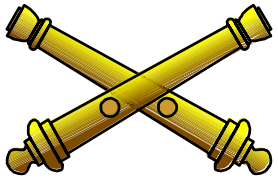
GUNNERY DEPARTMENT

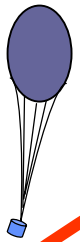


USAFAS

GUNNERY DEPARTMENT

FIVE REQUIREMENTS FOR ACCURATE PREDICTED FIRE

4
ACCURATE
MET INFO

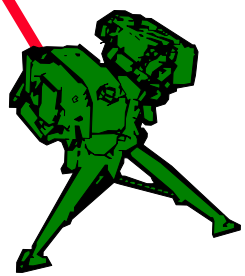


2
ACCURATE
BATTERY LOCATION

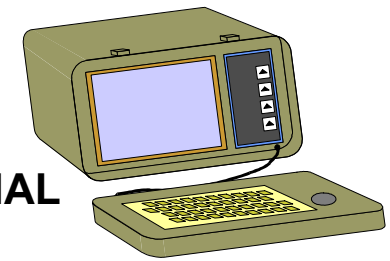
3
ACCURATE
WPN & AMMO INFO

POW !

1
ACCURATE
TARGET LOCATION

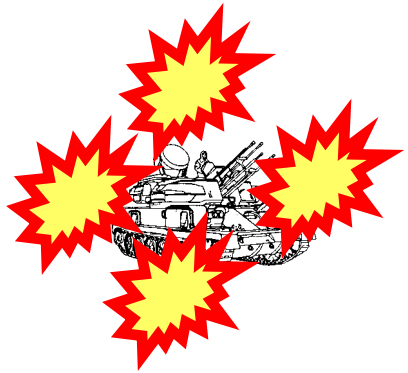


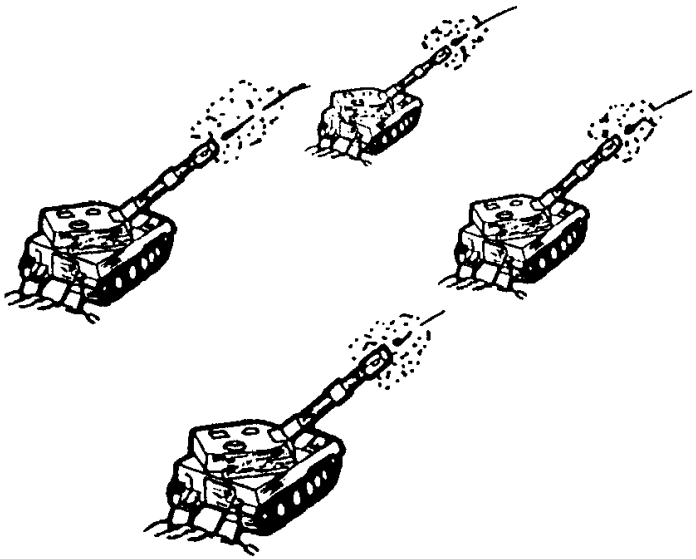
5
ACCURATE
COMPUTATIONAL PROCEDURES



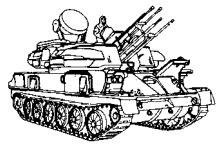
USAFAS

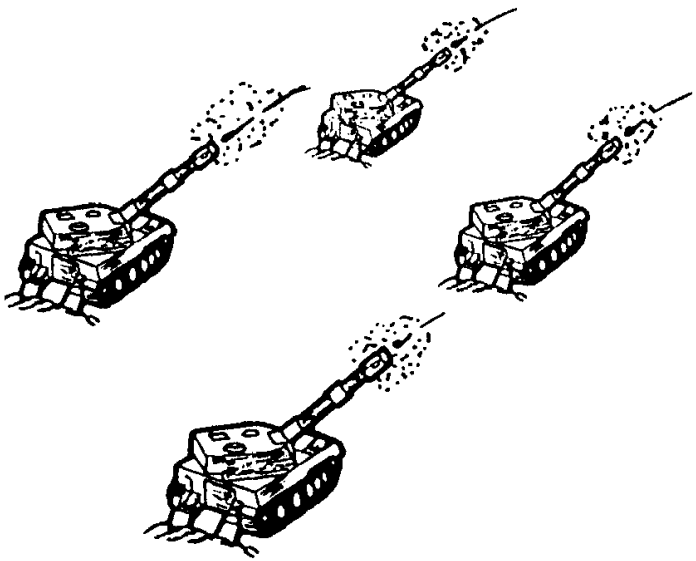
DATA FIRED UNDER STANDARD CONDITIONS





DATA FIRED UNDER NON-STANDARD CONDITIONS





TERMINOLOGY

MUZZLE VELOCITY (MV) - The velocity achieved by a projectile as it leaves the tube of howitzer. (m/s)

STANDARD MUZZLE VELOCITY - An established muzzle velocity used for comparison. Also known as Reference MV. Dependant on weapon system, propellant type, charge, and projectile family.

MUZZLE VELOCITY VARIATION (MVV) - The change in muzzle velocity of a weapon from the standard muzzle velocity (m/s;+/-). It is simply the difference between standard MV and the achieved MV during actual firing

TERMINOLOGY

- **PROJECTILE FAMILY - Projectiles with the same or nearly the same ballistic characteristics**

105 mm

HE
DPICM
RAP

155 MM

HE
DPICM
RAP
COPPERHEAD
ERDPICM (BB)

TERMINOLOGY

PROPELLANT TYPE - The nomenclature of the propellant used for a particular charge

105 mm	155mm
M67	M3A1
M176	M4A2
M200	M119A1/A2
M229	M203/A1

CHARGE GROUP - The charges within the propellant type which can be assigned an MVV

TERMINOLOGY

Preferred Charges

Within a charge group, those charges for which it is preferred to measure and transfer MVs. The performance of a preferred charge is indicative of the performance of other preferred charges within the charge group.

Restricted Charges

Within a charge group, those charges for which it is not preferred to measure and transfer MVs. The performance of a restricted charge is not indicative of the performance of other charges within the charge group.

TERMINOLOGY

Propellant Lot

A propellant made by the same manufacturer at the same location with the same ingredients

- 18,000 - 30,000 propellants per lot
- 82% probability that the round-to-round variation will not exceed 1.5 m/s

The difference in the performance between two separate lots of the same propellant type could vary greatly

TERMINOLOGY

M93/M94 Muzzle Velocity System (MVS)

These are devices used to measure the speed of the projectile as it leaves the muzzle of a weapon. Both devices operate using the same Doppler Effect principle as a police radar gun.

Calibration - The determination of a MVV for every weapon in the firing unit from M93/M94 readings

Absolute Calibration: a calibration in which the achieved MV of weapon is compared to the standard firing table MV.

Comparative Calibration: a calibration in which the achieved MV of weapon is compared to the MV of another weapon

TERMINOLOGY

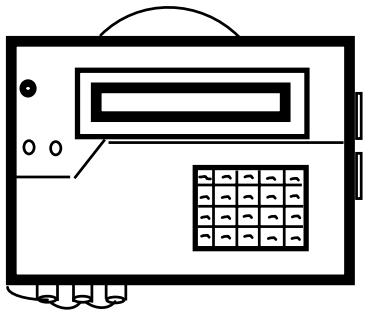
MVS Readout Muzzle Velocity - The initial actual velocities measured by the M93/M94 during a calibration which do not include corrections for any known non-standard projectile weight and/or propellant temperature.

CALIBRATED MV – Muzzle Velocity which has been corrected for any known non-standard projectile weight and/or propellant temperature

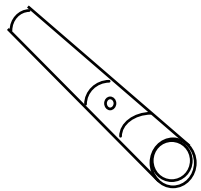
HISTORICAL MV - A calibrated MV that has been recorded in a MV Logbook

Calibrated MV - Standard MV = MVV

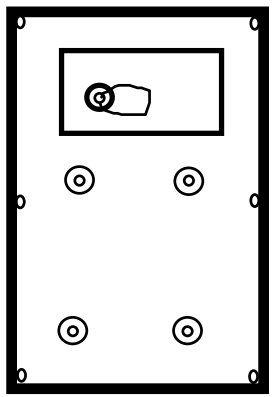
M93/M94 (MVS) COMPONENTS



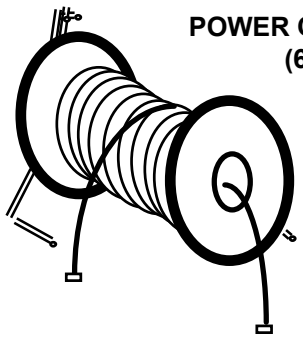
CONTROL PROCESSOR
AND DISPLAY UNIT (M94 Only)



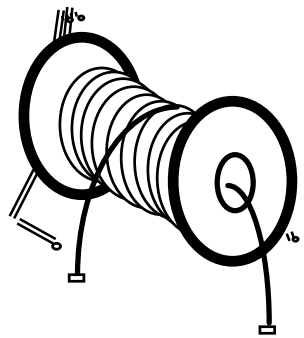
DOPPLER SIMULATOR



TRANSCEIVER
(REAR VIEW)



POWER CABLE
(60 METER)



INTERCONNECTION CABLE
(30 METER)

M93/M94 Capabilities

M93 PART OF THE PALLADIN (M109A6) SYSTEM

M93 STORES UP TO 500 MVVs

M94 DESIGNED FOR TOWED HOWITZERS (M119/M198)

M94 STORES UP TO 1000 MVVs FOR UP TO 6 DIFFERENT HOWITZERS

USES DOPPLER PRINCIPLE W/ DIGITAL SIGNAL PROCESSING

AUTOMATICALLY CORRECTS FOR NON-STANDARD CONDITIONS (PROP TEMP AND SQUARE WEIGHT) AND CALCULATES AN MVV

CAN MEASURE 18 ROUNDS/MINUTE

OPERATION OF M93/94

MOUNT TRANSCEIVER TO WEAPON (M94 Only)

CONNECT CONTROL PROCESSOR DISPLAY UNIT (CPDU) TO TRANSCEIVER AND TO VEHICLE POWER(M94 Only)

PERFORM OPERATIONAL CHECKS (SYSTEM TESTS)

ENTER MISSION DATA (WPN, PROJO TYPE AND SQUARE WT, PROP TYPE AND LOT #, PROP TEMP)

DEPRESS MEASURE KEY, VERIFY READY

MEASURE MVs

CALCULATE MVV WITH CPDU/AFCS AND STORE IN CPDU/AFCS

VERIFY MVV STORED

SHUT DOWN

WHEN SHOULD WE CALIBRATE?

WITH

EVERY

ROUND

FIRED!!!

REQUIREMENTS FOR A CALIBRATION

6 Usable Rounds (with 1-2 warm-up rounds)

Fired within 20 minutes

Assurance of Validity Table

MVS MV Average

Calculated after three rounds are measured and validated by the MVS

Calculated after any rounds are discarded by the operator

MVS automatically discards any measured rounds which are +/- 3.0 m/s from the determined average

MVS then continuously recalculates the average until there are no rounds +/- 3.0 m/s from the average

M93/M94 Average Muzzle Velocity:

313.2 m/s

(Before Corrections for non-standard square weight and propellant temperature)

GUNNERY DEPARTMENT

MVCT-1

MVCT-1

HOWITZER, 155MM, M109A1 AND M198

PROJ, HE, M107

CHARGE
4G

CORRECTIONS TO MUZZLE VELOCITY (M90 READOUT) IN METERS PER SECOND
TO COMPENSATE FOR DIFFERENCES IN
PROJECTILE WEIGHT AND PROPELLANT TEMPERATURE

TEMPERATURE OF PROPELLANT DEGREES F	PROJECTILE WEIGHT IN SQUARES							TEMPERATURE OF PROPELLANT DEGREES C
	1SQ	2SQ	3SQ	4SQ	5SQ	6SQ	7SQ	
-40	1.1	2.9	4.6	6.4	8.1	9.9	11.7	-40.0
-30	0.3	2.1	3.8	5.6	7.4	9.1	10.9	-34.4
-20	-0.4	1.3	3.1	4.8	6.6	8.4	10.1	-28.9
-10	-1.2	0.6	2.4	4.2	5.9	7.7	9.5	-23.3
0	-1.8	0.0	1.7	3.5	5.3	7.1	8.8	-17.8
10	-2.4	-0.6	1.1	2.9	4.7	6.5	8.2	-12.2
20	-3.0	-1.2	0.6	2.4	4.1	5.9	7.7	-6.7
30	-3.5	-1.7	0.1	1.8	3.6	5.4	7.2	-1.1
40	-4.0	-2.2	-0.4	1.3	3.1	4.9	6.7	4.4
50	-4.5	-2.7	-0.9	0.9	2.7	4.5	6.2	10.0
60	-4.9	-3.1	-1.4	0.4	2.2	4.0	5.8	15.6
70	-5.4	-3.6	-1.8	0.0	1.8	3.6	5.4	21.1
80	-5.8	-4.0	-2.2	-0.4	1.4	3.2	5.0	26.7
90	-6.2	-4.4	-2.6	-0.8	1.0	2.8	4.6	32.2
100	-6.6	-4.8	-3.0	-1.2	0.6	2.4	4.2	37.8
110	-7.1	-5.3	-3.5	-1.7	0.1	1.9	3.7	43.3
120	-7.5	-5.7	-3.9	-2.1	-0.3	1.5	3.3	48.9
130	-7.9	-6.1	-4.3	-2.5	-0.7	1.1	2.9	54.4

USAFAS

INTERPOLATION

80	→	+1.4
82	→	???
90	→	+1.0

+10 (80 – 90); +2 (80 – 82); x (+1.4 – ???); - 0.4 (+1.4 – +1.0)

$$\frac{+2}{+10} = \frac{x}{-0.4}$$

$$x = -0.08 \sim -0.1$$

$$10x = -0.8$$

$$\begin{array}{r} +1.4 \\ +\ (-0.1) \\ \hline ??? = +1.3 \end{array}$$

Determination of a Calibrated MV

M93/M94 Average Muzzle Velocity: 313.2 m/s

Muzzle Velocity Corrections for Non-standard conditions: + 1.3 m/s

Measured MV + Corrections = Calibrated MV

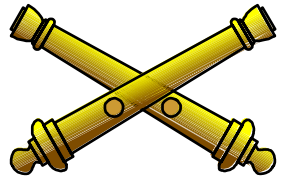
313.2 m/s + (+ 1.3 m/s) = 314.5 m/s

Determination of a Muzzle Velocity Variation (MVV)

Calibrated MV	-	Standard MV	=	MVV
314.5 m/s	-	316.0 m/s	=	- 1.5 m/s

MVV = - 1.5 m/s

GUNNERY DEPARTMENT



DA Form 4982-R

MUZZLE VELOCITY RECORD

For use of this form, see TC 6-40; the proponent agency is TRADOC.

DATE

POWDER MODEL

FIRST-LOT CALIBRATION

SHELL/FAMILY	FIRST POWDER LOT NUMBER	GUN NUMBER/CHARGE FIRED							
ITEMS		1/	2/	3/	4/	5/	6/	7/	8/
1. WEAPON BUMPER NUMBER									
2. WEAPON TUBE NUMBER									
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TABULAR FIRING TABLE [TFT])									
4. CALIBRATED MUZZLE VELOCITY (BATTERY COMPUTER SYSTEM [BCS] ENTRY)									
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 4 - LINE 3 = LINE 5)									

SECOND-LOT CALIBRATION

SHELL/FAMILY	POWDER GROUP	GUN NUMBER/CHARGE FIRED							
ITEMS		1/	2/	3/	4/	5/	6/	7/	8/
6. SECOND-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TFT)									
7. SECOND-LOT CALIBRATED MUZZLE VELOCITY									
8. SECOND-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 7 - LINE 6 = LINE 8)									
9. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 5)									
10. CHANGE IN MUZZLE VELOCITY VARIATION (LINE 8 - LINE 9 = LINE 10)									

SECOND-LOT INFERENCE

11. SECOND-LOT STANDARD MUZZLE VELOCITY (FROM TFT)								
12. CHANGE IN MUZZLE VELOCITY VARIATION (LINE 10)								
13. FIRST-LOT MUZZLE VELOCITY VARIATION (LINE 5)								
14. SECOND-LOT CALIBRATED MUZZLE VELOCITY VARIATION (LINE 12 + LINE 13 = LINE 14)								
15. CALIBRATED MUZZLE VELOCITY (BCS ENTRY) (LINE 11 + LINE 14 = LINE 15)								

REMARKS

DA FORM 4982-R, NOV 88 EDITION OF SEPTEMBER 1984 IS OBSOLETE.

USAFAS

GUNNERY DEPARTMENT

DA Form 4982-R

MUZZLE VELOCITY RECORD For use of this form, see TC 6-40; the proponent is TRADOC.	DATE 17 Mar 00 POWDER MODEL M3A1

FIRST-LOT CALIBRATION

SHELL/FAMILY	FIRST POWERDE LOT NUMBER
M107/HE	WCB-35-5291

ITEMS	GUN NUMBER/CHARGE FIRED							
	1/ 4G	2/ 4G	3/ 4G	4/ 4G	5/ 4G	6/4G	7/ 4G	8/ 4G
1. WEAPON BUMPER NUMBER	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18
2. WEAPON TUBE NUMBER	1111	1125	6034	3341	3250	3297	5807	5768
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TABULAR FIRING TABLE (TFT))	316.0	316.0	316.0	316.0	316.0	316.0	316.0	316.0
4. CALIBRATED MUZZLE VELOCITY (BATTERY COMPUTER SYSTEM (BCS) ENTRY)	314.5							
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 4 - LINE 3 = LINE 5)	-1.5							

USAFAS

AN FDO SHOULD APPLY MVVs to FIRE MISSONS:

- To the same gun
- Within the same projectile family
- Within the same propellant lot
- To the same charge or transfer MVV data to other charges according to an order of preference

TRANSFERING ORDER OF PREFERENCE

1. Same Charge
2. Transfer down one charge
3. Transfer up one charge
4. Transfer down two charges
5. Transfer up two charges
6. Transfer to any preferred charge
7. Transfer from preferred to restricted charges

Should We Transfer a Restricted Charge MVV?

NO! <u>NEVER</u> transfer from a restricted to a preferred charge

Therefore we should

<u>NEVER</u> calibrate a restricted charge

SHOULD THE MVV BE TRANSFERRED?

Howitzer: M198
Lots calibrated: M3A1 - Lots G&T
M4A2 - Lots W&Z

<u>Example #1</u>: Gun #4 calibrated with M825, Lot T, Charge 5

– FM, #4 3 rds, SH DPICM, Lot M/T, Chg 4, Fz Ti…

YES (Transfer down 1 CHG)

<u>Example #2</u>: Gun #3 calibrated with M107, Lot Z, Charge 6

– FM, #3 1 rd, SH WP, Lot S/Z, Chg 6, Fz Q…

YES (Chg match)

<u>Example #3</u>: Gun #1 calibrated with M107, Lot G, Chg 4

– FM, #1 2 rds, SH HE, Lot A/T, Chg 4, Fz Ti…

NO (Wrong Prop Lot)

SUBSEQUENT LOT INFERENCE

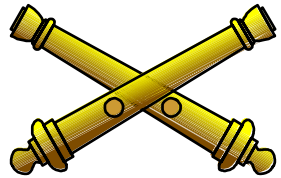
– A calibration technique which allows a firing unit to quickly update MV information for a given projectile family/propellant type combination when firing a new lot of propellant

– Subsequent lot calibration is used to isolate the difference/ change in efficiency between two propellant lots for one howitzer firing the same projectile family (w/ the new prop lot)

–The difference/change in propellant efficiency is applied to the first lot calibration data for the other howitzers to determine calibration data for the second (new) lot

GUNNERY DEPARTMENT

SUBSEQUENT LOT INFERENCE



MVV = Shooting Strength + Ammunition Efficiency + ~~Round-to-round Variation~~

MVV = Shooting Strength + Ammunition Efficiency

MVV = Shooting Strength + Propellant Efficiency + Projectile Efficiency

Ammunition Efficiency = Propellant Efficiency

MVV = SS + PE

USAFAS

REQUIREMENTS FOR AN INFERRED CALIBRATION

1. Calibration of one lot for the entire unit

2. A Calibrated MV for one gun with new propellant lot

* The subsequent lot should be calibrated with the same or adjacent charge as the first lot.

SECOND LOT INFERENCE

MUZZLE VELOCITY RECORD For use of this form, see TC 6-40; the proponent is TRADOC.	DATE 17 Mar 00 POWDER MODEL M3A1

FIRST-LOT CALIBRATION

SHELL/FAMILY	FIRST POWERDE LOT NUMBER
M107/HE	WCB-35-5291

ITEMS	GUN NUMBER/CHARGE FIRED							
	1/ 4G	2/ 4G	3/ 4G	4/ 4G	5/ 4G	6/ 4G	7/ 4G	8/ 4G
1. WEAPON BUMPER NUMBER	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18
2. WEAPON TUBE NUMBER	1111	1125	6034	3341	3250	3297	5807	5768
3. FIRST-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TABULAR FIRING TABLE (TFT))	316.0	316.0	316.0	316.0	316.0	316.0	316.0	316.0
4. CALIBRATED MUZZLE VELOCITY (BATTERY COMPUTER SYSTEM (BCS) ENTRY)	314.5	310.5	311.9	314.2	313.6	311.3	317.0	315.0
5. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 4 - LINE 3 = LINE 5)	-1.5	-5.5	-4.1	-1.8	-2.4	-4.7	+1.0	-1.0

SECOND LOT INFERENCE

KM-625-5194 17 Mar 00 SECOND-LOT CALIBRATION

SHELL/FAMILY	POWDER GROUP	GUN NUMBER/CHARGE FIRED							
M107/HE	M3A1								
ITEMS		1/	2/	3/	4/	5/ 5G	6/	7/	8/
6. SECOND-LOT CHARGE STANDARD MUZZLE VELOCITY (FROM TFT)						376.0			
7. SECOND-LOT CALIBRATED MUZZLE VELOCITY						370.3			
8. SECOND-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 7 - LINE 6 = LINE 8)						-5.7			
9. FIRST-LOT PIECE MUZZLE VELOCITY VARIATION (LINE 5)						-2.4			
10. CHANGE IN MUZZLE VELOCITY VARIATION (LINE 8 - LINE 9 = LINE 10)						-3.3			

SECOND LOT INFERENCE

SECOND-LOT INFERENCE								
11. SECOND-LOT STANDARD MUZZLE VELOCITY (FROM TFT)	376.0	376.0	376.0	376.0	376.0	376.0	376.0	376.0
12. CHANGE IN MUZZLE VELOCITY VARIATION (LINE 10)	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3
13. FIRST-LOT MUZZLE VELOCITY VARIATION (LINE 5)	-1.5	-5.5	-4.1	-1.8	-2.4	-4.7	+1.0	-1.0
14. SECOND-LOT CALIBRATED MUZZLE VELOCITY VARIATION (LINE 12 + LINE 13 = LINE 14)	-4.8	-8.8	-7.4	-5.1	-5.7	-8.0	-2.3	-4.3
15. CALIBRATED MUZZLE VELOCITY (BCS ENTRY) (LINE 11 + LINE 14 = LINE 15)	371.2	367.2	368.6	370.9	370.3	368.0	373.7	371.7
REMARKS								

DA FORM 4982-R, NOV 88

EDITION OF SEPTEMBER 1984 IS OBSOLETE.
L 1701 Army--Fort Sill, Okla.

PREDICTIVE MV TECHNIQUE

Technique in which the MV of a weapon is determined through mathematical procedures using some given information

PREDICTING MVV

MVV = Shooting Strength + Propellant Efficiency

MVV = SS + PE

PREDICTING MVV

SS = Pullover Gage Reading (POG)

OR

SS = EFCs

OR

SS = POG + EFCs (since last POG)

GUNNERY DEPARTMENT

DA Form 2408-4

WEAPON RECORD DATA

For use of this form, see DA PAMs 738-750 and 738-751; the proponent agency is DSCLOG.

REQUIREMENT CONTROL SYMBOL
CSGLD-1051

1. TUBE SERIAL NO.	2. CANNON TYPE, MODEL OR SERIES	3. ORGANIZATION (UIC)	4. SPECIAL LIFE DATA
0105	155mm M185	1st BN 40th FA WAZQAA	500 EFC ROUND LIFE

5. END ITEM IDENTIFICATION: How Med FT SP 155mm M109A2 SN: 4888

8. RDS/EFC COMPUTATION

ZONE	EFC
1-6	0.25
7	0.75
8	1.00

7. CANNON SERIAL NO.	8. RETUBINGS	9. REBUSHINGS
11206	0	

10. Data *a*	Projectile Type *b*	Zone or Charge *c*	Rounds Fired *d*	EFC RDS Fired *e*	Cumulative RDS Fired *f*	Cumulative EFC RDS *g*	Remaining Life (EFC RDS) *h*	Remarks: Recoil Exercise (RE), Gage or Velocity Reading, Safety Inspection (SI) *i*	Signature *j*
	(Previous DA Form 2408-4 final entries)								
24 Dec 93								VELOCITY READING M3A1, LOT WCB-CT-3250, CHG 4, 313.6	

CONTINUE ON REVERSE

DA FORM 1 JAN 79 2408-4

EDITION OF 1 DEC 77 WILL BE USED

USAFAS

SHOOTING STRENGTH

Howitzer: M109A3
EFCs: 1000

What is the Loss in MV (SS)? -2.0 M/S

Howitzer: M109A3
Pullover Gage Reading (POG): 6.181 inches

What is the Loss in MV (SS)? -11.7 M/S

SHOOTING STRENGTH

Howitzer: M198
EFCs: 1000

What is the Loss in MV (SS)? -7.6 M/S

Howitzer: M198
Pullover Gage Reading (POG): 6.180 inches

What is the Loss in MV (SS)? -9.5 M/S

PREDICTING MVV

SITUATION #1:

M198 Howitzer, New Tube (NO WEAR)
Propellant Efficiency = -5.2 M/S

MVV = Shooting Strength + Propellant Efficiency

= (POG + EFCs) + PE

= (0 + 0) + (- 5.2 m/s)

MVV = - 5.2 m/s

PREDICTING MVV

SITUATION #2:

4 Months later, same M198 Howitzer
Erosion EFCs = 1400 EFCs
Propellant Efficiency = -5.2M/S

MVV = Shooting Strength + Propellant Efficiency

= (POG + EFCs) + PE

* No POG reading available, enter Wear Table with EFCs cumulated, then determine Loss in MV (SS).

MVV = EFCs + PE

= (-10.3 m/s) + (-5.2 m/s)

= -15.5 m/s

PREDICTING MVV

SITUATION #3:

M198 Howitzer, Month 7, Howitzer just back from Semi-annual Maintenance
Pullover Gage Reading = 6.141 Inches
Propellant Efficiency = -5.2 m/s

MVV = Shooting Strength + Propellant Efficiency

= (POG + EFCs) + PE

* Must enter the Wear Table with POG in inches, then determine Loss in MV (SS).

MVV = (POG) + PE

= (-4.7 m/s) + (-5.2 m/s)

MVV = -9.9 m/s

PREDICTING MVV

SITUATION #4:

11 Months, same M198 Howitzer

Pullover Gage Reading =	6.141 Inches
Erosion EFC'S since last POG =	450 EFCs
Propellant Efficiency =	-5.2 m/s

MVV = Shooting Strength + Propellant Efficiency

= (POG + EFCs) + PE

** 1st: Convert POG to EFCs

2nd: Add value to cumulated EFCs since the last POG

3rd: Total EFCs will be used to determine Loss in MV

PREDICTING MVV

MVV = (EFCs~Old POG + EFCs since last POG) + PE

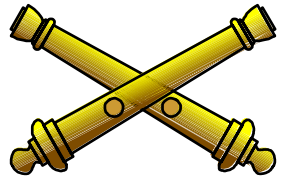
= (600 EFCs + 450 EFCs) + (-5.2 m/s)

= (-7.9 m/s) + (-5.2 m/s)

MVV = -13.1 m/s

MUZZLE VELOCITY MANAGEMENT ORDER OF PREFERENCE

1. Calibration of each howitzer
2. Subsequent Lot Inferred Calibration
3. Predicted MVVs
4. Shooting Strength



ATTEMPT TO CALIBRATE WITH EVERY ROUND FIRED !!!

If you can't calibrate:

1. **Infer**
2. **Predict MVVs**
3. **Use Shooting Strength**

NEVER ASSUME STANDARD MV