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HUMAN FACTORS EVALUATION OF A RIFLE-LAUNCHED ROCKET PROJECTILE

Richard R. Kramer

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U. S. ARMY HUMAN ENGINEERING LABORATORY
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An experimental investigation was made of the aiming and cant errors associated with the firing of a rocket round from the muzzle of a rifle. The unusual features of the system were an appreciable weight at the muzzle (5-7 lbs) and an appreciably delay (.3 second) between ignition and launch. If ignition is accomplished by firing a ball round from the rifle, launch errors of 4-7 mils may be expected. If the ignition is recoilless, errors of 2 mils may be expected. Cant errors of about 1.40° (deg) appear typical.

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APPROVED: ______________________
JOHN D. WEISZ
Director
U. S. Army Human Engineering Laboratory

U. S. ARMY HUMAN ENGINEERING LABORATORY
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HUMAN FACTORS EVALUATION OF A RIFLE-LAUNCHED ROCKET PROJECTILE

INTRODUCTION

The problem of designing a lightweight infantry weapon system that accurately delivers a large warhead (1 kg or more) at moderate ranges (100-300 m) does not yet have a full satisfactory solution. Rifle-launched grenades suffer from low accuracy due to the launch method and the high trajectory. Rocket systems have been heavier than desired, and have not generally been as accurate as desired. A system which weighs 2 to 3 kg would be highly desirable if it could achieve system delivery errors of 1 to 2 m rad.

The Celesco Corporation has proposed a free rocket that achieves a flat trajectory without high velocity by the scheme shown in Figure 1. There are several features of the system which may pose stumbling blocks in the attempt to achieve small delivery errors.

1. There is a delay of .3 sec (nominal) between the time the trigger is pulled and the projectile leaves. If the rocket ignition is initiated by a ball rifle round, then the weapon will be recoiling during this period, disturbing the firer's aim. If, instead, the ignition sequence is initiated with a blank or other recoilless system (which requires that the bolt mechanism not operate) then some change in the point of aim during the .3 second can still be expected due to normal rifle wandering.

2. The system adds about 6 lbs to the front end of the M-16. Such a large weight can be expected to produce some increase in the aiming error.

3. The system is more cant-sensitive than a conventional ballistic system.

4. During the .3 second that the round is spinning, the turbine exhaust impinges on a supporting bracket that will apply both a torque about the spin axis, and predominately lateral displacement of the muzzle.

5. Upon release, the rocket motor will be exhausting downward and to the rear. Although the thrust is relatively small, there may be enough motor and ground debris blown back to cause discomfort, inducing anticipatory flinch.

If a system such as this is considered for further development, it will be necessary to evaluate the influence of these potential error sources. At this time, fireable systems are not available for test, so that evaluations must be based on simulations or calculations. We did not feel it worth the time and effort to construct a simulator to represent the blow back and turbine effects. However, we did feel that we could provide a good evaluation of the effects of weight, recoil and firing delay.

An additional potential problem occurred to us that is not directly related to the Human Engineering aspects of the system. As proposed, a disposable launch fixture would slide over the muzzle of the rifle. We wondered whether the alignment between the launcher and the rifle sights would be sufficiently repeatable from rifle to rifle as to not degrade system performance. The results of this investigation are given in the appendix.

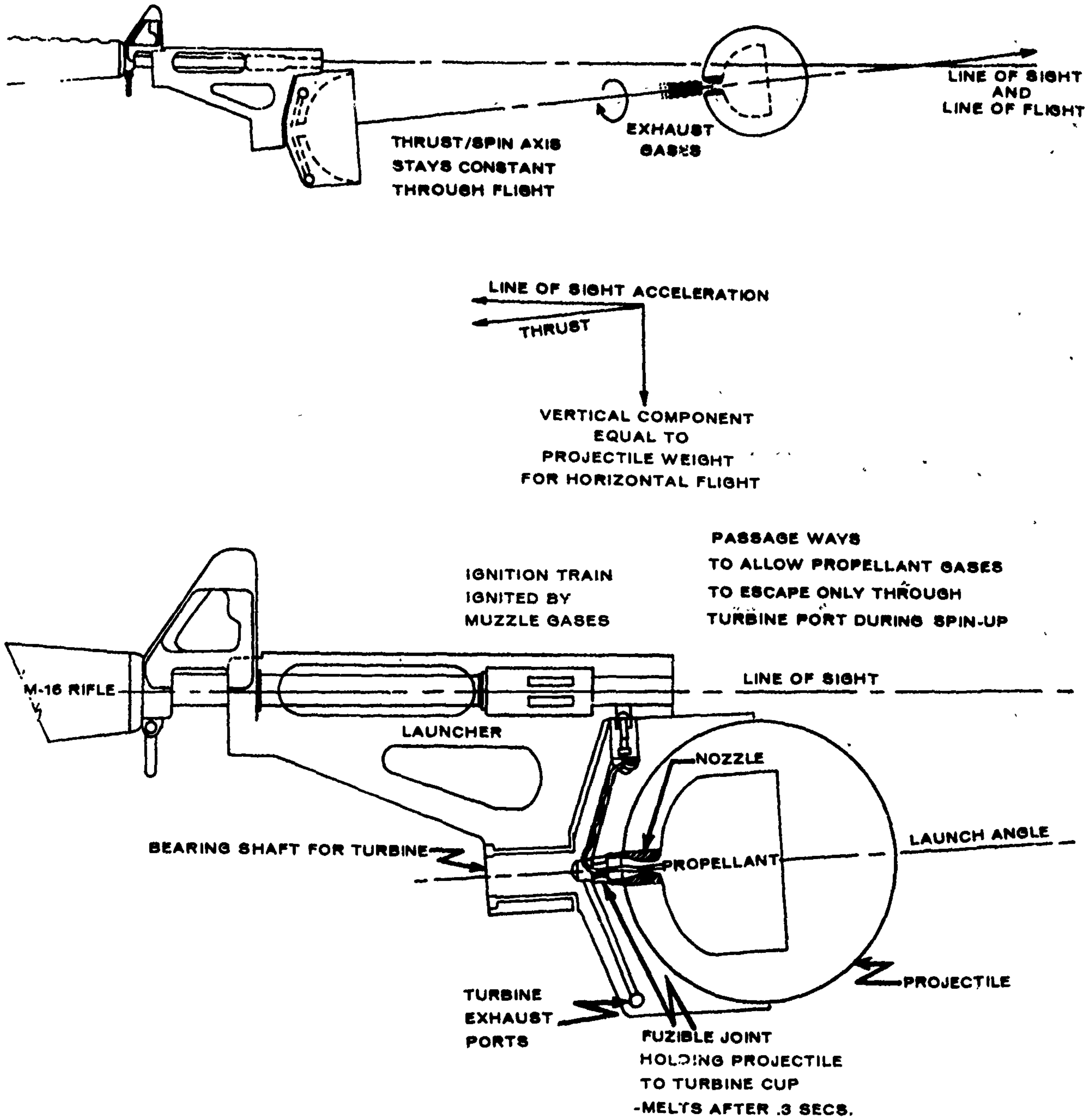

Fig. 1. Schematic of free rocket proposed by Celesco Corporation.

METHOD

General

The evaluation consisted of measurements of aiming error and cant angle against simulated windows or bunker openings. Measurements were taken at trigger pull, and .3 second later, using a small gun camera. The test was divided into the phases shown in Table 1. Twelve infantrymen served as test firers. Within each phase (where appropriate), the firing order was counterbalanced to preclude learning or other order effects.

Instrumentation

The simulation and measurement system modeled the weight, muzzle blast deflection, and, to a degree, the noise of the rocket. Figure 3 shows the fixture mounted to the muzzle. The purpose of the dome is to represent the top portion of the rocket which is close enough to the muzzle to deflect an appreciable amount of gas, thus exerting a downward impulse on the weapon. The camera, mounted underneath the dome, was electrically driven, and took a picture while the hammer was falling, and another .3 second later. The camera was equipped with a nominal 175 mm catadioptric lens, and took a 30-frame strip of 16 mm film. The effective resolution of the camera is better than 0.1 m rad.

At .3 second, a horn loudspeaker located about 1.5 m to the front of the firer emitted a 1 second burst of white noise. The sound-pressure level at the firer's position was about 120 db. The burst of noise, acting as a simulation of the departing rocket, served to accustom the firer to the duration of the .3 second spin-up delay.

For the zeroing phase, the targets were standard 25 m zeroing targets. For all other phases, with one exception, the targets were 4-ft-square white panels with 12" wide by 6" high black insets. The exception occurred in Phase 3, which used a window at the top of a tower as one of the targets.

Familiarization

The firers were instructed as to the features of the rocket, including its flat trajectory, large warhead, low signature, and easy employment using the M-16 rifle. They were also informed about the firing delay and its significance regarding aiming, and the importance of eliminating cant. They all understood the general principles of how the rocket worked, how the data was being collected, and that the purpose of the test was to gather data so that the weapon system designers could build the most effective system possible. Following the talking orientation, each soldier fired 10 blanks and 10 rounds of ball ammunition for familiarization.

TABLE 1

Test Outline

Phase	Description	Number of Ammo and Type	Muzzle Weight	Firing Position	Target Range and Angle of Site
0	Zeroing	120 Ball	3 lbs.	Prone Supported	41.5 m, 0^o
1	Kneeling	72 Ball & 72 Blank	5 lbs.	Kneeling	44, 96, 145 m, 0^o
2	Prone	432 Ball & 432 Blank	3, 5, 7, lbs.	Prone & Prone Supported	44, 96, 145 m, 0^o
3	Uphill	192 Blank	5 lbs.	Prone & Prone Supported	45m, 9.2^o and 49m, 18.9^o
4	Downhill	192 Blank	5 lbs.	Prone & Prone Supported	77m, -10.1^o and 49m, -17.9^o

Fig. 2. View downrange.

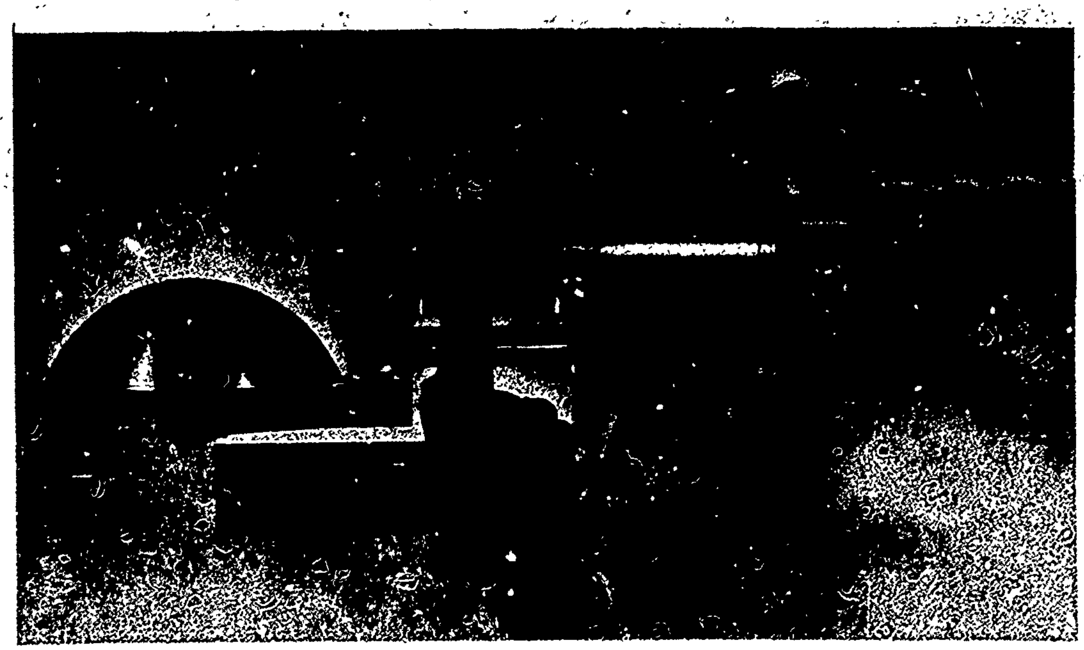

Fig. 3. Rocket simulator and gun camera.

Fig. 4. Shooter in firing position.

RESULTS

Table 2 shows the aiming and cant errors measured for each phase of the test. The results are the averages of the firers' standard deviations $\left(\frac{1}{12}\sum_{f=1}^{12} S_f \text{ where f is the firer number.}\right)$.

Corrections were made to account for boresight shift versus launcher weight (probably caused by barrel droop) and for range errors caused by parallax due to the camera offset from the rifle sights.

DISCUSSION

The zeroing aiming errors appear reasonable, and lead us to conclude that the addition of the test fixture did not destroy the accuracy achievable with the M-16 rifle in a prone sandbag position, and that the camera remained sufficiently stable with respect to the line of sight. The average standard deviation of cant error is less than one degree and is the lowest average value measure during any of the phases.

For the remainder of the test, aiming errors at trigger pull ranged from about 1 to 2 milliradians. In general, blank ammunition produced larger aiming errors, heavier weight at the muzzle tended to produce larger errors, and firing at the large angles of depression and elevation produced the largest errors. The effect of firing position appears to be negligible, possibly because any effect is overwhelmed by some other phenomenon that appears to be inflating the aiming errors. One possibility is that the gunners were concentrating on preparing themselves for the rocket release, or were willing to accept slop in their sight picture at trigger pull, feeling that they had time to correct before the rocket took off.

At rocket release, the pattern of errors is quite different from that at trigger pull. The effect of weight is stabilizing, that is, errors with the 7-pound weight attached are less than those with 3 pounds. Blanks produce markedly less dispersion than do ball rounds, and a sandbag or other support helps a little when firing blanks, and a lot when firing ball.

The cant angle data appears to be very noisy and unaffected by the test conditions. The average standard deviation of the cant error is approximately 1.4°.

CONCLUSIONS

For targets about the size of a window, at ranges of 200 meters or so, it appears that a rocket system such as that proposed by Celesco would not be severely limited in performance by aiming or cant errors provided initiation of the rocket is affected by a recoil-free system such as the firing of a blank round. Aiming errors at launch of about 2 mils may be expected from a prone-supported position, and about .5 mil larger for an unsupported position. If a ball round must be used, then launch error will increase to about 4 to 7 mils depending on the steadiness of the firer's position.

In all cases, the standard deviation of the cant error will be in the vicinity of 1.4°.

TABLE 2

Average Standard Deviations of Aiming and Cant Errors

CONDITION				STANDARD DEVIATION (MILLIRADIANS)			
Position	Weight	Ammo	Remarks	At Trigger Pull		Trigger Pull + .3 Sec	
				Aiming	Cant	Aiming	Cant
Prone(S)*	3 lbs.	Ball	Zeroing	.43	12.4	-	-
Kneeling	5	Ball		.8	13.3	5.5	22.9
Kneeling	5	Blank		1.2	15.6	2.3	22.4
Prone(S& U)	3	Ball & Blank		[illegible]	38.8	5.1	30.9
Prone(S& U)	5	Ball & Blank		1.4	27.2	4.9	28.2
Prone(S& U)	7	Ball & Blank		1.4	22.1	4.6	27.9
Prone(S)	3,5,7	[illegible]		1.1	34.0	3.7	31.6
Prone(S) Pron	3,5,7	Blank		1.2	22.8	2.0	31.7
Prone(U)	3,5,7	Ball		1.2	21.5	7.0	21.8
Prone(U)	3,5,7	Blank		1.6	26.7	2.4	21.7
Prone(U)	5	Blank	Uphill+9.2°	1.1	22.2	1.8	25.5
Prone(U)	5	Blank	Uphill+18.9°	1.8	19.2	2.1	21.2
Prone(S)	5	Blank	Uphill+9.2°	1.0	27.6	1.5	30.5
Prone(S)	5	Blank	Uphill+18.9°	2.0	29.8	1.9	17.6
Prone(U)	5	Blank	Downhill-10.1°	1.1	19.1	1.1	20.9
Prone(U)	5	Blank	Downhill-17.9°	1.9	16.1	2.2	18.3
Prone(S)	5	Blank	Downhill-10.1°	1.0	23.2	1.0	17.1
Prone(S)	5	Blank	Downhill-17.9°	2.0	22.0	1.7	18.4

* (S) denotes supported, (U) denotes unsupported.

APPENDIX

TEST USED TO DETERMINE THE DEGREE OF MISALIGNMENT BETWEEN THE SIGHTS AND THE MUZZLES FOR A SAMPLE OF M-16 RIFLES

In order to accurately launch a rocket from the muzzle of an M-16 rifle, either a separate sighting system must be provided, or the launcher must be reliably aligned with the rifle's sights. In the case of disposable, one-shot launchers, each launcher must be properly aligned with all rifles. The purpose of the test described here was to measure the degree of misalignment between the sights and the muzzles for a sample of M-16's.

A jig that held an optical sight was constructed to clamp on the muzzle in a manner representative of the way a launcher would be attached. Two methods were used. In the one case, (as shown in Fig. 1A) the jig seated on the rear of the flash suppressor and on the shoulder of the barrel immediately in front of the front sight. In the other case, the jig seated on the rear of the flash suppressor and the bayonet.

Ten rifles were zeroed at 25 meters, all by the same firer. Each rifle was then mounted in a fixture and the jig attached. A target was placed 25 meters from the weapon, and the difference between the points of aim of the rifle sight and the jig sight was noted.

The results are shown in Table 1A. For the launcher, the figures of interest are the standard deviations, which represent mainly rifle-to-rifle variability in the alignment between the rifle sights and exterior of the muzzle.

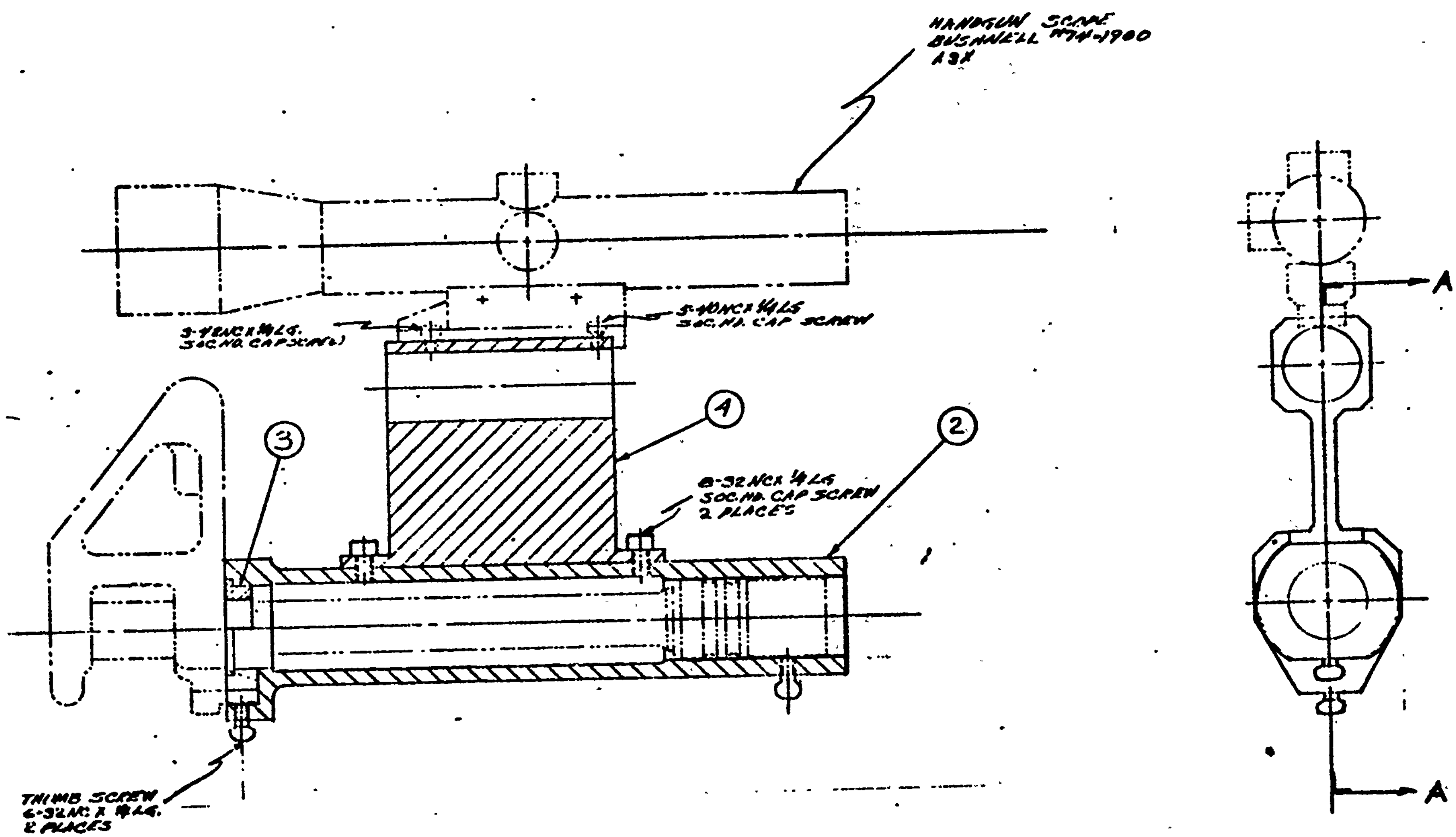

Fig. 1A. Aligning attachment (R.A.W.).
-1 Assembly

TABLE 1A

Sight/Muzzle Alignment

Rifle Serial Number	Bayonet Stud		Barrel Shoulder	
	Y Difference	X Difference	Y Difference	X Difference
820183	- 7.00 in.	- 2.00 in.	- 3.88 in.	+ 0.44 in.
825327	- 7.94	- 4.19	- 3.38	+ 0.31
830696	- 7.94	- 4.12	- 3.75	- 0.75
828934	- 8.75	- 2.19	- 5.00	- 0.19
832099	- 8.38	- 3.81	- 2.63	- 0.38
800222	- 8.25	- 3.94	- 2.94	- 1.50
824052	- 9.94	- 2.06	- 4.88	- 0.12
805418	- 7.88	- 3.38	- 3.00	- 1.19
821149	- 9.25	- 1.69	- 4.55	- 1.25
806399	- 11.06	- 1.94	- 4.88	- 0.88
Mean	- 8.64	- 2.93	- 3.89	- 0.55
Standard Deviation	± 1.17	± 1.04	± 0.89	± 0.67
Range	- 7.00 to - 11.06	- 1.69 to - 4.19	- 2.63 to - 5.00	- 0.44 to - 1.50