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**GENERAL MOTORS CORPORATION**

**FIRST INTERIM REPORT ON GM DRL'S  
2-1/4 INCH GUN PROJECT**

by

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and

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ABSTRACT

A high velocity light-gas gun of 2-1/4" caliber has been built and put into operation at GM Defense Research Laboratories during the past year. Four proof rounds have now been fired and have demonstrated a highly successful gun operation with a projectile weight of 0.44 lb at a velocity of 22,000 fps as programmed. This report is a brief account covering the description of the gun, the results of the firings, and an evaluation of the gun's performance.

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## INTRODUCTION

A high velocity light-gas gun of 2-1/4" caliber has been designed, built and put into operation at GM Defense Research Laboratories. This gun is similar to 20 mm light-gas guns now in use on GM DRL's free-flight ranges. In effect, it extends GM DRL's ballistic capabilities from 20 mm to 2-1/4" (57 mm).

Four rounds have now been fired from the 2-1/4" gun. The performance of the gun has been so highly satisfactory that this brief report has been prepared to give an account of the firings. A description of the gun and an evaluation of its performance are also included.

The 2-1/4" Gun Project has been sponsored by General Motors Corporation and by the Advanced Research Projects Agency of the Department of Defense. The design and building of the gun and its associated range facility together with the firing of the four proof rounds reported herein have been a GM project. The 20 mm scaled firing program and the interior ballistic computer analysis have been carried out under an ARPA contract.

## DESCRIPTION OF GUN AND RANGE

The GM DRL 2-1/4" gun is classed as an accelerated-reservoir light-gas gun. Basically this is a two-stage gun with gunpowder for the propellant of the first stage and hydrogen for the propellant of the second. A piston compresses the hydrogen. The hydrogen propels the model. First and second stages are joined by a heavy steel cylinder whose bore tapers from one end to the other. The piston is heavy and, being made of deformable material, penetrates deeply into the tapered bore at the end of the compression stroke. The end of the taper is closed initially with a high-pressure diaphragm.

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The action of the heavy piston in penetrating the taper generates a moving reservoir of high-pressure hydrogen in this region. The net result is that a nearly constant hydrogen pressure propels the model during the firing of the second stage, an optimum condition for firing fragile models. This type of piston action is also the source of the name: accelerated-reservoir light-gas gun.

The overall view of the 2-1/4" gun is shown in Figure 1. The gun breech is in the left near foreground and the high pressure housing and coupling sections are shown in the middle and background of the photograph. The 75-foot launch tube can be seen in position and projecting into the blast chamber at the end of the pre-flight (or evaluation) range. Orthogonal spark stations can be seen in the background.

A schematic of the 2-1/4" gun is shown in Figure 2. The overall length is 196'. The gun is mounted for free recoil, and 158 tons is the recoiling weight.

A few dimensions of individual parts may be of interest. The powder chamber has an I.D. of 16", an O.D. of 30", and a length of 7'. The pump tube has an I.D. of 10", an O.D. of 20", and a length of 107'. The cylinder housing the accelerated-reservoir in the coupling section has an O.D. of 38" and a length of 7'. Its bore tapers from 10" to 2-1/4" in a distance of 56". The reservoir cylinder is surrounded by a massive cylindrical structure that weighs 50 tons. The launch tube has an I.D. of 2-1/4", an O.D. of 15", and a length of 75'.

The pre-flight range consists of three tanks connected end to end for a total length of 173'. The first tank, 16' long by 8' in diameter, contains the blast of hydrogen. The middle tank, 140' long by 4' in diameter, has three orthogonal spark photography stations situated along its length. The last tank, 17' long by 8' in diameter, is an impact tank.

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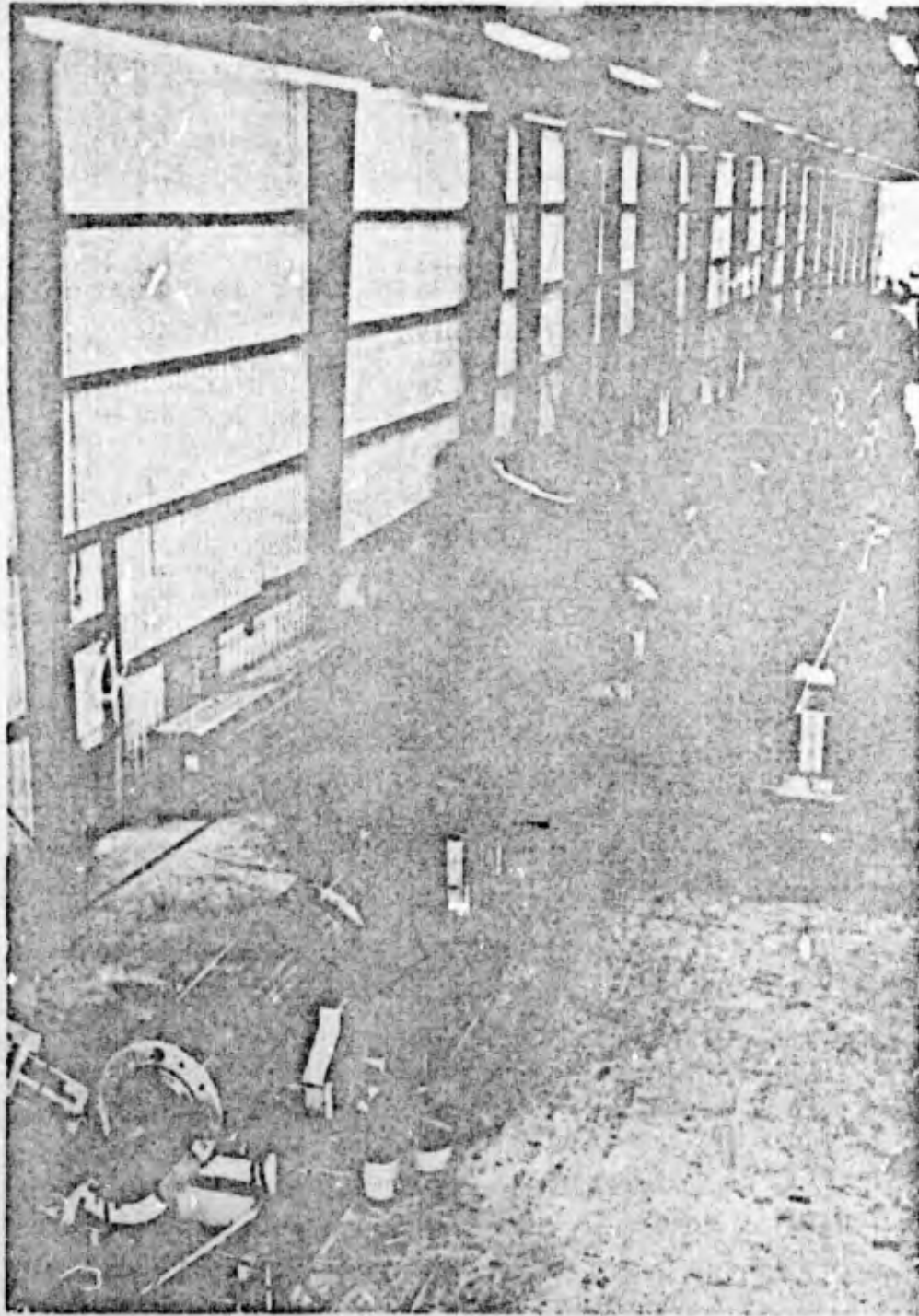


Figure 1 2-1/4" Gun and Range

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TOTAL RECOILING GUN 158 TONS  
MUZZLE VELOCITY 25,000 fps

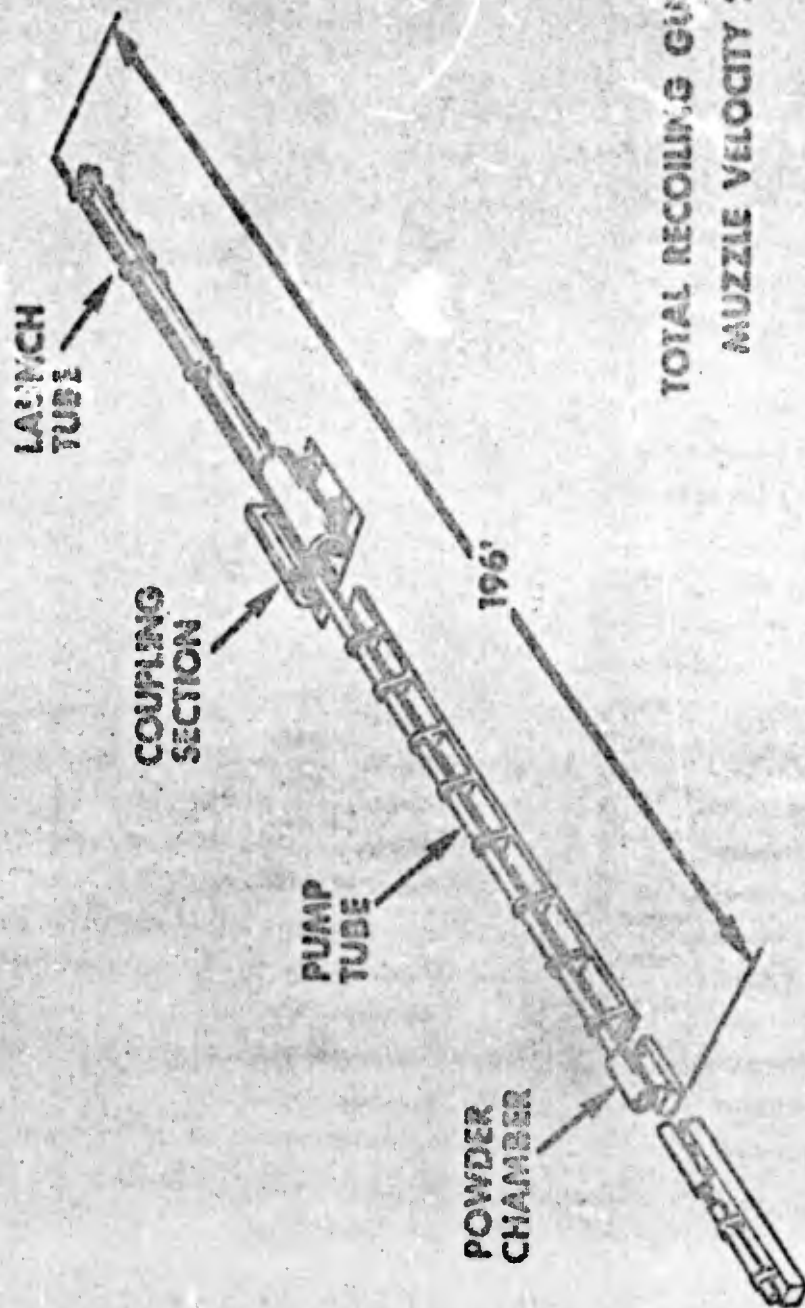


Figure 2 Schematic of 3-1/4" Gun

### Mechanical Features of Gun

The 2-1/4" gun has many unusual mechanical features. Three of these are particularly important in the functioning of the gun, namely: (1) the free-recoil system, (2) the welded launch tube, and (3) Hovair launch tube transporter.

The gun is designed so that it is free to recoil during the firing. The powder chamber, pump tube, and launch tube are supported on large, plane-roller bearings. The high pressure housing and coupling sections are supported on air bearing pads. The total recoiling weight is 158 tons and this large mass not only reduces the recoil distance to around 2" but also holds the recoil stresses along the length of the gun to manageable values. The measured firing movement has shown a maximum excursion of about 1.8" for the four shots fired so far. The motion of the gun is smooth without apparent "jerkiness." The free-recoil system eliminates the necessity of large and heavy mount structures and minimizes load concentrations during the firing cycle.

The launch tube is fabricated from three individual 25-foot lengths of gun tube by welding the three sections together to form a continuous tube of 75-foot length. The tube was honed to a nominal bore diameter of 2.3". The welded joints between sections show no discontinuities in the bore; in fact, a bore-scope inspection fails to reveal the welded region. If the launch tube continues to hold up under repeated firings, this technique will represent a substantial step forward in the manufacture of long launch tubes.

Another unique feature of this gun is the use of GM DRL's Hovair\* for transporting the launch tube from the gun to the honing machine. The gun tubes are honed between each round; this operation requires transporting the launch tube and its mount quickly and easily from the gun to the hone and positioning the

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\*Hovair<sup>®</sup> is a GM-developed air bearing system that uses relatively small airflows at low pressures to suspend loads frictionlessly.

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tube accurately at both locations. The problem lies in the 40-ton weight of mount and tube. To solve this problem, ten Hovalr pads are situated around the base of the mount. When air is supplied to these at a pressure of 8 psi, they raise the mount about 2" and support it on an air cushion. In this state two men can move the unit easily, despite its 40-ton weight. At the gun and at the home the tube is positioned accurately by allowing the mount to settle over pins secured in the floor.

#### BALLISTICS PROGRAM

The program as fired to date has been of a four-fold purpose:

1. To test the integrity of the mechanical components of the gun in a logical sequence with increasing severity of test
2. To demonstrate the velocity capability of the gun with cylindrical plastic models, bore fitting in size
3. To establish the relationship between velocity and loading conditions
4. To correlate these initial results with both computed and scaled experimental results so that one may proceed with confidence to the more difficult launching of sabot models.

The firing conditions for this gun - and indeed its major design parameters - have been predicted from three sources of information in addition to the extensive practical experience with the accelerated-reservoir light-gas guns extant at GM DRL. These information sources are:

1. The gun design method described in GM DRL TR64-27 by John S. Curtis, "An Analysis of the Interior Ballistics of the Constant Pressure Gun."
2. A digital computer study referred to in GM DRL TR66-01E by Daniel J. Collins and David K. Sangster, "Parametric Studies of a Fixed Geometry Light-Gas Gun."
3. An experimental program of scaled firings in 20 mm and caliber 30 accelerated-reservoir light-gas guns. These scaled firings will be reported separately in a later report.

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**FIRING RESULTS**

Results of the firings are as follows:

Shot No.	Date	Light Gas	Model Type	Model Mass (gms)	Velocity (fps)
1	6-10	Helium	Cylinder, Zelux	400	11500
2	6-21	Hydrogen	Cylinder, Polyethylene	200	18900
3	6-29	Hydrogen	Cylinder, Polyethylene	200	22000
4	7-25	Hydrogen	Cylinder, Zelux (Ballasted)	260	21100

The preflight range was evacuated for the first round (p less than 1 torr) and filled with nitrogen at a pressure of 10 torr (mm of Hg) for shots 2 and 3.

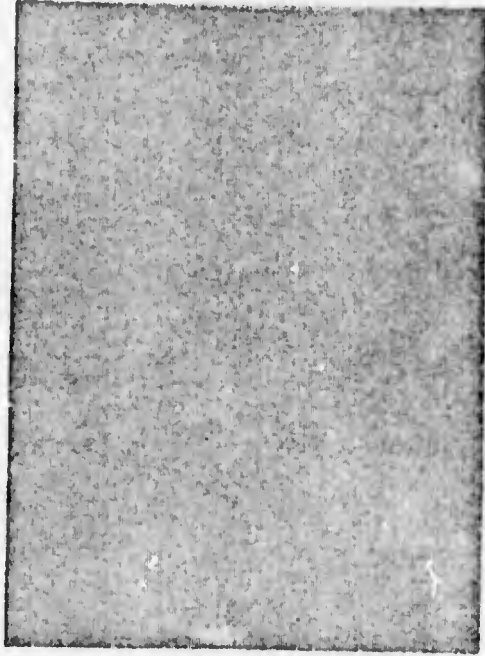
Typical shadowgraphs from station #1, 52' from the gun muzzle, for shots 2 and 3 are shown in Figure 3. These pictures are orthogonal projections, marked U (up) and D (down) respectively. They show the contour of the polyethylene cylinder and the outline of the head shock wave. The cross of the reference grid and an arrow giving the direction of motion can also be seen.

Studies of high speed impact are being carried out as a part of the 2-1/4" gun development program. Various types of targets are placed in the impact chamber round by round. The results of the impact tests will be reported separately.

Stress records on various parts of the gun are being made in order to study this aspect of its performance. Stress levels measured to date are consistent with predicted values. These results will also be reported separately.

The future firing schedule is listed in Table I. Shot #4 has completed the proof testing of the gun. The program continues under ARPA sponsorship with the development of techniques for firing sabot models.

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Shot #3



Shot #2

Figure 3 Representative Spark Photographs of Models in Flight

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Shot No.	Date	Light Gas	Model Type	Model Mass (gms)	Velocity (fps)
5	7-29	Hydrogen	Cu Plated Sphere, 1-1/2" Dia.	260	20000
6	8-5	Hydrogen	Cu Plated Sphere, 1-1/2" Dia.	260	22000
7	8-12	Hydrogen	Cone, 12-1/2°, 3/4" Dia.	250	20000
8	8-19	Hydrogen	Cone, 12-1/2°, 3/4" Dia.	250	22000
9	8-23	Hydrogen	Cylinder, Zelon	125	25000
10	8-26	Hydrogen	Cone, 12-1/2°, 3/4" Dia.	230	23000
11	9-2	Hydrogen	Cone, 12-1/2°, 1" Dia.	325	21000
12	9-4	Hydrogen	Cone, 6°, 3/4" Dia.	200	19000
13	9-16	Hydrogen	Cone, 3°, 3/4" Dia.	200	22000

Table I. PROJECTED FIRING PROGRAM

**PERFORMANCE EVALUATION**

A comparison of the velocities obtained in the 2-1/4" gun with those in the 20 mm gun scaled firings and the computed velocities are shown in Figure 4. The model velocity is plotted as a function of piston velocity, since this latter parameter is basic to the gun's performance.

The agreement between the three velocities is close. Refinements in the computer program will probably produce even better agreement.

The 20 mm scaled firings have the same velocity variation as the 2-1/4" firings, with the 2-1/4" velocities falling about 2% higher than the 20 mm velocities. This is both significant and encouraging. It supports the contention that "big guns shoot the same as little guns, only better."

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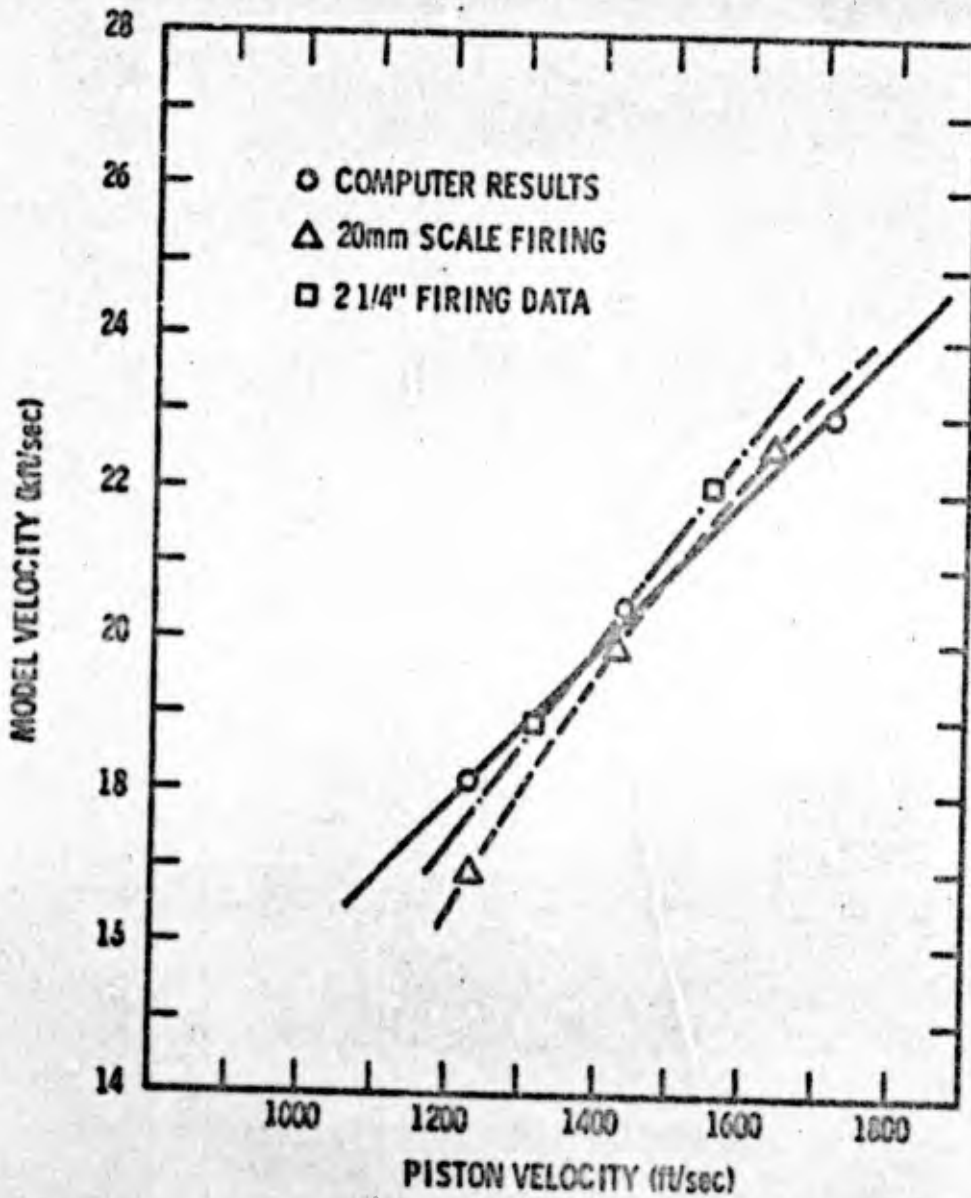


Figure 4 Velocity Characteristic Curves

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