples and found to fall to within 1°C of the conditioning temperature in no more than 10 minutes of being placed in the conditioning chamber. Equilibrium of the grain takes place within this chamber by natural convection and radiation with the ambient chamber environment. A minimum time of 20 minutes was, therefore, selected for the conditioning which takes place outside the gun. No consideration was given to any phase or chemical changes which may require much longer equilibrium times.

The barrel is brought to the subambient firing temperature by controlling the flow of liquid nitrogen vapor through the conditioning portion of the barrel. The coils are wrapped in insulating material and extend at least 2 cm beyond either end of the loaded propellant grain. Superambient conditioning is controlled by adjusting the electric current in the wrapped heating strip. In either case, the temperature difference over the volume of the grain is less than one half degree. The temperature stability within the barrel should be at least 1°C per minute or less.

Once the approximate firing temperature is attained, the conditioned grain is taken from the conditioning chamber and loaded into the barrel. A flexible hose with a quick connector is used between the barrel and the low pressure reservoir. This enables transfer of the grain into the center of the conditioned region of the barrel within 5 seconds. If conditioned tweezers are used, nearly all effects of the transfer on the temperature of the grain are eliminated.

The low pressure reservoir is then pressurized corresponding to the desired velocity, the universal counter is set, and the solenoid valve is remotely opened when the proper temperature is reached. The velocity is calculated by dividing the distance between IR detectors, measured earlier, by the time of flight. The fired grain and any fragments are then recovered from the fabric bag for later analysis.

D. Analysis

In tests conducted thus far, a semi-empirical parameter called the total fracture number (TFN) has been used to evaluate the grain damage. This somewhat subjective index is calculated for each set of initial conditions, i.e., impact velocity and temperature, and permits ranking of propellants by degree of fracture.

The TFN is computed in the following way. If N grains are tested, each grain is assigned a fracture number (FN) from 0 to 10. If no fracture occurs the FN = 0. If chipping of the impact surface occurs, then the FN = 1. If the grain fractures more severely, the FN equals the number of larger shards. If the number of shards is greater than ten, then the FN = 10. Figure 1 shows an undamaged whole grain before firing. Figure 2 shows grains with various degrees of damage and the corresponding assigned FN's. The TFN equals ten times the sum of the individual FN's divided by N. This gives the TFN scale a one hundred-point range. The TFN, then, will indicate the overall severity of fracture suffered by the grains during impact. Table II represents a guide for the interpretation of the TFN. A more quantitative parameter based on surface area extractions from closed bomb tests using damaged grains is being developed to replace this simple scale.

Table II. Interpretation of TFN Parameter.

<u>TFN</u>	<u>Likely Result</u>
0	No fracture.
5 - 15	Chipping.
15 - 40	Fracture into a few large shards.
40 - 65	Fracture into 4 - 6 larger pieces with few fine particles.
65 - 100	Fracture into many pieces with significant amount of fine particles.

E. Gun Propellant Tests

JA2 propellant, Lot RAD 81E001S110, and M30 propellant, Lot RAD 67878, (description sheets can be found in Appendix B) were used in the gas gun tester in order to compare their fracture responses. Tests were conducted at room temperature (23°C), 0°C, -10°C, -20°C, -30°C, -40°C and -46°C. For each temperature, the impact velocities ranged from 30 to about 100 m/s with five samples tested at each velocity. The total fracture number was calculated for each temperature-velocity combination, as described in the previous section.

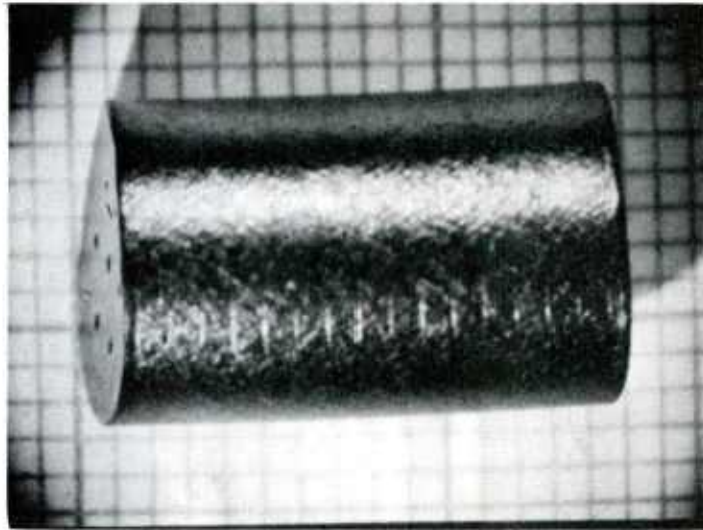


Figure 1. Unmodified JA2 Grain Used in the Gas Gun Impact Tester.

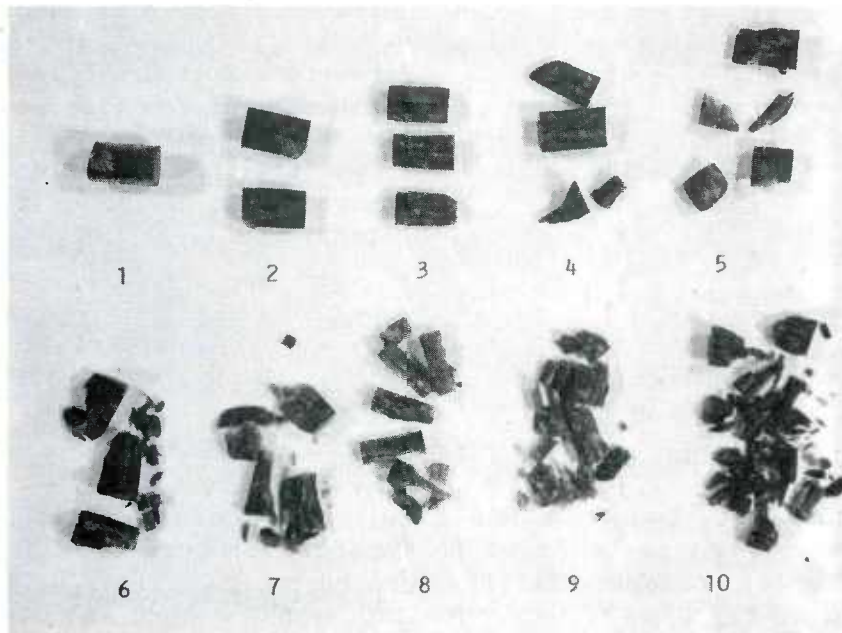


Figure 2. JA2 Grains Damaged in the Gas Gun and the Assigned Fracture Numbers.

III. RESULTS AND DISCUSSION

A. The Device

The gas gun impact tester can deliver a single grain of gun propellant at a selected velocity (between 30 and 120 m/s) and temperature (between -50 and 60°C) against an impact plate for fracture response evaluation. The velocities have about a 1 percent precision and seem to be within about 1 to 2 percent of the calculated values. Once the gun and samples are conditioned, the maximum rate of testing is about one firing per 2 minutes.

B. The Gun Propellant Tests

The results for the JA2 and M30 tests are given in Figures 3 and 4, and show the Total Fracture Number vs Velocity for each propellant. From the data, it is clear that there was a significant difference in the fracture characteristics of the two propellants. M30 fractured at all temperatures. It fractured more than JA2 at higher temperatures (above -20°C) and less than JA2 at lower temperatures (below -30°C). M30 also showed a uniform increase in the amount of fracture as the velocity was increased or as the temperature was lowered. This indicates that fracture may play an integral role in the ballistic performance of the M30 propellant. In contrast, JA2 had no significant fracture at any velocity down to -10°C. Below -20°C JA2 demonstrated a significant increase in its susceptibility to brittle fracture. The data also indicate that at low temperatures the fracture increased dramatically above an impact velocity of about 65 m/s. This sudden change in fracture susceptibility may be severe enough to produce anomalous interior ballistic behavior at -30°C that is worse than at lower temperatures because of the higher burning rate at -30°C.

C. Future Modifications and Analysis

To obtain more information about the fracture event, the propellant grains will be impacted against a piezoelectric force gage instead of the plate. Tests with plastic plugs have shown that the force-time curve can easily be recorded. The impulse of the collision (the integral of the force vs time curve for the impact event) against the force gage was found to be 1.65 times the momentum of the plug just before impact, which is a very reasonable value for this type of collision (in an ideal elastic collision this value is 2, and for a totally inelastic collision it is 1). The force-time profile will reveal when fracture occurs and, if flat-ended samples are used, failure stresses can be calculated.

High speed photography can also be implemented to show how the grain impacts, and how fracture proceeds. The velocity and stress information from the other instrumentation could also be checked with the film record.

The most immediate need is the development of a quantitative analysis technique to measure the degree of fracture damage. The direction in current interior ballistic theory development is to treat the propellant grains as real particles, capable of deformation or damage, rather than as the idealized

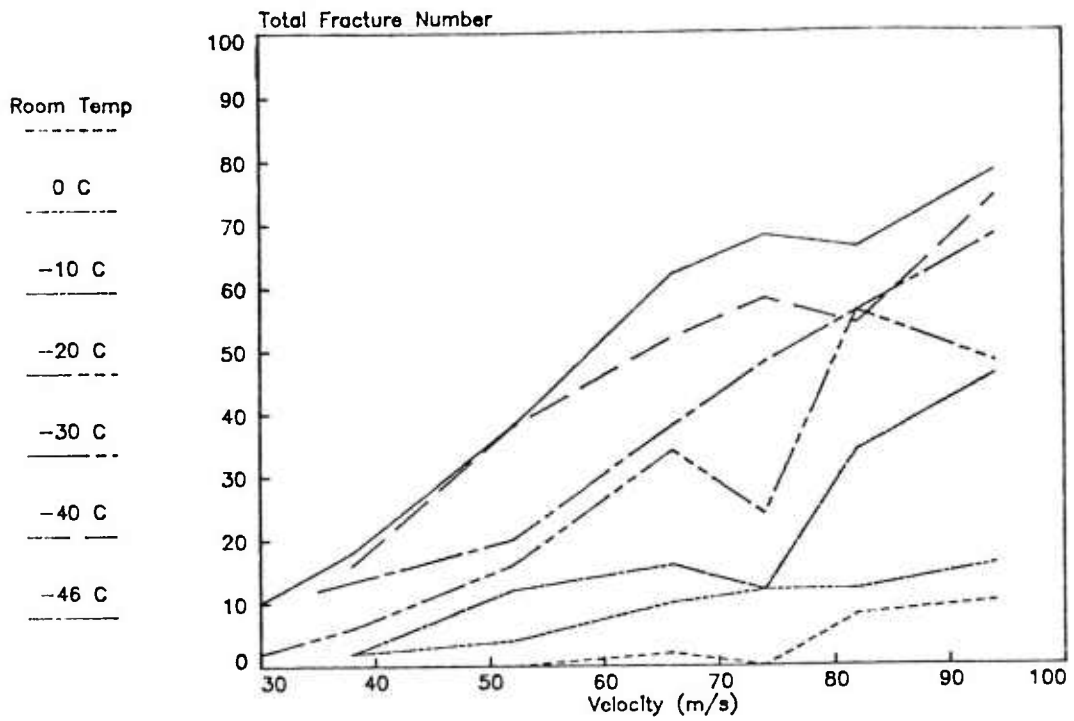


Figure 3. Total Fracture Number vs Velocity for M30 from Room Temperature to -46°C.

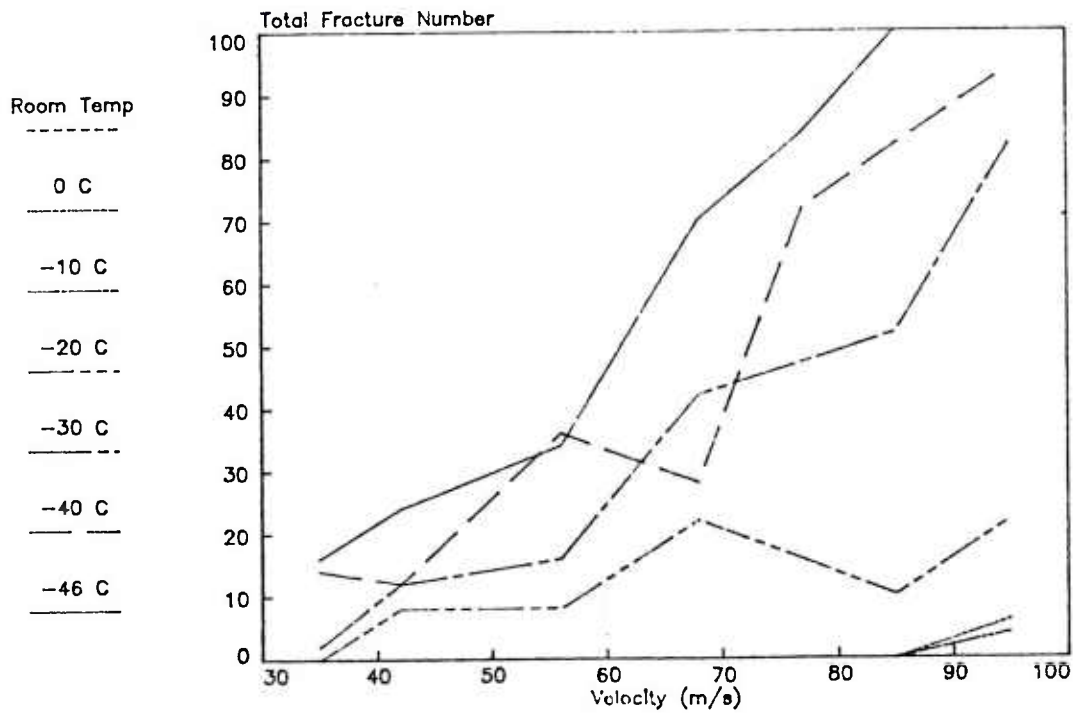


Figure 4. Total Fracture Number vs Velocity for JA2 from Room Temperature to -46°C

infinitely stiff, nondeformable entities as currently described. A quantitative measure of fracture damage would permit such a treatment. This, in turn, would permit the computation of augmented mass generation rates as a result of grain damage. Such a capability would dramatically improve the ability to predict catastrophic events in guns.

This future quantitative damage analysis will be based on experimentally determined changes of the propellant surface area profile vs mass fraction burned.⁴ The technique involves the use of the "inverse reduction" mode of CBRED2, a closed bomb analysis program. In this method, measured burning rates of undamaged grains are used as input in analyzing the pressure-time histories of closed bomb firings of damaged propellant grains. The output from the computations is surface area vs mass fraction burned. Efforts to extract meaningful numbers from this analysis procedure are in progress, and the results will lead to greater insight into the effects of fracture and, more importantly, numbers that can be used to predict performance.

IV. CONCLUSIONS

A technique has been developed to evaluate the fracture response of gun propellant to impacts at velocities from 0 to 120 m/s over a temperature range of -50 to 60°C. The gas gun device measures impact velocities within 2 percent and provides a temperature conditioned barrel to ensure that impact conditions are well known. Tests using the technique have been performed on two different propellant formulations under the same testing conditions and a fracture response difference has been measured and interpreted. The technique serves a valuable role in an effort to link standard, highly structured mechanical properties testing, with fracture response evaluation under conditions more closely approximating early ignition within the gun tube.

V. ACKNOWLEDGEMENTS

The authors would like to extend special thanks to SP4 Dianne Bolden, who conducted many of the gas gun firings, for her diligent efforts in carrying out this and other portions of the experimental procedure. Much appreciation is also due to Dr. Arpad A. Juhasz and Dr. Martin S. Miller for their time and suggestions while reviewing this report.

⁴C. Price and A. Juhasz, "A Versatile User-Oriented Closed Bomb Data Reduction Program (CBRED)," BRL Report 2018, USA ARRADCOM, Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, September 1977. ADA-049465.

REFERENCES

1. W. G. Soper, "Ignition Waves in Gun Chambers," Combustion and Flame, 20, pp 152-162, 1973.
2. R. J. Lieb, and J. J. Rocchio, "Standardization of a Drop Weight Mechanical Properties Tester for Gun Propellants," Technical Report ARBRL-TR-02516, USA ARRADCOM Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, July 1983. ADA-132966.
3. R. J. Lieb, and J. J. Rocchio, "High Strain Rate Mechanical Properties Testing on Lots of Solid Gun Propellant with Deviant Interior Ballistic Performance," 1982 JANNAF Structures and Mechanical Behavior Subcommittee Meeting, CPIA Publication 368, pp 23-38, October 1982.
4. C. Price and A. Juhasz, "A Versatile User-Oriented Closed Bomb Data Reduction Program (CBRED)," BRL Report 2018, USA ARRADCOM, Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, September 1977. ADA-049465.

APPENDIX A

Gas Gun Impact Tester
Description

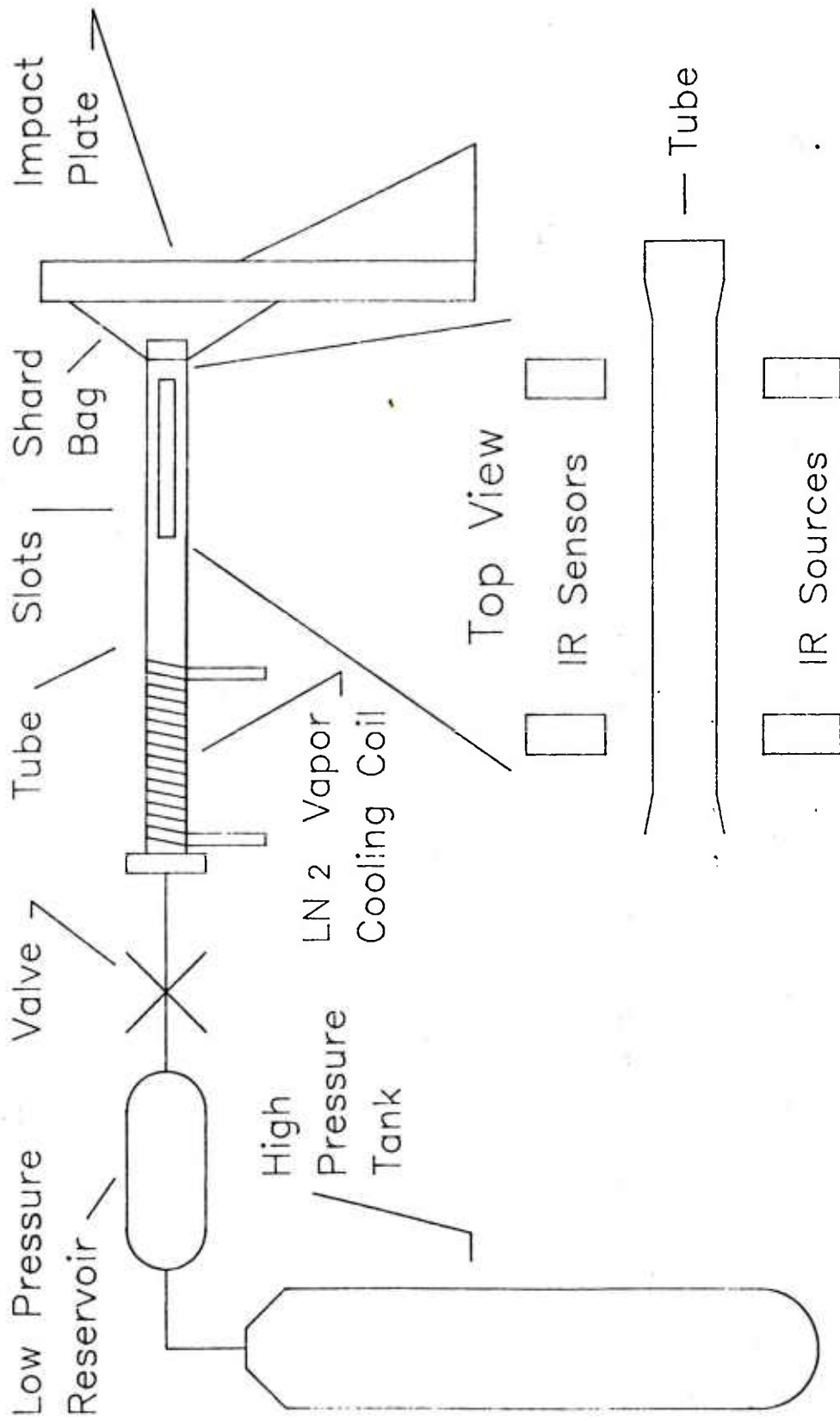


Figure A-1. Schematic Diagram of the Gas Gun Impact Tester.

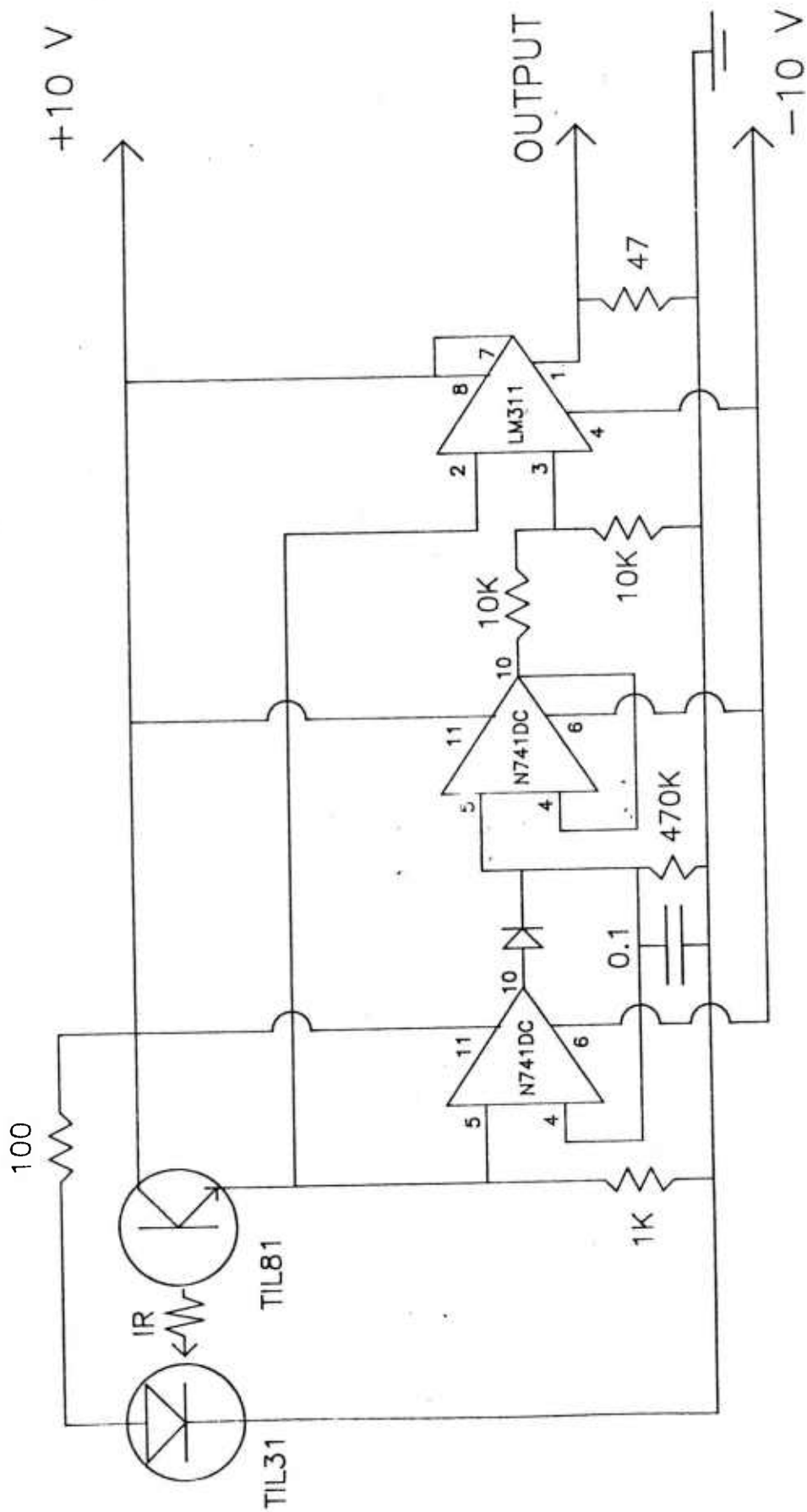
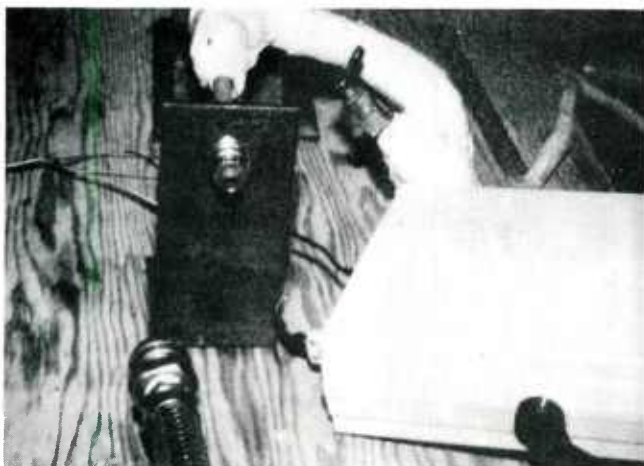


Figure A-2. Schematic Diagram of the Infrared Detectors and Pulse Generator.



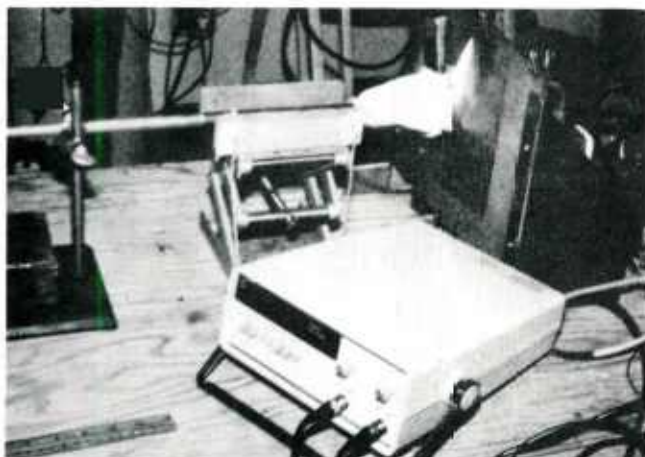
a. Gas Gun Impact Tester.



b. Quick-Fit Connection at the Breech.



c. Breech Showing Flexible Connection and Temperature Controlled Region.



d. Infrared Sensors, Shard Bag, and Impact Plate at Muzzle.



e. Slots Permitting Nitrogen Exhaust and Velocity Measurement.

Figure A-3. Photographs of the Gas Gun and Its Components.

Table A-I. List of Commercially Available Gas Gun Components

Temperature Measurement:	Omega, Model 199, Digital Display Thermocouple.
Time-of Flight Measurement:	Hewlett-Packard, Model 5314A, Universal Counter.
Low Pressure Reservoir:	Whitey, Model 4EK080-304L-HDEA-1000CC, Stainless Steel Cylinder.
High Volume Valve:	Automatic Switch Company, Model 8210C7, Solenoid Shut Off Valve.
Flexible Hose:	Swagelok, Model SS-8HO-1-8-S8, 0.5" ID with Quick Connects.

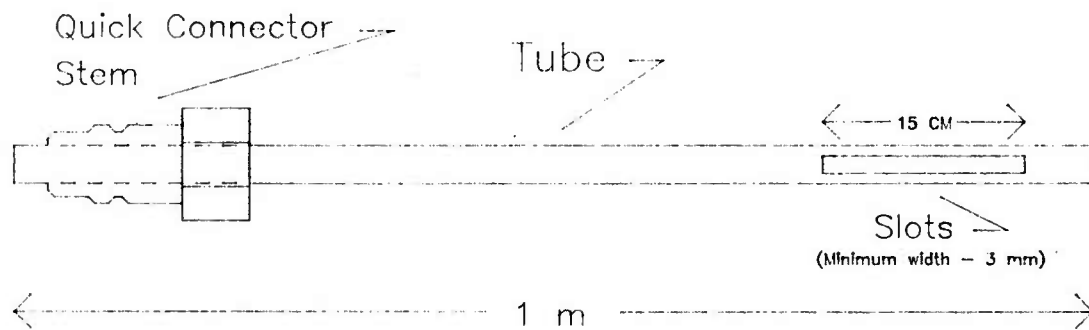


Figure A-4. The Barrel, Consisting of a Selected Diameter Tube with Slots near the Muzzle Inserted into a Quick Connector.

APPENDIX B
Propellant Description Sheets

PROPELLANT DESCRIPTION SHEET				EXEMPT PARA 7-2a AP 335-15							
COMPOSITION PROPELLANT L546011A-21 1/2 caliber, 120mm X576 with APFSDS-T, DM13 and APFSDS-T simul., DM28			LOT NUMBER RAD81E001S110								
SPECIFICATION MONEYWELL TRANSLATION PD-17			PACKED AMOUNT 15,150 Pounds								
MFG AT RADFORD ARMY AMMUNITION PLANT, RADFORD, VA.			CONTRACT NUMBER 120mm TANK AMMUNITION MERCULES/MONEYWELL F.D. 219584								
NITROCELLULOSE											
ACCEPTED BLEND NUMBERS			NITROGEN CONTENT	KI STARCH (65.5°C)	STABILITY (134.5°C)						
C95005			MAX 13.01 %	MIN	MIN						
C95006			MIN 12.91 %	MIN	MIN						
C95007			AVG 12.98 %	45 + MIN	30 + MIN						
EXPLOSION HP											
MANUFACTURE OF SOLVENTLESS PROPELLANT											
PERCENTAGE REMIX TO WHOLE											
TEMPERATURES °		PROCESS- DRYING		TIME							
FROM	TO			DAYS	HOURS						
100		Load Forced Air Dry at Ambient Temperature									
100	104	Increase Temperature to 104°F									
104		Hold at Temperature									
104	Amb	Cooled and Removed			4						
PROPELLANT COMPOSITION			TESTS OF FINISHED PROPELLANT								
CONSTITUENT	PERCENT FORMULA	PERCENT TOLERANCE	PERCENT MEASURED	TESTS	FORMULA	ACTUAL					
NITROCELLULOSE	59.50	±2.00	59.22	HEAT 120°C	No CC 40'	No CC 60'					
NITROGLYCERIN	14.90	±1.00	15.36	NO FUMES	1 hour	NF 1 hour					
DIETHYLENE GLYCOL DINITRATE	24.80	±1.50	24.48	FORM OF PROPELLANT	Cylinder	Perf.					
AKARDIT II	0.70	±0.2	.85	*ITALIANI	≤1.0 Hg/mm	0.3666					
MAGNESIUM OXIDE	0.05	MAX.	.04		(slope at 100mm)						
GRAPHITE	0.05	MAX.	.05	NDE	1120.0 cal	1117.3					
Total	100.0	100.0	100.0	IGNITION TEMP.	160°C min.	204.5					
Moisture	0.5	+ 0.3	.36	ABS DENSITY	1.565 min.	1.584					
UNGASIFIABLE CONSTITUENTS	0.3	MAX.	0.08	COMPRESSIBILITY	Info. Only	50.55					
METHYLENE CHLORIDE				BULK DENSITY	Info. Only	62.41					
SOLUBLE MATERIALS	40.4	±3.0	39.58	HYGROSCOPICITY							
GLAZE	0.02	NOM.	0.02	20% to 90° Hum	% Change	0.62					
**APPEARANCE				45% Hum	% Change	0.04					
CLOSED BOMB			PROPELLANT DIMENSIONS (inches)								
TEST	LOT NUMBER	TEMP °F	DYNAMIC RELATIVE QUICKNESS	RELATIVE FORCE	PARAMETER	SPECIFICATION	DIE	FINISHED	SPEC.	ACTUAL	STD DEV in % of Mean Dimensions
	RAD81E001S110	90°F			LENGTH (L)		0.540	0.535	6.25	1.11	
					DIAMETER (D)		0.355	0.345	6.25	1.36	
					PERF. DIA. (d)		0.024	0.0252			
STANDARD	NC-AU-746-79			100.00%	W1		0.069	0.0640			
					W0		0.072	0.0718			PACKED 5-12-81
					W2		0.071	0.0683			SAMPLED 5-12-81
					Webb		± 15%	10.0			TEST FINISHED 6-10-81
					Diff.						
					LD		1.4-1.8	1.549			OFFERED
					D.d		10-20	13.71			DESCRIPTION SHEETS FORWARDED 6-17-81
					UNIFORMITY	WT. 125 gr	N/A	128.10			
TYPE OF PACKING CONTAINER FIBER DRUMS PER MIL-STD. 652											
REMARKS **APPEARANCE AND CONDITION:											
Gray to Black, smooth, rectangular, without points, without dust, without foreign material.											
THIS LOT MEETS ALL CHEMICAL AND PHYSICAL REQUIREMENTS OF APPLICABLE SPECIFICATION											
SIGNATURE OF CONTRACTOR'S REPRESENTATIVE						SIGNATURE OF GOVERNMENT QUALITY ASSURANCE REPRESENTATIVE					
J. W. Pierce <i>[Signature]</i>						J. E. Bland <i>[Signature]</i>					

ARRCOM FORM 214R 10 AUG 77

AMC PROPELLANT DESCRIPTION SHEET

U.S. Army Lot No. RAD-67878 of 70 Cr. Approval No. M392A2 ITEM V3-24811 NGR FOR CTC. APDS-T.

Manufactured at RADEFORD ARMY AMMUNITION PLANT, RADEFORD, VA Packed Amount 165.011 lbs.
 Contract No. W-11-173 A/C-37(A) Date 4-29-49 Specification No. MIL-46489B

ACCEPTED BLEND NUMBERS	NITROCELLULOSE	TESTS
<u>A-34, 907; 908; 909; 910; 911; 912; 914</u>	Nitrogen Content	AI Starch (65°C)
	Maximum <u>12.67</u> %	<u>45+</u> Min
	Minimum <u>12.53</u> %	<u>45+</u> Min
	Average <u>12.61</u> %	<u>45+</u> Min
		Stability (134°C)
		<u>30 +</u> Min
		<u>30</u> Min
		<u>30 +</u> Min

MANUFACTURE OF PROPELLANT

0.22 Pounds Solvent per Pound XX Dry Weight Ingredients Consisting of 60 Pounds Alcohol and 40 Pounds ACETONE per 100 Pounds Solvent.
 Percentages Refer to Weights 10

TEMPERATURES		PROCESS-SOLVENT RECOVERY AND DRYING	TIME	
From	To		Days	Hours
		LOAD FORCED AIR DRY AT AMBIENT TEMPERATURE.		
		INCREASE TEMPERATURE 50° PER HOUR UNTIL 140° IS REACHED.		
		HOLD TEMPERATURE AT 140° FOR 40 HOURS.		

TESTS OF FINISHED PROPELLANT				STABILITY AND PHYSICAL TESTS		
PROPELLANT COMPOSITION	Percent Formula	Percent Tolerance	Percent Mixture	Formula	Actual	Actual
NITROCELLULOSE	28.00	±1.30	27.61	Heat Test 120°C	NO CC 40'	60'
NITROGLYCERIN	22.50	±1.00	22.17	NO FUMES		60'
NITROQUANTIDINE	47.70	±1.00	47.96	Form of Propellant		CC-D
ETHYL CELLULOSE	1.50	±0.10	1.49	NO. OF PERFORATIONS		7
CPYOLITE	0.30	±0.10	0.27			
TOTAL	100.00		100.00			
TOTAL VOLATILES	0.50	MAX.	0.21			
GRAPHITE GLAZE	0.2	MAX.	0.17			

CLOSED BOMB				PROPELLANT DIMENSIONS (inches)				Mean Variation in % of Mean Dimensions	
Lot	Lgt. H.-Bar	Temp. °F	Initial Pressure	Final Pressure	Specification	Die	Finished	Spec.	Actual
	RAD-67878	+40	95.65	100.46		0.662	0.6663	±.25 MAX.	0.66
	RAD-67878	-40	92.17	97.86		0.313	0.2770	±.15 MAX.	0.73
	RAD-63928	420	100.00%	100.00%		0.036	0.0314		
					Inner	0.0530	0.0463		Test Finished 11/9/70
					Outer	0.0500	0.0451		Sampled 11/9/70
					Average	0.0515	0.0457		Test Finished 11-25-70
					15% MAX.		2.61		Offered 12-3-70
					L/D	2.10 TO 2.50	2.41		Description Sheet
					D/D	1.2 TO 1.5	8.81		Perforated 10 Dec 70

Type of Packing Container FIBER DRUMS PER MIL-STD- 452B
 Remarks _____

THIS DOCUMENT CONTAINS THE CHEMICAL AND PHYSICAL REQUIREMENTS OF THE APPLICABLE SPECIFICATION.

Contractor's Representation: P. W. Steele 12-3-70
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