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EVALUATION TEST OF RADAR CHRONOGRAPH SET, NM87

ADB004019

December 1974

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Fire Control Development & Engineering Directorate

U.S. ARMY ARMAMENT COMMAND  
FRANKFORD ARSENAL  
PHILADELPHIA, PENNSYLVANIA 19137

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**20. Abstract (cont.)**

and is capable of the same order of precision as is possible with the M36 Radar Chronograph Set which is the item currently used for muzzle velocity measurements.

Report indicates some limitations and recommends improvements for utilization of the equipment.

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## INTRODUCTION

The evaluation of the NM87 Radar Chronograph was authorized under PSTC Project #3-220132. The project was initiated as part of the Foreign Materiel Program to acquire sufficient test data to evaluate the operational performance, reliability, maintainability, and durability of the NM87 Radar Chronograph under actual tactical conditions.

## DESCRIPTION OF MATERIEL

The Radar Chronograph Set, Mera Bergen Model NM87, is designed to measure the muzzle velocity of field artillery weapons under actual tactical conditions. The NM87 consists of the following items:

- Doppler Radar (Figure 1)
- Chronograph (Figure 2)
- Cable Reel Assembly (Figure 3)
- Mounting Set
- Transport Case

The doppler radar unit houses the transmitter/receiver, and is normally mounted directly on the gun carriage. The chronograph unit incorporates the logic circuits, the numeric display, the power distribution circuits, and all operational controls. The cable reel assembly consists of two cables; one cable is used for battery connection and one cable for power and signal transmission to the doppler radar and the chronograph.

The mounting set consists of brackets with necessary supports and screws to mount the doppler radar to the gun/carriage.

The transport case houses all the above mentioned items with the exception of the cable reel assembly.

The doppler radar transmits continuous power on a wavelength of approximately three centimeters. The radar beam is transmitted along the trajectory of the projectile by means of a parabolic antenna. When the projectile leaves the muzzle and enters the radar beam, some of the transmitted power is reflected and detected in the receiver. By counting doppler periods between transmission and reception of reflected radar emissions, the position of the projectile is determined independent of the velocity. After 2176 doppler periods (corresponding to a trajectory of 35 meters), an electronic gate is opened for a duration of 128 doppler periods (corresponding to a base length of 2 meters). During this time, the flight time of the projectile is measured and is presented in 1/4 microsecond units on a 5-digit numeric display. By means of conversion tables, the displayed reading is converted to velocity at the muzzle in meters/second.

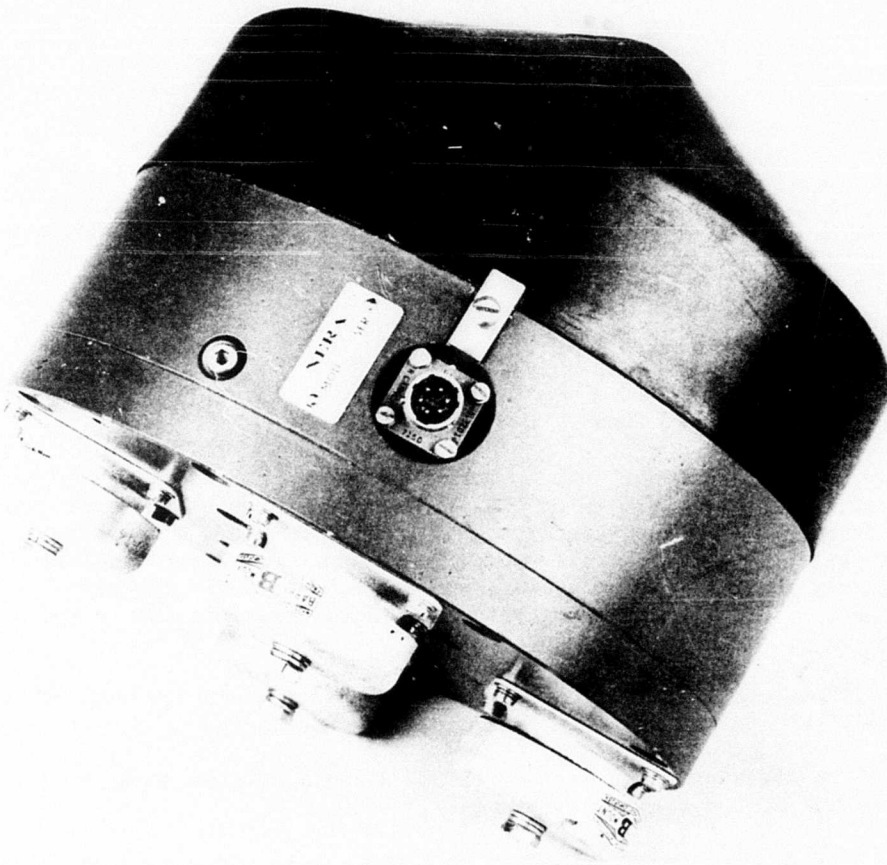


Figure 1. Radar Chronograph NM87, Doppler Radar



Figure 2. Chronograph NM87, Chronograph



Figure 3. Radar Chronograph NM87, Cable Reel Assembly

## EVALUATION OBJECTIVES

The objective of the evaluation program described herein was:

- a. Evaluation of the electrical and mechanical features of the NM87 Chronograph to determine whether it can be handled, operated, and maintained safely by operating personnel in a field artillery environment.
- b. Evaluation of reliability, durability, and maintainability of the NM87 Chronograph under actual tactical conditions, including exposure to ambient field conditions, the shock of repeated firings, and the ease or difficulty experienced in assembly and disassembly of the test item for firing tests.
- c. Comparison with other muzzle velocity measuring devices in terms of advantages and disadvantages, state-of-the-art, and potential for savings in operation.

## RESULTS OF EVALUATION TEST PROGRAM

The NM87 is easy to install, simple to operate, rugged, reliable, and requires little maintenance. Its functional performance complies with the specification requirements furnished by the manufacturer.

It was not possible to design a firing test which would demonstrate the accuracy of the NM87. However, a series of firing tests were conducted which constituted an adequate performance demonstration. From the firing test data, inferences were drawn with regards to the precision of measurement, namely, that there is no indication of any statistically significant differences in precision between the NM87 and the other muzzle velocity measurement devices tested with standard weapon projectile combinations. Test data also revealed that the NM87 does not have the capability to reliably measure the muzzle velocity of 8-inch RAP projectiles fired at charge 9.

Our results relative to the precision of the NM87 were confirmed by the U.S. Army Ballistic Research Laboratories. The data gathered by Frankford Arsenal during this test were presented to the BRL for analysis. The data were analyzed in accordance with the methodology adopted by the U.S. and other NATO nations as the most efficient and unbiased means of estimating and comparing relative chronograph performance when two or more instruments are used to make simultaneous measurements of gun muzzle velocities. It must be pointed out that the data reduction process did not include corrections for the recoil velocity of the doppler radar when it was mounted on the weapon.

## DETAILS OF EVALUATION TEST

### Introduction

The NM87 Radar Chronograph Set was tested in accordance with the evaluation schedule contained in Appendix A. Most of the criteria shown in this report were extracted from the supporting documents furnished by the manufacturer. Where no specific criteria were available, the ones used were based on experience and knowledge in the testing of similar types of items.

Upon receipt of the test item in November 1972, inspection and laboratory performance tests were conducted. At the conclusion of the laboratory tests, trial chronographings were conducted on various weapon ammunition combinations. All major adjustments, repairs, and modifications were performed by Frankford Arsenal personnel.

Most of the environmental tests were conducted at Frankford Arsenal. However, some environmental phases of the test were conducted concurrently with the firing accuracy tests. All testing on this program was completed in March 1974.

Discrepancies observed during the conduct of the evaluation program were reported to Frankford Arsenal by telephone, test reports, and equipment performance reports.

### Physical Characteristics

The test item and its accessories were visually inspected for workmanship and mechanical operability.

The test item was measured and weighed. The results were compared with the manufacturer's specified values. The complete weights and measurements are given in Table I.

All markings were visually inspected and found to meet the requirements of Standard MIL-STD 130.

It is possible to interchange component assemblies of the NM87 Chronograph with other radar chronograph sets. This was done during firing tests at Yuma Proving Ground in March 1974.

TABLE I.  
Radar Chronograph, NM87  
Weights and Measurements

Doppler Radar (Figure 1)

Weight-----28.5 pounds  
Diameter----- 8.7 inches  
Depth----- 9.0 inches

Chronograph (Figure 2)

Weight----- 8.0 pounds  
Length-----10.6 inches  
Width----- 7.5 inches  
Height----- 4.1 inches

Cable Reel Assembly (Figure 3)

Weight-----26.5 pounds  
Length-----14.4 inches  
Width-----12.6 inches  
Height-----15.9 inches

Transport Case W/E

Weight-----84.0 pounds  
Length-----21.0 inches  
Width-----13.0 inches  
Height-----15.0 inches

Circuit Description

Refer to Block Diagram Figure 4.

The Gunn Oscillator generates a signal with a nominal frequency of 9525 MHz and an output power of approximately 20mW. The signal is fed via the circulator and the antenna elements to the antenna. The parabolic antenna directs the transmitter power in a narrow beam into the projectile trajectory.

A small part of the transmitter power is reflected because of mismatch in the antenna element and fed via the circulator to the frequency mixer. The reflected power is thus used as a local oscillator signal. The signal reflected from the projectile has its frequency changed due to the velocity of the projectile. This signal is below that of the transmitted frequency and the frequency difference,  $f_d$ , is

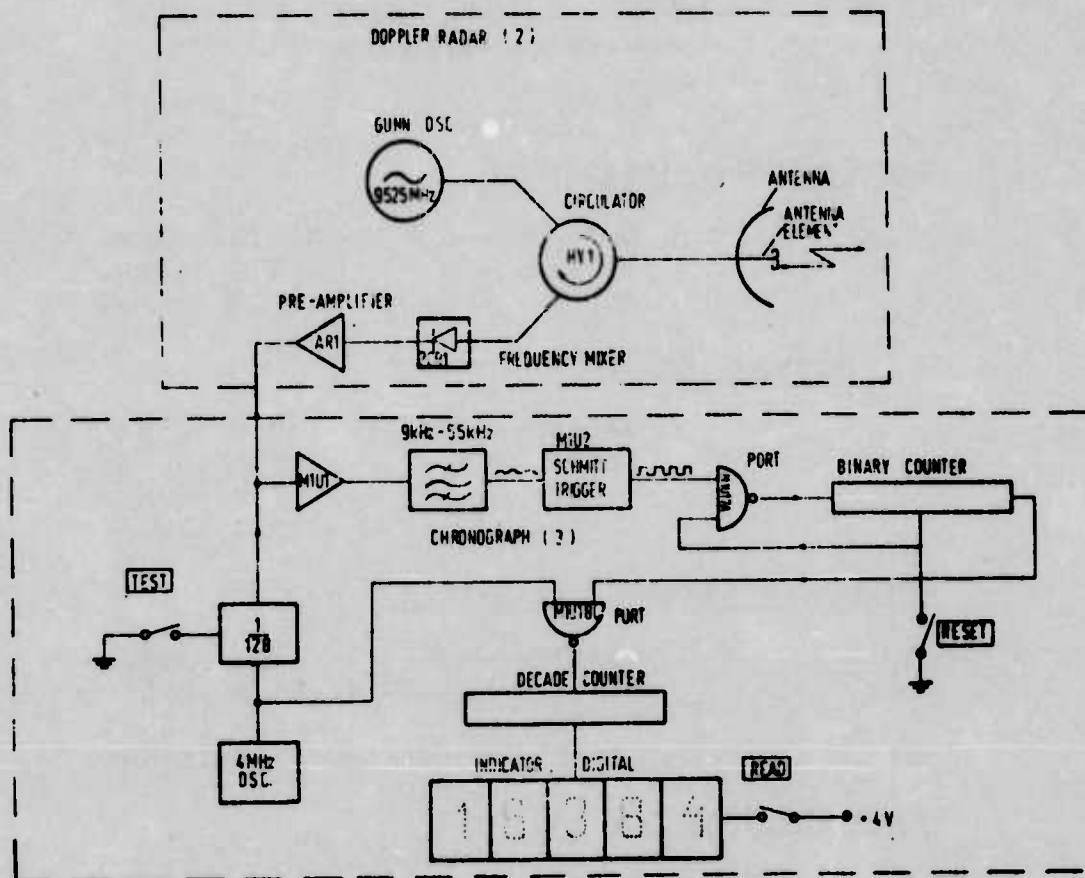


Figure 4. Radar Chronograph NM87, Block Schematic Diagram

given by Doppler's equation:

$$f_d = \frac{2V}{\lambda}$$

where  $V$  = velocity of projectile  
 $\lambda$  = wavelength of transmitted signal

The reflected signal is fed to the frequency mixer via the antenna, the antenna element, and the circulator.

In the frequency mixer, the reflected signal is mixed with the local oscillator signal. The output is a signal with a frequency



equal to the difference between the transmitted frequency and the reflected frequency. This signal is amplified in the preamplifier and then transmitted to the chronograph. Here, the signal is further amplified and fed via a band-pass filter to the Schmitt Trigger. The output of the Schmitt Trigger consists of square wave pulses with constant amplitude.

The square wave pulses are connected to a gate and then to a binary counter. After a preset number of pulses are counted, a gate (MIUI8C), is opened and 1/4 microsecond clock pulses from the 4MHz oscillator are fed to the decade counter.

After a time determined by the duration of a predetermined number of doppler pulses, the gate is closed. The number of 1/4 microsecond pulses fed to the decade counter during this time interval, can be read on the 5-digit numeric indicator when the READ push button is depressed.

A control circuit is incorporated to check the operation of the chronograph. When the TEST push button is depressed, a simulated doppler signal is fed to the input amplifier of the chronograph. If the radar chronograph set is functioning correctly, the control signal generates a reading of 16348  $\pm$  1 on the numeric indicator.

#### Operator's Controls and Indicators

The numbers are referred to Figure 5.

- a. BATTERY 24V(1). Connector for connection of the power cable.
- b. ON-OFF (2). Combined power switch and circuit breaker.
- c. DOPPLER RADAR (3). Connector for connection the signal and power cable between the doppler radar and the chronograph units.
- d. TEST (4). Push button switch which applies an internal simulated doppler signal to the input of the chronograph.
- e. READ indicator (5). Lit when information is stored in the register and is extinguished when the RESET button is pressed.
- f. READ (6). When this push button is pressed, the numeric display will display the information stored in the register.

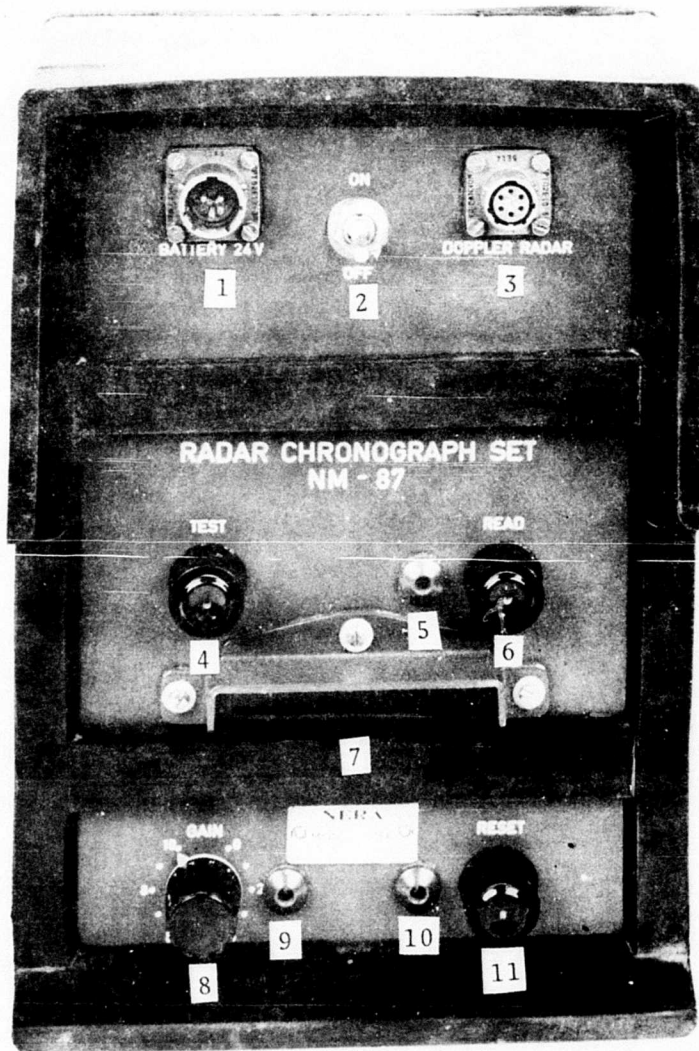


Figure 5. Radar Chronograph NM87, Operator's Controls and Indicators

g. NUMERIC (7). Presents a 5-digit reading of the registered time interval. It is activated when the READ button is pressed.

h. GAIN (8). Potentiometer for adjustment of the gain.

i. NOISE (9). Flashes for each noise or signal pulse which is received.

j. RESET (10). Lit to indicate that the set is ready for operation and is extinguished when a reading is obtained or when one or more noise pulses are received.

k. RESET (11). Push button is pressed to make the set ready for operation. It is pressed just before the shot is fired.

#### Electrical Characteristics

The electrical performance characteristics of the NM87 were measured in accordance with the test methods and procedures delineated in Military Specification MIL-C-14816. This specification covers the performance requirements of the USA Standard M36 Radar Chronograph Set. The results were compared with the specific characteristics of the manufacturer's (NERA Bergen) documentation furnished with the equipment.

The electrical characteristics are given in Table II.

#### Continuous Operation Test

The NM87 was set up in the normal operating mode. An operational test, relative power, and frequency test of the system performance was made and the results recorded. The chronograph was operated continuously eight hours a day for a period of five days. Performance tests were conducted periodically and the results compared with the initial test results. No failures, erratic readouts, or degradation of performance were observed during the continuous operation test.

#### Safety Inspection

As configured, the NM87 presents no electrical or mechanical hazards to operating personnel. However, mounting the doppler radar, Figure 1, on the 155 MM M109, the 8-inch M110, and the 175 MM M107 in

TABLE II.  
Radar Chronograph, NM87  
Electrical Characteristics

DOPPLER RADAR

Frequency	9525 MHz
Output power	20mW
Antenna gain	22dB
Antenna beamwidth	10°
Antenna polarization	Vertical
Receiver sensitivity	-88dBn

CHRONOGRAPH

Velocity range	150 - 850 meter/second
Clock frequency	4MHz
Display	5-digit (solid state)

POWER

Battery voltage	24 volt
Power consumption	Approximately 20W

accordance with the manufacturer's instructions constitutes a safety hazard to personnel (strain or rupture). This was confirmed by personnel of the Human Factors Engineering Division at Frankford Arsenal.

The doppler radar, which is removed as one unit, weighs 28.5 pounds. Two men are required to grasp and hold the doppler radar unit when mounting and setting up the equipment for operation. This places them in an awkward and unsafe position and is particularly hazardous if footing is unsure.

Firing Tests

Firing tests were conducted at the U.S. Army Artillery Board, Fort Sill, OK during July and August 1973. The primary objective of this firing test program was to determine the capability of the NM87 to chronograph standard cannon artillery.

The NM87 was set to measure projectile velocities at 35 meters from the muzzle. The doppler radar was mounted on the 155 MM Howitzer, M109 as specified by the manufacturer. The rounds from the 105 MM Howitzer, M102 were chronographed with the doppler radar unit mounted on a tripod. To install the doppler radar on the 175 MM Gun M107 and the 8-inch Howitzer M110, a special mounting bracket was fabricated at Frankford Arsenal, see Figure 6. The radar chronograph set was mounted on these weapons as illustrated in Figure 7.

A summary of the firing data for 25 weapon/ammunition combinations fired at Fort Sill is presented in Table III. The displayed readouts obtained from the NUMERIC DISPLAY were converted to velocity (m/s) through the use of the conversion tables furnished with the Operator's Manual, TM 11-5 840 25/200-12.

Based on the number of rounds fired (501), the usage factor and the number of rounds successfully chronographed as shown in Table IV, the overall performance of the set is considered satisfactory.

The evaluation of the NM87 performance was made by comparison among three different muzzle velocity measuring systems (M36, MVR-103, and XMR). The instrumented technical data acquired at the test site were recorded on magnetic tape for use in subsequent analysis and to serve as a permanent record of the test firing.

The data used for analysis was derived from the FADAC computer which had been programmed to compute "normalized" muzzle velocity. This was accomplished by modifying the Cannon FADAC program to accept CHRON DELAY inputs in milliseconds instead of entering the delay gate setting as is normally done for the Radar Chronograph M36 (U.S. Army Standard) muzzle velocity extrapolation routine. All meteorological and ballistic data that affect the trajectory were also entered into the computer. The program scheme uses an automatic successive approximation procedure to adjust the stored muzzle velocity obtained from the test items until the computed quadrant elevation is equal to the input quadrant elevation.

The BRL analysis of the data is presented in Appendix B. A summary of some of the terms found in these data is contained on pages 3 and 4 of Appendix C.

An attempt by Rock Island Arsenal personnel to measure the projectile velocity of 8-inch RAP rounds (XM650E3) when fired at charge 9 utilizing the NM87, was unsuccessful during the week of 18 March 1974 at Yuma Proving Ground. The cause of failure was considered to be the fire ball associated with the XM650E3 projectile when fired at charge 9. The tube used for firing these rounds does not have a muzzle brake. Therefore, the fire ball, instead of being thrown out sideways, is sucked behind the airborne projectile. The fire ball

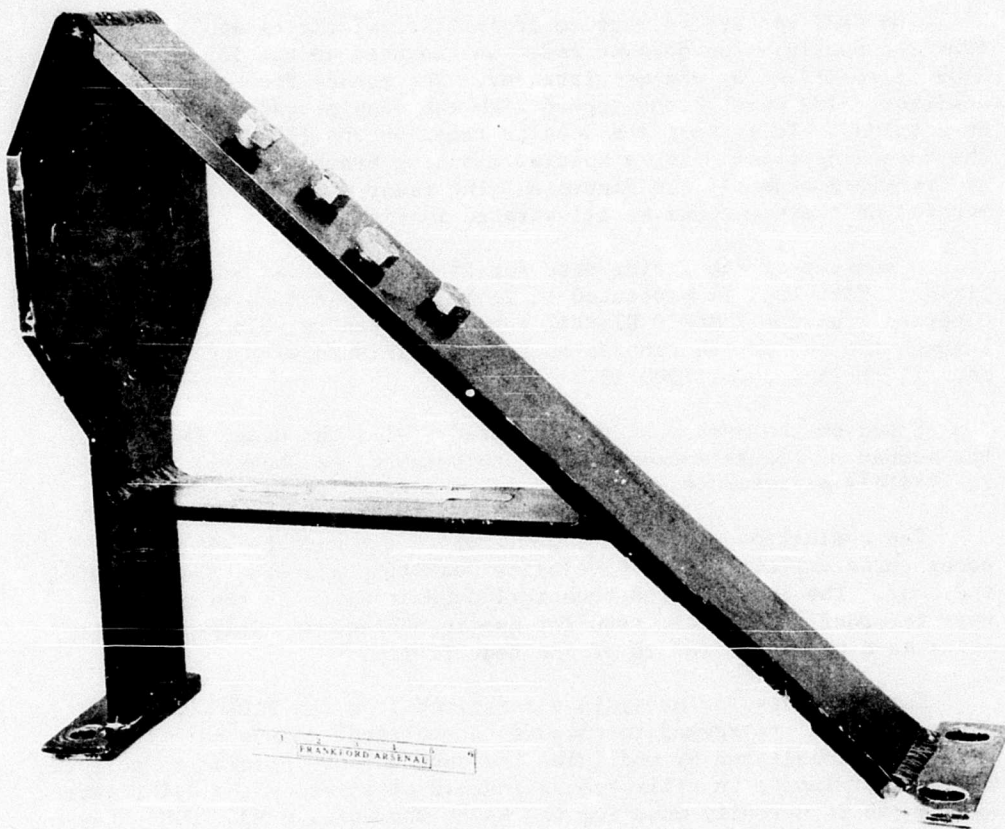


Figure 6. Radar Chronograph NM87, Special Mounting Bracket

appears as an extension to the projectile rear (the radar beam normally reflects off the projectile rear). Therefore, until the fire ball dissipates, the NM87 doppler radar had a very poor reflective target.

In order to investigate this theory, the doppler signal from the NM87 was simultaneously fed to both the signal processing section of the NM87 and to a Frankford Arsenal developed signal processing unit. This was accomplished by sampling the doppler signal from the unit, refer to Figure 4, and feeding it to the Frankford Arsenal processor. Utilizing this configuration, a firing test consisting of 15 rounds of the XM650E3 projectile, fired at charge 9, was conducted on 29 March 1974 at Yuma Proving Ground.

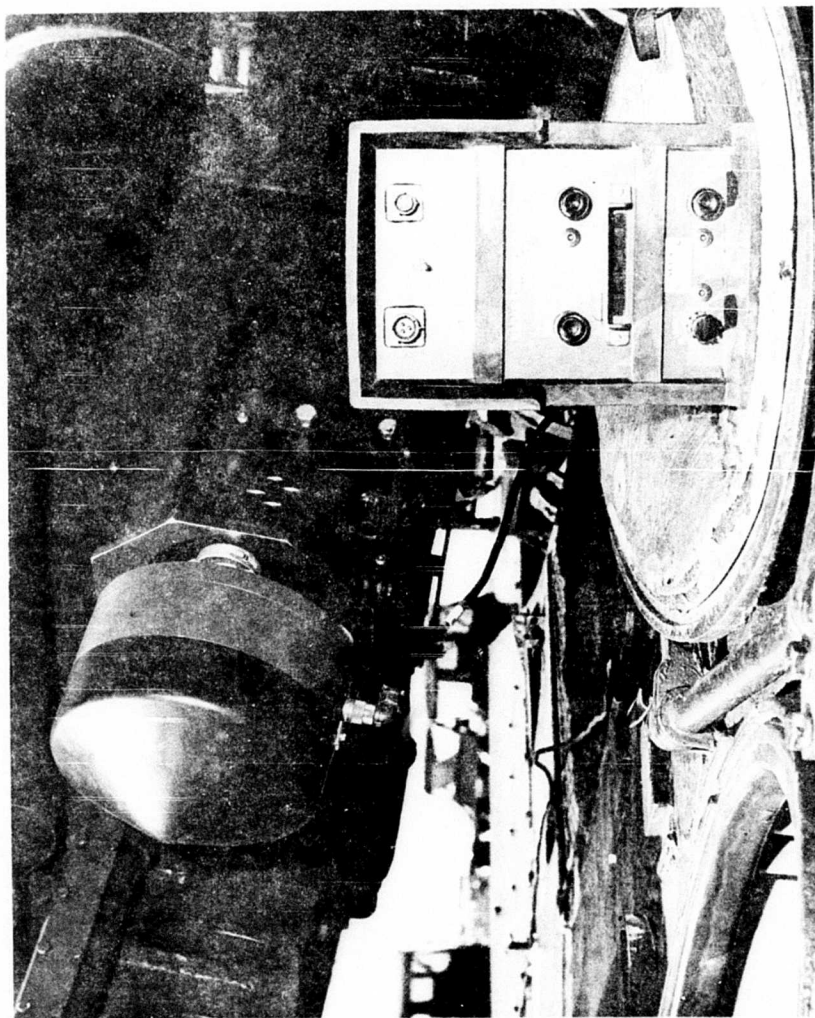


Figure 7. Installation of Radar Chronograph Set, NM87 on the 8-inch Howitzer M110

TABLE III.  
Radar Chronograph, NM87  
Firing Data Summary Sheet

<u>WEAPON</u>	<u>ZONE</u>	<u>ROUNDS</u>		<u>MEAN VELOCITY (m/s)</u>	<u>NOTE</u>
		<u>FIRED</u>	<u>RECRD</u>		
105MM Howitzer, M102	1	22	22	184.6	
	4	19(1)	19	269.8	
	5	20(2)	20	316.2	
	7	5	5	485.2	
	7(RAP)	9	2	-----	A
155MM Howitzer, M109	1	20	20	200.1	B
	3G	20	20	277.1	
	4G	20	17	316.7	C
	5G	20	20	371.5	
	3W	20	20	281.4	
	4W	20	20	321.9	
	5W	30	30	378.1	
	6W	19(2)	19	463.4	
	7W	19(3)	18	563.6	D
7(RAP)	4(3)	4	-----	E	
175MM Gun, M107	1	25	24	501.7	F
	2	25	25	704.2	G
	3	30	30	915.6	H
8-inch Howitzer, M110	2	20	20	270.5	
	3	20	20	303.9	
	4	19(3)	19	346.3	
	5G	20(1)	20	415.7	I
	5W	20	20	420.5	
	6W	20	20	500.5	
	7W	20	20	594.1	

Notes:

The following comments disregard those rounds which were missed because of operator shortcomings such as:

- (1) (M)IN control not adjusted before firing.
- (2) Equipment not turned on or no input power.
- (3) Failure to reset before firing.



Notes - Cont'd

A Only two rounds were acquired during the mission. These readouts were so obviously in error that this mission was deleted for subsequent precision analysis. To date, it has not been determined if the NM87 is capable of chronographing RAP projectiles. It is unlikely that the problem experienced at the test site can be attributed to improper setup of equipment and/or an inexperienced operator.

B Although the NM87 acquired all rounds fired, two of the readouts were deleted through a visual examination of the data. The measurements were found to be in error when compared to measurements of other data points of the same weapon/ammunition combination.

C On three rounds the readout display was approximately twice the expected value (half the velocity) for this charge. The cause of the erroneous readout is unknown. It is definitely not a recording error.

D One round was deleted when it was observed that the measurement was found to be in error when compared to measurements of other data points of the same weapon/ammunition combination.

E The readouts obtained for the four rounds acquired were so inconsistent that this mission was deleted for subsequent precision analysis. To date, it has not been conclusively determined that the NM87 cannot chronograph RAP rounds.

F Operator neglected to record the readout, the readout display before reset.

G Although the NM87 acquired all rounds fired, one round generated a readout display approximately three times the expected value (1/3 the velocity) for this charge. The cause of the erroneous readout could not be determined.

H Although the NM87 acquired all rounds fired during this mission, eight readings were deleted through a visual examination of the data. The measurements were found to be in error when compared to measurements of other data points of the same weapon/ammunition combination. It has been determined that the marginal performance of the equipment (22 out of 30 rounds) is due to operation beyond the design specification. The technical data furnished with the NM87 specifies an effective operating velocity range to 850 meters/second.

I During the first nine rounds, only six readouts were correct. The remaining rounds were deleted because they did not compare with other data points of the same weapon/ammunition combination. Subsequent discussions with the operator revealed that during the first ten rounds, the GAIN control could have been incorrectly set.

**TABLE IV.**  
**Radar Chronograph, NM87**  
**Summary of Firing Test Data**

Attempts to chronograph	486
Total rounds chronographed	474
Total rounds missed	24*
Chronographing percentage (%)	92.6
Set usage during firing (%)	97.0

**NOTES:**

Total rounds fired - 501.

Rounds missed because of human error have not been considered in the calculations.

\*Includes erroneous readouts determined by comparison of measurements to other data points of the same weapon/ammunition combination.

The round by round data for this date is presented in Appendix D. The results of this firing test are shown in Table V. An examination of this data indicates that the NM87 correctly measured only one round of 15 rounds fired. The Frankford Arsenal signal processor, utilizing the common doppler signal from the NM87, measured eight rounds out of 15. It appears that the NM87 doppler radar is marginal relative to its ability to provide useable doppler signal from this weapon/projectile combination. The probable cause for failure is the fire ball experienced with this projectile when fired at charge 9.

**Human Factors Evaluation**

**Doppler Radar**

Because of the weight of the doppler radar (28.5 pounds), two men should be required to install this equipment on the weapon, one man to hold it in position, while a second man secures the mounting

**TABLE V.**  
**Radar Chronograph, NM87**  
**Diring Data Summary Sheet for XM650E3 Projectile**

<u>Round Number</u>	<u>Charge</u>	<u>Velocity/Range</u> (m/s-m)	
		<u>FA Processor</u>	<u>NM87 Processor</u>
914	9	791.4/28	578.8/35
915	9	000.0/0	794.1/35
916	9	794.9/28	763.8/35
917	9	789.6/140	442.5/35
918	9	000.0/0	746.0/35
919	9	000.0/0	442.5/35
920	9	791.4/126	429.0/35
921	9	793.5/28	438.8/35
922	9	000.0/0	562.5/35
923	9	797.1/28	789.5/35
924	9	791.2/126	502.7/35
925	9	000.0/0	655.5/35
926	9	000.0/0	643.9/35
927	9	795.4/28	770.9/35
928	9	000.0/0	424.5/35

hardware. With two men, installation on the M107, M109, and the M110 was accomplished in approximately five minutes, including cable hookup to the chronograph.

#### Chronograph

Controls are well placed and clearly labeled. Receptacles are correctly positioned for right-angled cable connectors to route cables over the chronograph so as not to interfere with controls.

The TEST, READ, and RESET push buttons are well positioned for thumb operation when the chronograph is hand held. However, the push buttons should have rubber boots to prevent water entry into the chronograph. This could result in system malfunctions during freezing conditions. Further, the 5/8 inch diameter push buttons do not conform to MIL-STD 1472A which specifies 3/4 inch diameters.

At a weight of eight pounds, the chronograph is too heavy to be hand held for any length of time. It is suggested that a neck strap be used for hand held relief. The lower half of the outside facing edges of the rubber encasement should be rounded for greater palm comfort.

### **Cable Reel Assembly**

This assembly weighs 26.5 pounds and can be carried by one man. However, it is quite awkward and should be carried by two men.

### **Mounting Set**

There appears to be no human engineering problem with regards to the mounting sets, particularly when the swivel head wrench is utilized and since positional accuracy is not critical.

### **Transport Case**

The loaded transport case weighs 83.5 pounds and can be carried by two men if the lifting height does not exceed 4.5 feet.

## **Technology and Methodology**

The system is simple to operate, reliable, and capable of achieving the same order of precision as is possible with other velocity measurement methods. However, the most significant defect in the system is its failure to have indications of possible erroneous displays. The operator has no assurance that the values displayed on the chronograph readout are valid muzzle velocity measurements.

The chronographing range for this system, a maximum of 35 meters, will be inadequate for weapon/projectile combinations in the 1975 - 1985 time frame. Changes in the target reflectivity of projectiles currently being developed will require increased range capabilities in order to capture the projectile in its trajectory.

The component technology utilized in the NM87 is slightly behind the current state-of-the-art. The electronics in many areas of the doppler radar and chronograph assemblies, Figures 8 and 9, is such that the size and weight of the NM87 can be reduced by replacing discrete and small/medium scale integrated component assemblies with MOS/LSI (Metal oxide semiconductor/large scale integrated) circuitry.

## **Reliability and Maintainability**

Determination of the reliability of the system existing at the end of the evaluation is considered impractical in this report because no failures were encountered during the test and evaluation phase. No maintenance difficulties were observed in setup or tear down of the

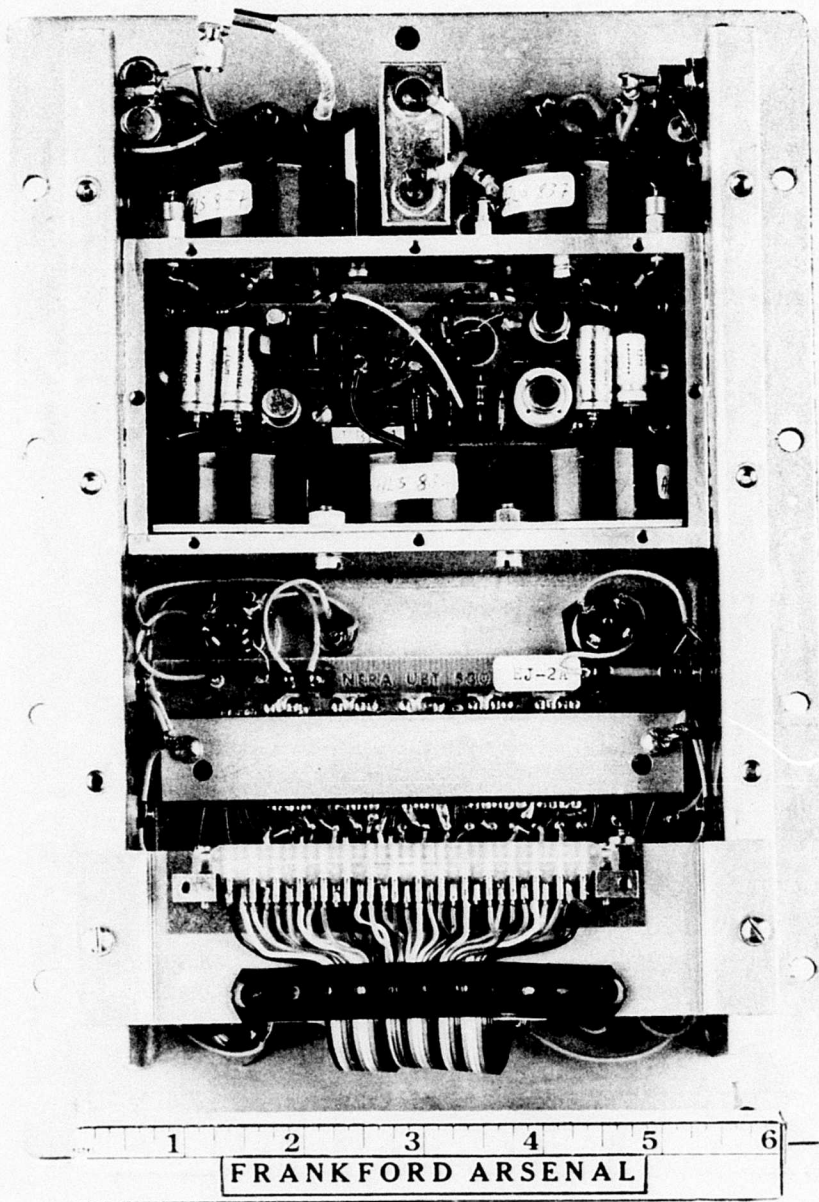


Figure 8. Radar Chronograph Set NM87, Digital Indicator and Voltage Regulator Assembly

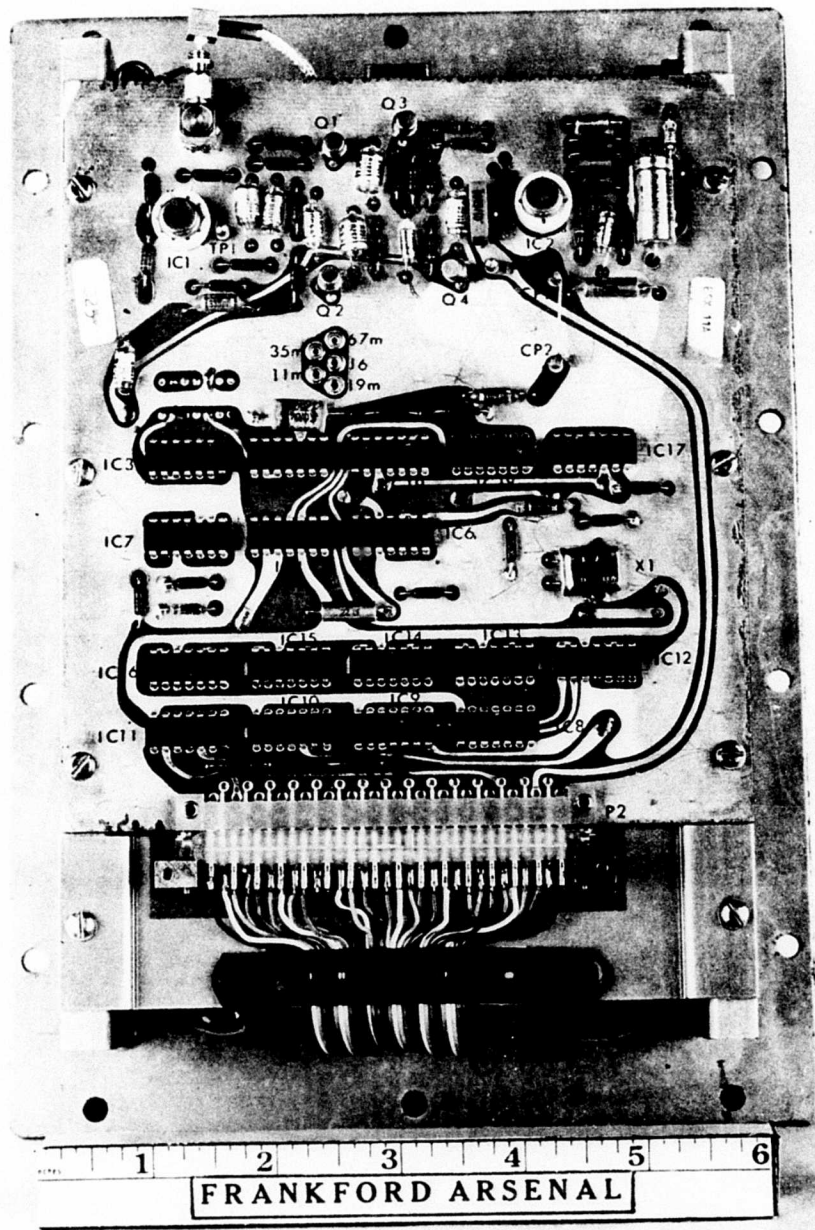


Figure 9. Radar Chronograph Set NM87, Digital Counter Assembly

major assemblies with either the tools or mounting sets provided with the system.

#### Ruggedness

The NM87 is capable of withstanding exposure to the shock of repeated firings and transportation over cross country without adverse effects on operational performance. Further, it was not sensitive to weather and ambient light conditions.

#### Adaptability

The NM87 is adaptable to all standard cannon artillery. It can be mounted on carriage to follow the azimuth and elevation of the tube with the mounting set furnished with the system; or other mounting brackets, see Figure 6, for special applications.

The system can also be mounted on a tripod with no adverse affect on performance. This permits greater versatility in deployment and reduces the initial set up time without any sacrifice of the required stability.

Because of the system's low power consumption, it is capable of being operated directly from vehicle power systems.

#### CONCLUSIONS

There is no indication of any statistically significant differences in precision between the NM87 and other muzzle velocity measurement devices tested with standard weapon/projectile combinations.

Preliminary test data indicated that the NM87 does not have the capability to reliably measure the muzzle velocity of the XM650E3 projectile fired at charge 9 (8-inch RAP).

The NM87 is easy to install, simple to operate, rugged, reliable, and capable of achieving the same order of precision as is possible with other doppler radar velocity measurement devices.

### RECOMMENDATIONS

Error detecting features should be incorporated into the design to assure the operator that the values displayed on the chronograph readout are valid muzzle velocity measurements.

The chronographing range capability should be increased from the present maximum of 67 meters to 300 meters. Increased range capabilities will be required to chronograph projectiles under current development.



**APPENDIX A**  
**Radar Chronograph Set NM87**  
**Evaluation Schedule - 18 September 1972**

	<u>M/DAYS</u>
Physical Inspection and Inventory	4
Conformance of Physical Characteristics with Test Item Specifications	5
Safety Inspection	5
Electrical Characteristics	
Receiver Sensitivity	20
Doppler Frequency Response	20
Transmitter Frequency	5
Transmitter Output	5
Calibration	5
Antenna Beamwidth	3
Antenna Gain	4
Boresighting	8
Monitor Circuits	6
Power Source	2
Power Consumption	5
Continuous Operation Test	4
Firing Accuracy Test	
Howitzer, 105MM	15
Howitzer, 8-inch	15
Howitzer, 155MM	15
Gun, 175MM	15
Ruggedness Test	
Shock	4
Vibration	10
Transport	24
Electromagnetic Inteference Tests	10
Environmental Characteristics	
Low Temperature Test	5
High Temperature Test	5
Rain Test	2
Sand and Dust Test	4
Reliability Assessment	20
Maintainability Assessement	15
Human Factors Assessment	20
Physical Teardown	25
Determination of Special Features, Technology, and Methodology Utilized in Test Item	20

**APPENDIX B**  
**BRL Analysis - Customer Service Test**  
**Fort Sill, Oklahoma, 8 - 23 August 1973**

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 1, ROUNDS 200-221 OE = 350 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-07 E	XMR F	MEAN
DELETED 1	0.00	181.00	181.10	181.60	181.70	0.00	0.00
DELETED 2	0.00	179.30	179.10	179.10	179.40	0.00	0.00
DELETED 3	0.00	178.60	179.10	178.60	178.50	178.30	0.00
4	178.30	178.50	177.60	177.60	177.90	177.70	177.93
5	177.30	177.20	177.10	176.60	177.90	176.30	177.07
6	178.30	178.50	179.10P	178.10	178.40	178.20	178.43
7	179.00	179.00	179.10	178.60	179.40	178.60	178.95
8	181.10	181.00	181.10	180.10	180.40	180.40	180.68
9	179.60	179.60	181.60	181.10	181.00	181.20	180.68
10	184.40	184.00	183.10	183.60	183.60	183.80	183.75
11	183.70	184.00	183.10	183.10	183.20	183.50	183.43
12	185.40	185.30	185.60	184.60	184.80	184.40	185.02
13	193.40	193.00	193.60	192.60	192.70	192.60	192.98
14	190.70	190.30	189.60	189.60	189.90	189.60	189.95
15	188.70	188.30	187.60	187.60	187.90	188.00	188.02
16	188.70	188.30	187.60	188.10	187.90	188.00	188.10
17	187.40	187.00	187.10	186.60	186.60	186.20	186.80
18	187.70	186.60	185.60	186.10	186.20	186.00	186.20
19	187.70	187.30	187.60	187.10	187.00	185.70P	187.07
20	188.10	187.60	187.10	187.10	187.20	185.90	187.17
21	188.70	188.60	187.60	188.10	188.00	187.70	188.12
22	188.70	188.60	187.60	188.10	188.20	188.00	188.20

MEAN	185.05	184.88	184.65	184.44	184.64	184.31	
VARIANCE	23.054	21.484	19.830	21.113	19.307	20.201	
STND DEV	4.801	4.635	4.453	4.595	4.394	4.404	
PROB ERR	3.239	3.126	3.004	3.099	2.964	3.032	
GRAND MEAN	184.661	AVERAGE VARIANCE	20.6314	STND DEV	4.5641	PROB ERR	3.0785

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY 1 OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 \* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)  
 6 INSTRUMENTS WITH 10 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRAYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 1, ROUNDS 200-221 OE = 350 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-07 E	XMR F
M36-1	0.0000	22.2394	21.0890	21.9273	20.9943	21.3325
M36-2	22.2394	0.0000	20.3484	21.1459	20.2558	20.5223
GE-1	21.0890	20.3484	0.0000	20.3143	19.4091	19.7469
GE-2	21.9273	21.1659	20.3143	0.0000	20.1478	20.5453
NM-07	20.9943	20.2558	19.4091	20.1478	0.0000	19.6070
XMR	21.3325	20.6223	19.7469	20.5453	19.6070	0.0000
COV 1-CLD INST	107.5825	104.6319	100.9077	104.1007	100.4140	101.8541
COV EXCLD INST	202.1630	205.1136	200.8377	205.6448	209.3315	207.8914
EST (SIGMA E1)	0.2370	0.1426	0.3511	0.0369	0.0745	0.2480
EST (SIGMA E1)	0.48685	0.37761	0.59252	0.19172	0.27288	0.49001

PRECISION RANK 4 3 1 2 5

TOTAL COVARIANCE = 309.7455      PARAMETER VARIANCE = 20.650      PARAM STD DEV. = 4.5442

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 3, ROUNDS 243-263 RE = 1250 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E DELETED	XMR F	MEAN
DELETER 1	240.20	240.10	239.30	239.30	0.00	0.00	0.00
DELETER 2	243.10	242.60	241.80	242.30	0.00	241.70	0.00
DELETER 3	241.10 I	239.60	239.80	239.30	0.00	238.60	239.68
4	238.10	237.60	237.30	237.30	0.00	236.60	237.42
5	234.70	234.60	233.80	234.30	0.00	233.50	234.18
6	234.10	233.60	233.30	233.30	0.00	232.90	233.44
7	234.70	234.30	233.80	234.30	0.00	233.50	234.12
8	233.70	233.30	233.30	233.30	0.00	232.80	233.68
9	235.70	233.30	233.80	233.30	0.00	232.50	233.32
10	235.10	235.00	235.30	234.30	0.00	234.00	234.74
11	235.70	234.60	235.80	235.30	0.00	234.70	235.22
12	234.10	234.60	233.30	233.30	0.00	233.50	233.64
13	236.40	235.00	237.30	237.40	0.00	235.40	236.78
14	237.40	236.60	237.30	236.30	0.00	235.00	236.46
15	237.40	237.30	237.80	236.80	0.00	236.40	237.14
16	235.40	235.30	235.80	234.60	0.00	234.50	235.16
17	235.40	235.30	235.80	234.60	0.00	234.50	235.16
18	235.40	235.30	235.80	234.60	0.00	234.30	235.12
19	238.10	237.60	237.30	237.30	0.00	236.70	237.40
20	237.10	236.60	237.30	236.30	0.00	235.90	236.64
21	236.40	236.30	235.80	235.80	0.00	235.30	235.92
22	237.70	237.30	237.80	237.80	0.00	236.50	237.42
MEAN	236.22	235.68	235.88	235.53	0.00	234.66	
VARIANCE	3.506	2.651	3.481	3.144	0.000	2.543	
STND DEV	1.872	1.628	1.866	1.773	0.000	1.595	
PROB ERR	1.263	1.098	1.258	1.196	0.000	1.076	
GRAND MEAN=	235.632	AVERAGE VARIANCE=	3.0652	STND DEV=	1.7508	PROB ERR=	1.1809

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 20 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL ORRYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 3, ROUNDS 243-263 OE = 1250 MILS

COVARIANCE MATRIX

	M38-1 A	M38-2 B	GE-1 C	GE-2 D	MP-87 E	XMR F
M38-1	0.0000	2.7879	3.2879	3.2505	DELETED	2.8549
M38-2	2.7879	0.0000	2.7651	2.5822	0.0000	2.4986
GE-1	3.2879	2.7651	0.0000	3.1533	0.0000	2.8212
GE-2	3.2505	2.5822	3.1533	0.0000	0.0000	2.7030
MP-87	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
XMR	2.8549	2.4986	2.8212	2.7030	0.0000	0.0000
COV INCLD INST	12.1813	10.6338	12.0275	11.8891	0.0000	10.8777
COV EXCLD INST	16.5234	18.0709	16.6772	17.0158	0.0000	17.8270
EST (SIGMA E1)	0.1692	0.3464	0.2487	0.1355	0.0000	0.0758
EST (SIGMA E1)	0.41130	0.58832	0.49869	0.36807	0.00000	0.27524
PRECISION RANK	3	5	4	2	0	1

TOTAL COVARIANCE = 20.7047      PARAMETER VARIANCE = 2.870      PARAM STD DEV. = 1.0942

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, OPL ORYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 4, ROUNDS 222-241 QE- 180 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	MH-87 E	XMR F	MEAN
DELETED 1	269.40	269.30	269.60	268.60	0.00	268.70	0.00
2	271.10	271.00	271.60	270.60	270.40	269.90	270.77
3	270.40	270.60	271.10	270.10	269.80	269.40	270.23
4	270.10	270.00	269.60	269.60	269.50	269.10	269.70
5	269.10	269.30	269.60	269.10	268.00	268.60	269.03
6	268.70	269.00	269.10	268.10	268.00	267.40	268.38
7	270.70	270.30	271.10	270.10	270.00	269.80	270.33
8	270.40	271.00	271.60	270.60	270.40	270.50	270.75
9	270.40	270.30	269.60	270.10	269.50	269.70	269.93
10	272.10	271.60	271.10	271.10	271.00	270.50	271.23
11	274.70	275.00	275.60	274.60	274.30	274.30	274.75
12	270.70	270.60	271.10	270.10	270.00	270.00	270.42
13	270.70	270.60	271.10	270.10	270.00	270.70	270.98
14	271.40	271.00	271.10	271.10	270.60	268.50	269.07
15	269.40	269.30	269.60	269.10	268.50	268.70	269.10
16	269.40	269.30	269.60	269.10	268.50	268.50	269.53
17	270.10	270.20	269.60	269.60	269.20	268.50	269.57
18	270.10	270.20	269.60	269.60	269.30	268.60	269.50
19	270.10	269.60	269.60	269.60	269.30	268.60	269.50
20	270.70	270.60	271.10	270.60	270.00	269.90	270.48
MEAN	270.54	270.50	270.65	270.15	269.85	269.63	
VARIANCE	1.655	1.674	2.164	1.719	1.802	2.025	
STND DEV	1.286	1.294	1.471	1.311	1.342	1.423	
PROB ERR	0.068	0.073	0.092	0.094	0.095	0.060	

GRAND MEAN= 270.220 AVERAGE VARIANCE= 1.8399 STND DEV= 1.3564 PROB ERR= 0.9149

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

6 INSTRUMENTS WITH 19 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT GILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL OORYON  
 NORMALIZED DATA 105MM MONITZER M102, ZONE 4, ROUNDS 222-241 SEE 180 MILS

COVARIANCE MATRIX

	M38-1 A	M38-2 B	SE-1 C	SE-2 D	MH-07 E	XMR F
M38-1	0.0000	1.6228	1.7254	1.6504	1.6973	1.7461
M38-2	1.6228	0.0000	1.8028	1.6667	1.7117	1.7678
SE-1	1.7254	1.8028	0.0000	1.8165	1.0640	1.9902
SE-2	1.6504	1.6667	1.8165	0.0000	1.7335	1.8319
MH-07	1.6973	1.7117	1.0640	1.7335	0.0000	1.8587
XMR	1.7461	1.7678	1.9902	1.8319	1.8587	0.0000
COV INCLD INST	0.4420	0.5717	9.1990	0.6990	8.0652	9.1946
COV EXCLD INST	18.0437	17.9141	17.2080	17.7868	17.6205	17.2911
E8T (818MA E1)	0.0023	0.0372	0.2128	0.0104	0.0175	0.0787
E8T (818MA E1)	0.28998	0.19283	0.46133	0.13588	0.13225	0.27607
PRECISION RANK	5	3	6	2	1	4

TOTAL COVARIANCE = 20.4057      PARAMETER VARIANCE = 1.766      PARAM STD DEV. = 1.3208

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, SRL OBRON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 5, ROUNDS 266-284 OE = 208 - 200 MILS

DATA POINT	M36-1 A	M36-2 B	OE-1 C	OE-2 D	MH-67 E	XMR F	MEAN	
DELETED 1	314.00	0.00	317.60	317.60	0.00	316.60	0.00	
2	0.00	317.30	317.60	316.10	316.10	316.40	316.70	
3	0.00	319.40	318.60	319.10	319.10	317.70	318.58	
4	0.00	318.60	317.60	316.10	317.10	317.20	317.76	
5	0.00	0.00	316.10	316.60	315.40	315.50	0.00	
6	0.00	318.30	317.60	317.60	317.00	316.40	317.38	
7	0.00	316.80	316.18	316.10	315.40	315.48	318.96	
8	0.00	317.10	316.60	316.10	315.20	315.30	315.70	
9	0.00	315.30	314.60	315.10	314.10	313.60	318.48	
10	0.00	316.30	315.60	315.60	314.90	314.30	314.54	
11	0.00	317.30	317.80	318.60	316.00	315.80	315.34	
12	0.00	318.00	317.60	317.60	316.80	315.90	317.06	
13	0.00	316.98	317.10	316.60	315.70	315.70	317.18	
14	316.10	316.00	315.60	315.60	314.90	314.60	316.40	
15	319.30	319.10	319.60	318.60	317.90	317.70	315.34	
16	320.70	320.50	319.60	320.20	319.30	319.70	316.88	
17	317.50	317.30	317.60	316.10	316.20	316.20	319.86	
18	316.20	318.30	317.80	316.60	316.90	317.20	317.08	
19	317.20	317.30	317.60	316.60	316.00	315.30	317.32	
20	316.10	316.60	315.10	315.60	314.60	313.80	316.86	
21	0.00	317.49	317.10	317.06	316.23	316.02	315.06	
MEAN	0.000	1.765	1.844	1.964	1.679	2.204	316.02	
VARIANCE	0.000	1.329	1.394	1.401	1.296	1.485	316.70	
STND DEV	0.000	0.896	0.941	0.945	0.674	1.001	318.58	
PROB ERR	0.000	316.783	AVERAGE VARIANCE=	1.9113	STND DEV=	1.3825	PROB ERR=	0.19328

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 19 DATA POINTS EACH WERE USED IN THIS ANALYSIS.



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRVOM  
 NORMALIZED DATA 105MM MONITZER M102,ZOME 5, ROUNDS 266-284 OE - 208 - 200 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	OE-1 C	OE-2 D	MH-67 E	XMR F
DELETED	DELETED	0.0000	0.0000	0.0000	0.0000	0.0000
M36-1	0.0000	0.0000	1.7167	1.6637	1.7120	1.6880
M36-2	0.0000	1.7167	0.0000	1.7222	1.6944	1.6806
OE-1	0.0000	1.6637	1.7222	0.0000	1.6400	1.7849
OE-2	0.0000	1.7120	1.6944	1.6400	0.0000	1.6911
MH-67	0.0000	1.6880	1.6806	1.7849	1.6511	0.0000
XMR	0.0000	0.0000	7.0139	6.8108	6.8975	7.4046
COV INCLD IMBY	0.0000	6.9803	10.5396	10.7427	10.6560	10.1490
COV EXCLD IMST	0.0000	0.0375	0.1941	0.3490	0.0060	0.1932
EST (SIGMA E1)	0.00000	0.19365	0.44056	0.59078	0.07720	0.43954
EST (SIGMA E1)	0	2	4	5	1	3
PRECISION RANK						

TOTAL COVARIANCE = 17.5535      PARAMETER VARIANCE = 1.755      PARAM STD DEV. = 1.3249

CUSTOMER SERVICE TEST AT FORT BELL, CONDUCTED BY F.A., JULY-AUGUST 73, SRL 06RYON  
 NORMALIZED DATA 1058M HORIZER M102, ZONE 7, ROUNDS 301-310, SE = 1093

DATA POINT	M36-1 A	M36-2 B	SE-1 C	SE-2 D	NM-67 E	XMR F	MEAN
1	DELETED	DELETED	486.00 I	489.00 I	DELETED	486.50 I	486.50
2	489.30	0.00	486.00	487.00	0.00	488.80	486.53
3	489.60	0.00	485.50P	486.50	0.00	486.70	486.17
4	485.00	0.00	486.00	487.00	0.00	486.30	486.57
5	489.50	0.00	485.50	485.50	0.00	485.40P	488.10
6	489.20	0.00	486.00	486.00	0.00	485.70P	485.90
7	485.70	0.00	485.50	485.50	0.00	485.80P	485.53
8	442.20	0.00	484.00	485.00	0.00	485.20	484.73
9	477.50	0.00	485.50	485.50	0.00	485.80P	485.58
10	474.40	0.00	485.75	486.35	0.00	486.21	
MEAN	0.00	0.00	0.988	1.336	0.000	0.934	
VARIANCE	0.000	0.000	0.979	1.188	0.000	0.967	
STND DEV	0.000	0.000	0.989	1.090	0.000	0.983	
PROB ERR	0.000	0.000	0.660	0.780	0.000	0.652	

BRAND MEAN= 486.103 AVERAGE VARIANCE= 1.0763 STND DEV= 1.0374 PROB ERR= 0.6997

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 10 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

COVARIANCE MATRIX

	M36-1 A	M36-2 B	SE-1 C	SE-2 D	NM-67 E	XMR F
DELETED	DELETED	DELETED	0.0000	0.0000	DELETED	0.0000
M36-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SE-1	0.0000	0.0000	1.0139	1.0139	0.0000	0.0250
SE-2	0.0000	0.0000	1.0139	0.0000	0.0000	1.1072
NM-67	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
XMR	0.0000	0.0000	0.0000	1.1072	0.0000	0.0000
COV INCLD INST	0.0000	0.0000	0.0000	2.1211	0.0000	1.9322
COV EXCLD INST	0.0000	0.0000	0.0000	0.0000	0.0000	1.0139
EST (SIGMA E1)	0.0000	0.0000	0.2267	0.0400	0.0000	0.0160
EST (SIGMA E1)	0.00000	0.00000	0.47610	0.20000	0.00000	0.12849
PRECISION RANK	0	0	3	2	0	1
TOTAL COVARIANCE=	2.9461	PARAMETER VARIANCE =	0.982	PARAM STD DEV. =	0.9910	

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, SRL OARYON

NORMALIZED DATA 105MM HOWITZER M102, ZONE 7, ROUNDS 311-320, 9E = 1077

DATA POINT	M36-1 A	M36-2 B	9E-1 C	9E-2 D	NM-87 E	XMR F	MEAN
1	483.20	486.10	486.00	486.00 I	0.00	484.30 I	485.12
2	481.20	485.10	484.00	485.50	0.00	485.10	0.00
3	0.00	485.10	484.00	485.00	0.00	485.00	0.00
4	0.00	484.70	483.50	484.50	0.00	484.80	0.00
5	0.00	85.10	483.50	485.00	0.00	484.60	0.00
6	482.20	485.50	484.00	485.00	0.00	485.20	484.38
7	484.60	485.50	484.00	485.00	0.00	484.90	484.60
8	484.60	485.10	484.00	485.00	0.00	485.00	484.74
9	484.60	485.10	484.00	484.50	0.00	484.90	484.62
10	485.00	485.80	485.60	485.00	0.00	485.20	485.32

MEAN 484.03  
 VARIANCE 1.191  
 STNO DEV 0.392  
 PROB ERR 0.736

GRAND MEAN = 484.830 AVERAGE VARIANCE = 0.5151 STNO DEV = 0.7177 PROB ERR = 0.4841

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT, P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 6 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

COVARIANCE MATRIX

	M36-1 A	M36-2 B	9E-1 C	9E-2 D	NM-87 E	XMR F
M36-1	0.0000	-0.1327	-0.0240	-0.2233	0.0000	0.0593
M36-2	-0.1327	0.0000	0.3240	0.1583	0.0000	-0.0623
9E-1	-0.0240	0.3240	0.0000	0.3400	0.0000	-0.1560
9E-2	-0.2233	0.1583	0.3400	0.0000	0.0000	-0.1217
NM-87	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
XMR	0.0593	-0.0623	-0.1560	-0.1217	0.0000	0.0000
COV INCLD INST	-0.3207	0.2873	0.4840	0.1533	0.0000	-0.2887
COV EXCLD INST	0.4823	-0.1257	-0.3223	0.0683	0.0000	0.4423
EST (SIGMA E1)	1.4314	-0.0109	0.5643	0.1664	0.0000	0.3237
EST (SIGMA E1)	1.19641	0.00000	0.76338	0.40791	0.00000	0.56897
PRECISION RANK	5	1	4	2	0	3

TOTAL COVARIANCE = 0.1617 PARAMETER VARIANCE = 0.016 PARAM STD DEV. = 0.1271

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 7, ROUNDS 322-326, 9E= 405 MI.L8

DATA POINT	M36-1 A	M36-2 B	6E-1 C	6E-2 D	NM-87 E	XMR F	MEAN
1	489.40	469.20	488.00	488.50	486.90	486.60	488.43
2	487.60	467.70	487.60	487.50	485.50P	487.30	487.20
3	488.00	487.70	487.50	487.50	485.50P	487.60	487.30
4	485.90	486.40	486.10	485.90	484.30P	486.20	485.80
5	485.90	486.10	486.10	485.90	484.00P	486.00	485.67
MEAN	487.36	487.42	487.06	487.06	485.24	487.14	
VARIANCE	2.223	1.527	0.803	1.288	1.328	1.138	
STND DEV	1.491	1.236	0.895	1.135	1.152	1.067	
PROB ERR	1.006	0.633	0.604	0.755	0.777	0.720	
GRAND MEAN	486.660	AVERAGE VARIANCE=	1.3645	STND DEV=	1.1766	PROB ERR=	0.7936

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

6 INSTRUMENTS WITH 5 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

COVARIANCE MATRIX

	M36-1 A	M36-2 B	6E-1 C	6E-2 D	NM-87 E	XMR F
M36-1	0.0000	1.8235	1.2630	1.6760	1.6995	1.5870
M36-2	1.6235	0.0000	1.0485	1.3810	1.4240	1.3090
6E-1	1.2630	1.0465	0.0000	1.0030	0.9770	0.9145
6E-2	1.6760	1.3810	1.0030	0.0000	1.2670	1.1970
NM-87	1.6995	1.4240	0.9770	1.2670	0.0000	1.2205
XMR	1.5870	1.3090	0.9145	1.1970	1.2205	0.0000
COV INCLD INST	6.0710	6.9660	5.2260	6.5460	6.6060	6.2280
COV EXCLD INST	11.7615	12.8465	14.6065	13.2865	13.2245	13.6045
EST (95%MA E1)	0.1708	0.0172	0.1733	-0.0016	0.0073	0.0072
EST (95%MA F1)	0.41322	0.13134	0.41623	0.00000	0.08515	0.08515
PRECISION RANK	5	4	6	1	3	2
TOTAL COVARIANCEP	19.9325	PARAMETER VARIANCE =	1.322	PARAM STD DEV. =	1.1499	

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 7. (RAP), ROUNDS 327-345, OE = 405 MILS

DATA POINT	M36-1 A DELETED	M36-2 B	OE-1 C	OE-2 D	NM-87 E DELETED	XMR F DELETED	MEAN
1	0.00	542.80P	542.00	542.00	0.00	0.00	542.27
2	0.00	543.10	542.00	543.00	538.20	0.00	542.70
3	0.00	539.00	544.00	545.00	0.00	0.00	542.67
DELETED 4	0.00	544.90	0.00	544.50	554.30	0.00	0.00
5	0.00	547.30	545.50	548.50	0.00	0.00	546.43
6	0.00	540.10	542.00	542.30	0.00	0.00	541.47
7	0.00	546.20P	545.50	545.50	0.00	0.00	545.73
8	0.00	547.00	548.00P	547.00	0.00	0.00	546.67
9	0.00	543.90P	544.00	544.00	0.00	540.10	543.97
10	0.00	546.60	545.00	545.50	0.00	544.80	545.70
11	0.00	548.00P	547.50	547.50	0.00	543.80	547.87
12	0.00	548.30P	547.50	547.50	0.00	544.10	547.77
13	0.00	548.00	545.50	546.50	0.00	0.00	546.87
14	0.00	545.90P	545.50	545.50	0.00	0.00	545.63
DELETED 15	0.00	546.20	526.00	547.00	0.00	0.00	0.00
16	0.00	548.00	548.00	548.00	0.00	0.00	548.00
17	0.00	541.50	545.50	546.50	0.00	0.00	544.50
18	0.00	547.70	545.50	546.50	0.00	0.00	546.57
19	0.00	547.70	547.50	548.50	0.00	0.00	547.90

MEAN	545.36	545.21	545.72	545.72	0.00	0.00	545.36
VARIANCE	9.144	3.658	3.743	3.743	0.000	0.000	0.000
STND DEV	3.024	1.913	1.935	1.935	0.000	0.000	0.000
PROB ERR	2.040	1.290	1.305	1.305	0.000	0.000	0.000
GRAND MEAN	545.429	AVERAGE VARIANCE=	5.5150	STND DEV=	2.3264	PROB ERR=	1.5840

MEASUREMENTS FOUND TO BE OUTLIERS AT A .95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATED THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATED THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATED AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

3 INSTRUMENTS WITH 17 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL 06RYON  
 NORMALIZED DATA 105MM HOWITZER M102, ZONE 7. (RAPI), ROUNDS 327-345, DE = 405 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-67 E	XMR F
DELETED	DELETED	0.0000	0.0000	0.0000	DELETED	DELETED
M36-1	0.0000	0.0000	4.3528	4.1948	0.0000	0.0000
M36-2	0.0000	0.0000	0.0000	3.5824	0.0000	0.0000
GE-1	0.0000	4.3528	0.0000	0.0000	0.0000	0.0000
GE-2	0.0000	4.1948	3.5824	0.0000	0.0000	0.0000
NM-67	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
XMR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
COV INCLD INST	0.0000	8.5475	7.9351	7.7771	0.0000	0.0000
COV EXCLD INST	0.0000	3.5824	4.1948	4.3528	0.0000	0.0000
EST (SIGMA E1)	0.0000	4.1786	-0.0822	0.3188	0.0000	0.0000
EST (SIGMA E1)	0.00000	2.04417	0.00000	0.56461	0.00000	0.00000
PRECISION RANK	0	3	1	2	0	0
TOTAL COVARIANCE	12.1299	PARAMETER VARIANCE =			4.043	PARAM STR DEV. = 2.0108

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, SRL OBRVON

NORMALIZED DATA 155MM HOWITZER, M109, ZONE I, ROUNDS 401-420, GE = 460 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-A7 E	XMR F	MEAN
1	199.60	DELETED	199.30	199.20	199.20	197.00P	196.86
2	202.30	202.20	201.80	202.20	0.00	198.30	0.00
3	202.30 I	200.60	201.80	201.70	201.30	199.30P	201.28
4	200.60	0.00	201.30	200.20	199.90	198.10	200.02
5	200.60	196.20	201.30	200.20	199.80	198.40	200.06
6	200.60	198.20	201.30	200.20	0.00	198.70	0.00
7	199.60	196.20	199.80	199.20	198.80	196.50P	198.78
8	199.90	0.00	199.30	199.70	199.30	196.90P	199.02
9	199.60	0.00	199.30	199.20	198.90	196.80P	198.76
10	199.60	0.00	199.80	199.70	199.30	198.00P	199.34
11	199.90	0.00	199.80	198.70	199.40	0.00	0.00
12	200.30	0.00	199.80	199.70	200.40	197.50P	199.54
13	199.90	0.00	199.30	199.70	200.10	197.00P	199.20
14	200.60	0.00	201.30	200.70	200.90	198.10P	200.32
15	199.90	0.00	199.80	199.70	200.40	197.60P	199.48
16	201.30	0.00	201.80	201.20	201.50	198.60P	200.88
17	200.60	201.20	201.30	200.20	200.80	198.60	200.30
18	199.90	193.00	199.80	200.20	200.70	0.00	0.00
19	200.60	0.00	201.30	200.20	200.70	200.30	200.62
20	200.60	200.20	201.30	200.20	200.70	198.70	200.30

MEAN 200.37  
 VARIANCE 0.505  
 STND DEV 0.711  
 PROB ERR 0.479  
 GRAND MEAN= 199.798 AVERAGE VARIANCE= 0.7506 STND DEV= 0.8664 PROB ERR= 0.5844

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 16 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, 8RL ORRYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 1, ROUNDS 401-420, QE = 460 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E	XMR F
M36-1	0.0000	DELETED	0.6029	0.4815	0.4888	0.5394
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GE-1	0.6029	0.0000	0.0000	0.5979	0.6450	0.8442
GE-2	0.4815	0.0000	0.5979	0.0000	0.5042	0.5138
NM-87	0.4888	0.0000	0.6450	0.5042	0.0000	0.6317
XMR	0.5394	0.0000	0.8442	0.5138	0.6317	0.0000
COV INCLD INST	2.1126	0.0000	2.6900	2.0973	2.2697	2.5290
COV EXCLD INST	3.7367	0.0000	3.1593	3.7520	3.5796	3.3203
EST (SIGMA E1)	0.0714	0.0000	0.1774	0.0673	0.1798	0.3327
EST (SIGMA E1)	0.26725	0.00000	0.42117	0.25945	0.42309	0.57681
PRECISION RANK	2	0	3	1	4	5

TOTAL COVARIANCES = 5.8493      PARAMETER VARIANCE = 0.585      PARAM STD DEV. = 0.7648



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 30 ROUNOS 481-500, QE = 1219 MILS

DATA POINT	M36-1 DELETED A	M36-2 DELETED B	GE-1 C	GE-2 D	NM-87 E	XMR F	MEAN
DELETED 1	0.00	0.00	0.00	0.00	272.70	271.10	0.00
2	0.00	0.00	275.30	275.40	276.00	274.80	275.37
3	0.00	0.00	277.80	276.90	277.40	276.10	277.05
4	0.00	0.00	277.80	276.90	277.60	275.10	276.85
5	0.00	0.00	277.30	276.90	277.10	275.50P	276.70
6	0.00	0.00	277.80	276.90	277.40	276.10	277.05
7	0.00	0.00	277.80	277.40	277.70	276.10P	277.25
8	0.00	0.00	0.00	0.00	278.00	276.50	0.00
9	0.00	0.00	277.30	276.40	277.00	275.50	276.55
10	0.00	0.00	277.80	277.90	278.60	277.30 I	277.90
11	0.00	0.00	277.80	276.90	277.50	275.70	276.88
12	0.00	0.00	277.30	276.40	277.00	275.30	276.50
13	0.00	0.00	277.30	276.90	277.10	275.70	276.75
14	0.00	0.00	277.30	276.90	277.40	275.90	276.88
15	0.00	0.00	277.30	276.40	277.50	275.50	276.68
16	0.00	0.00	275.30	275.40	276.10	274.70	275.37
17	0.00	0.00	277.30	275.90	276.30	274.60	275.53
18	0.00	0.00	277.30	276.40	277.00	275.70	276.60
19	0.00	0.00	277.80	276.90	277.50	275.90	277.02
20	0.00	0.00	275.30	275.40	275.80	274.30	275.20

MEAN 275.54  
 VARIANCE 0.488  
 STND DEV 0.699  
 PROB ERR 0.471

GRAND MEAN= 276.568 AVERAGE VARIANCE= 0.6045 STND DEV= 0.7775 PROB ERR= 0.5244

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

4 INSTRUMENTS WITH 18 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL 08RYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 30 ROUNDS 461-500, OE = 1210 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	OE-1 C	OE-2 D	NH-87 E	XMR F
DELETED M36-1	DELETED	DELETED	0.0000	0.0000	0.0000	0.0000
DELETED M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OE-1	0.0000	0.0000	0.0000	0.6029	0.6147	0.5471
OE-2	0.0000	0.0000	0.6029	0.0000	0.4539	0.4304
NH-87	0.0000	0.0000	0.6147	0.4539	0.0000	0.4365
XMR	0.0000	0.0000	0.5471	0.4304	0.4365	0.0000
COV INCLD INST	0.0000	0.0000	1.7647	1.4673	1.5052	1.4140
COV EXCLD INST	0.0000	0.0000	1.3208	1.5983	1.5804	1.6716
EST (SIGMA E1)	0.0000	0.0000	0.2418	0.0119	0.0044	0.1030
EST (SIGMA E1)	0.00000	0.00000	0.49168	0.19887	0.06634	0.32098

PRECISION RANK 0 0 0 4 2 1 3  
 TOTAL COVARIANCE = 3.0856 PARAMETER VARIANCE = 0.514 PARAM STD DEV. = 0.7171

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BPL DRYDON

NORMALIZED DATA 155MM HOWITZER, M109, ZONE 48 ROUNDS 421-440, OE = 237 MILS

DATA POINT	M38-1 A	M38-2 B	GE-1 C	GE-2 D	NM-87 E	XMR F	MEAN
DELETED 1	0.00	0.00	315.70	315.20	315.60	313.60	0.00
DELETED 2	0.00	316.40	315.70	316.20	316.70	314.40	315.88
DELETED 3	0.00	316.40	317.20	316.70	317.30	315.50	316.62
DELETED 4	239.50	315.90	315.70	316.20	316.60	314.20	315.72
DELETED 5	0.00	314.30	315.20	314.20	0.00	0.00	0.00
DELETED 6	0.00	313.60	313.20	313.70	0.00	311.80	0.00
DELETED 7	0.00	314.90	315.70	315.20	318.10	314.10	315.60
DELETED 8	0.00	314.30	313.70	314.20	314.60	313.10	313.98
DELETED 9	315.00	314.90	315.70	314.70	315.50	313.90	314.94
DELETED 10	310.60	314.90	315.70	314.70	315.40	312.80P	314.70
DELETED 11	289.50	314.60	313.70	314.20	0.00	0.00	0.00
DELETED 12	251.50	316.40	315.70	316.20	316.40	314.30P	315.80
DELETED 13	260.00	315.90	315.70	316.20	316.60	314.20	315.72
DELETED 14	0.00	317.00	317.70	316.70	317.30	315.20	316.78
DELETED 15	0.00	316.70	317.20	316.70	317.00	314.70P	316.46
DELETED 16	0.00	314.30	313.70	314.20	317.30	312.40	314.38
DELETED 17	316.80	316.70	317.20	316.70	317.10	314.80P	316.50
DELETED 18	315.40	315.40	315.70	315.20	316.00	313.60	315.36
DELETED 19	316.50	316.50	315.70	316.20	316.80	314.70	315.98
DELETED 20	317.10	317.10	317.70	317.20	317.40	315.30P	316.94
MEAN	0.00	315.86	315.96	315.82	316.69	314.20	
VARIANCE	0.000	0.892	1.432	0.950	0.765	0.779	
STND DEV	0.000	0.944	1.197	0.975	0.875	0.882	
PROB ERR	0.000	0.637	0.407	0.657	0.590	0.595	

GRAND MEAN= 315.710 AVERAGE VARIANCE= 0.9636 STND DEV= 0.9816 PROB ERR= 0.6621

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT. I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS. P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 16 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORTON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 48 ROUNDS 421-440, GE = 257 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	RE-1 C	RE-2 D	NH-87 E	YMR F
DELETED M36-1	DELETED	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED M36-2	0.0000	0.0000	0.9565	0.8958	0.3774	0.7427
RE-1	0.0000	0.9565	0.0000	0.9058	0.5071	0.9067
RE-2	0.0000	0.6958	0.9958	0.0000	0.4463	0.7900
NH-87	0.0000	0.3774	0.5071	0.4463	0.0000	0.3807
YMR	0.0000	0.7427	0.9067	0.7900	0.3807	0.0000
COV INCLD INST	0.0000	2.9724	3.3660	3.1300	1.7135	2.6200
COV EXCLD INST	0.0000	4.0286	3.6349	3.0710	5.2875	4.1810
EST (SIGMA E1)	0.0000	0.0772	0.3551	0.0302	0.7897	0.0685
EST (SIGMA F1)	0.0000	0.2785	0.5989	0.1767	0.8863	0.25592
PRECISION RANK	0	3	4	1	5	2
TOTAL COVARIANCE =	7.0010	PARAMETER VARIANCE =	0.700	PARAM STD DEV. =	0.8367	

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBYON  
 NORMALIZED DATA 195MM HOWITZER, M109, ZONE 50 ROUNDS 701-720, GE = 680 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-67 E	XMR F	MEAN
1	372.30	DELETED	371.60	372.00	372.00	370.20P	371.62
2	369.50	371.10	369.60	369.00	369.40	367.30P	368.96
3	368.80	368.10	368.60	368.00	369.00	367.20	368.32
4	370.80	370.70	370.60	370.00	370.90	369.00	370.26
5	370.20	370.00	369.60	369.50	370.20	368.00	369.50
6	369.80	369.40	369.60	370.00	370.20	368.20P	369.56
7	369.80	0.00	371.10	372.00	370.70	370.40	370.80
8	370.80	0.00	372.60	370.00	370.90	369.00	370.26
9	372.60	0.00	372.10	371.50	372.40	371.00	371.92
10	371.60	0.00	371.60	372.00	371.60	369.00P	371.20
11	370.50	370.00	369.60	370.00	370.50	369.10	369.94
12	371.90	371.80	371.10	371.50	371.90	369.90	371.26
13	371.60	371.50	372.10	371.50	371.70	370.20	371.32
14	372.30	371.80	372.10	371.50	372.10	370.10P	371.62
15	373.30	0.00	373.60	373.00	373.30	371.80P	373.00
16	373.80	373.50	373.60	373.00	373.60	371.80	373.16
17	371.60	0.00	371.60	371.00	372.60	369.60P	371.06
18	372.60	0.00	371.60	372.00	372.60	371.10	371.98
19	371.90	371.50	372.10	371.50	372.10	370.00P	371.52
20	372.90	372.50	372.10	372.50	372.90	371.60	372.40

MEAN 371.43  
 VARIANCE 1.852  
 STND DEV 1.361  
 PROR ERR 0.918

GRAND MEAN= 370.983 AVERAGE VARIANCE= 1.7810 STND DEV= 1.3345 PROB ERR= 0.9001

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 20 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL 08RYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 50 ROUNDS 701-720, SE = 680 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	SE-1 C	SE-2 D	NM-87 E	XMR F
M36-1	0.0000	0.0000	1.6697	1.5879	1.6626	1.6771
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SE-1	1.6697	0.0000	0.0000	1.6382	1.5704	1.6651
SE-2	1.5879	0.0000	1.6382	0.0000	1.5482	1.7145
NM-87	1.6626	0.0000	1.5704	1.5482	0.0000	1.6072
XMR	1.6771	0.0000	1.6651	1.7145	1.6072	0.0000
COV INCLD INST	6.5973	0.0000	6.5434	6.4887	6.3884	6.6639
COV EXCLD INST	9.7436	0.0000	9.7974	9.8522	9.9525	9.8769
EST (SIGMA E1)	0.1770	0.0000	0.1474	0.2108	0.0059	0.1933
EST (SIGMA E1)	0.42066	0.00000	0.38390	0.45918	0.07886	0.43971

PRECISION RANK 3 0 2 5 1 4  
 TOTAL COVARIANCE= 16.3409 PARAMETER VARIANCE = 1.634 PARAM STD DEV. = 1.2783

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 155MM HOWITZER, M109, 70NE 3W ROUNDS 441-460, GE = 300 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NH-87 E	XMR F	MEAN
DELETED 1	DELETED	279.10	277.20	277.70	266.00	277.00	0.00
DELETED 2	276.80	278.50	277.70	278.20	278.90	277.40	278.14
DELETED 3	255.40	279.50	0.00	279.20	279.80	278.60	0.00
DELETED 4	270.20	248.00	279.20	278.20	278.90	277.60	0.00
DELETED 5	235.00	282.20	281.70	281.70	282.30	281.00	281.78
DELETED 6	268.80	278.50	279.20	279.20	279.80	278.40	279.22
DELETED 7	275.20	283.20	283.20	282.70	283.40	281.90	282.88
DELETED 8	222.60	283.20	293.70	282.70	283.40	281.40	282.96
DELETED 9	300.70	279.80	279.20	279.20	279.90	278.40	279.30
DELETED 10	236.00	282.50	283.20	282.70	283.30	281.60	282.66
DELETED 11	244.40	254.60	275.60	276.20	276.40	275.10	0.00
DELETED 12	290.00	280.80	281.10	280.70	281.10	279.40P	280.62
DELETED 13	220.60	283.50	283.70	283.20	283.60	282.10P	283.22
DELETED 14	340.30	282.50	0.00	0.00	282.60	281.30	0.00
DELETED 15	259.20	282.20	281.60	281.70	282.40	280.70	281.72
DELETED 16	312.80	281.50	281.60	280.70	281.30	280.10	281.04
DELETED 17	252.40	280.80	281.60	280.70	281.30	280.10	280.90
DELETED 18	206.20	276.70	277.60	277.70	278.20	276.50	277.34
DELETED 19	0.00	272.10	283.70	283.70	284.30	282.50	0.00
DELETED 20	0.00	279.20	279.10	279.20	280.10	278.40	279.20

MEAN	0.00	280.97	281.01	280.74	281.36	279.84
VARIANCE	0.000	4.081	4.491	3.249	3.180	3.233
STND DEV	0.000	2.020	2.119	1.802	1.783	1.798
PROB ERR	0.000	1.383	1.429	1.216	1.203	1.213

GRAND MEAN= 280.784 AVERAGE VARIANCE= 3.6466 STND DEV= 1.9096 PROB ERR= 1.2880

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 14 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE SM ROUNDS 441-460, GE = 300 MILS

COVARIANCE MATRIX

	M36-1	M36-2	GE-1	GE-2	NM-67	XMR
	A	B	C	D	E	F
DELETED M36-1	DELETED	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED M36-2	0.0000	0.0000	4.1312	3.5665	3.5379	3.5898
GE-1	0.0000	4.1312	0.0000	3.7648	3.7068	3.7478
GE-2	0.0000	3.5665	3.7648	0.0000	3.2055	3.2174
NM-67	0.0000	3.5379	3.7068	3.2055	0.0000	3.1897
XMR	0.0000	3.5898	3.7478	3.2176	3.1897	0.0000
COV INCLD INST	0.0000	14.8254	15.3507	13.7544	13.6399	13.7448
COV EXCLD INST	0.0000	20.8322	20.3069	21.9032	22.0177	21.9127
EST (SIGMA E1)	0.0000	0.1400	0.1997	0.0220	0.0292	0.0131
EST (SIGMA E1)	0.00000	0.37417	0.44689	0.14819	0.17097	0.11451
PRECISION RANK	0	4	5	2	3	1

TOTAL COVARIANCE = 35.6576      PARAMETER VARIANCE = 3.566      PARAM STD DEV. = 1.8863



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRON

NORMALIZED DATA 155MM HOWITZER, M109, ZONE 4W ROUNDS 461-480, GE = 229 MILS

DATA POINT	M36-1 A	M36-2 B	6E-1 C	6E-2 n	NM-87 F	XMR F	MEAN
1	DELETED	DELETED	321.60	321.20	321.70	320.10	321.15
2	299.50	306.40	323.70	324.30	322.70	323.10	323.45
3	295.20	323.20	323.70	322.70	323.50	322.00	322.98
4	276.70	321.80	321.20	321.20	319.40	320.40	320.55
5	329.20	321.20	321.70	320.70	321.60	319.50	320.87
6	300.30	322.10	321.70	322.70	320.20	321.00	321.40
7	284.10	321.50	321.20	321.20	321.70	320.50	321.15
8	334.70	322.10	325.20	324.30	327.60 I	322.90	325.00
9	0.00	323.60	323.70	322.70	323.50	322.40	323.07
10	277.60	321.80	321.20	321.20	322.10	320.30	321.20
11	317.50	317.30	317.70 I	317.20 I	317.50	316.20 I	317.15
12	0.00	0.00	321.20	320.20	320.70	319.40	320.38
13	0.00	0.00	323.20	322.20	322.80	321.10	322.33
14	0.00	0.00	321.20	320.20	320.80	319.30	320.38
15	0.00	0.00	321.20	321.20	322.10	319.80	321.07
16	0.00	0.00	321.20	321.70	322.20	320.80	321.48
17	230.40	0.00	321.20	321.70	322.30	320.30	321.38
18	0.00	320.00	321.70	322.20	322.60	320.50	321.75
19	0.00	320.40	0.00	320.20	320.80	318.70	0.00
20	0.00	0.00	321.20	320.70	321.20	319.50	320.65
MEAN	0.00	0.00	321.83	321.55	321.91	320.48	
VARIANCE	0.000	0.000	2.470	2.478	3.983	2.386	
STND DEV	0.000	0.000	1.572	1.574	1.996	1.545	
PROB ERR	0.000	0.000	1.060	1.062	1.346	1.042	
GRAND MEAN=	321.441	AVERAGE VARIANCE=	2.8292	STND DEV=	1.6820	PROB ERR=	1.1345

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 • INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)  
 4 INSTRUMENTS WITH 19 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 4M ROUNDS 401-480, OE = 229 MILS

COVARIANCE MATRIX

	M36-1	M38-2	GE-1	GE-2	NM-67	XMR
DELETED M36-1	DELETED	DELETED	0.0000	0.0000	0.0000	0.0000
DELETED M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GE-1	0.0000	0.0000	0.0000	2.2474	2.7337	2.2606
GE-2	0.0000	0.0000	2.2474	0.0000	2.4842	2.3680
NM-67	0.0000	0.0000	2.7337	2.4842	0.0000	2.4229
YMR	0.0000	0.0000	2.2806	2.3889	2.4229	0.0000
COV INCLD INST	0.0000	0.0000	7.2414	7.1005	7.6408	7.0524
COV EXCLD INST	0.0000	0.0000	7.2760	7.4172	6.8770	7.4653
EST (SIGMA E1)	0.0000	0.0000	0.0873	0.2169	1.1812	0.1730
EST (SIGMA E1)	0.00000	0.00000	0.25946	0.48574	1.08663	0.41596
PRECISION PANK	0	0	1	3	4	2

TOTAL COVARIANCE = 14.5177      PARAMETER VARIANCE = 2.420      PARAM STD DEV. = 1.5555

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRYON  
 NORMALIZED DATA 155MM HOWA, M109, 5W ROUNDS 721-40, 786-795, QE=666-680 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-07 E	XMR F	MEAN
DELETED	375.90	DELETED	DELETED	375.50	379.60	374.60	0.00
2	381.40	375.80	376.10	381.00	381.50	379.90	380.95
3	380.00	381.20	381.60	379.50	380.10	378.70	379.57
4	378.70	0.00	374.10	378.50	378.70	377.30P	378.30
5	378.40	0.00	0.00	378.00	378.30	377.10	377.95
6	379.70	0.00	383.60	379.00	379.40	378.10	379.05
7	379.00	0.00	0.00	379.00	379.20	377.70P	378.73
8	379.00	0.00	354.20	378.50	379.00	377.90	378.60
9	375.90	0.00	349.60	378.50	376.20	374.60	376.35
10	378.00	0.00	376.10	377.50	376.20	377.00	377.18
11	377.50	0.00	0.00	376.50	377.20	375.70	376.73
12	376.90	0.00	0.00	376.50	377.20	375.70	376.57
13	374.60	0.00	0.00	374.50	374.50	373.50	374.37
14	376.60	0.00	0.00	376.50	376.90	375.00P	376.25
15	377.40	0.00	0.00	377.00	377.50	376.00	376.98
16	379.70	0.00	0.00	379.00	380.30	378.40	379.35
17	378.40	0.00	0.00	378.00	378.60	377.95	377.95
18	377.70	0.00	0.00	377.50	377.60	377.18	377.18
19	377.40	0.00	0.00	378.00	378.30	376.90	377.65
20	376.70	0.00	0.00	377.00	377.70	376.10	376.88
21	377.40	269.40	0.00	369.50	377.60	376.30	0.00
22	379.70	340.60	0.00	379.00	378.60	377.30	378.70
23	380.40	372.80	0.00	380.50	380.90	379.40	380.30
24	380.00	305.60	0.00	379.50	380.10	378.50	379.53
25	378.40	0.00	0.00	378.00	378.10	377.80	377.85
26	379.00	0.00	0.00	378.50	379.00	377.80	378.57
27	379.00	0.00	0.00	379.50	378.30	378.00	378.70
28	378.70	0.00	0.00	378.00	378.60	377.30	378.20
29	374.60	0.00	0.00	374.00	374.80	373.40	374.20
30	373.90	0.00	0.00	374.00	374.30	372.50P	373.68
MEAN	378.10	0.00	0.00	377.89	378.14	376.77	
VARIANCE	3.313	0.000	0.000	2.970	3.150	3.148	
STND DEV	1.820	0.000	0.000	1.723	1.775	1.774	
PROR ERR	1.228	0.000	0.000	1.162	1.197	1.197	
GRAND MEAN	377.725	AVERAGE VARIANCE	3.1451	STND DEV	1.7734	PROB ERR	1.1962

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

4 INSTRUMENTS WITH 28 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT PORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRVON  
 NORMALIZED DATA 159MM HOV., M109, 5W ROUNDS 721-40, 766-795, 9E=666-680 MIL6

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-67 E	XMR F
M36-1	0.0000	DELETED	DELETED	2.9200	3.0853	3.1625
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GE-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GE-2	2.9200	0.0000	0.0000	0.0000	2.7951	2.6783
NM-67	3.0853	0.0000	0.0000	2.7951	0.0000	3.0130
XMR	3.1625	0.0000	0.0000	2.6783	3.0130	0.0000
COV INCLD INST	9.1678	0.0000	0.0000	8.5934	8.6935	9.053A
COV EXCLD INST	8.6864	0.0000	0.0000	9.2A08	8.9608	8.8004
EST (SIGMA E1)	0.0966	0.0000	0.0000	0.3276	0.207A	0.045A
EST (SIGMA E1)	0.31075	0.00000	0.00000	0.57236	0.45589	0.21363
PRECISION RANK	2	0	0	4	3	1

1 TOTAL COVARIANCE= 17.8542 PARAMETER VARIANCE = 2.976 PARAM STD DEV. = 1.7250

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, SRL OBRYON  
 NORMALIZED DATA 155MM MORTIZER, M159, ZONE 64 ROUNDS 741-760, OE = 1111 MILS

DATA PRINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-67 E	XMR F	MEAN
1	461.70	0.00	DELETED	461.10	461.60	460.30	461.18
2	464.00	0.00	0.00	464.10	464.10	462.30P	463.62
3	462.70	0.00	0.00	463.60	463.30	461.60	462.80
4	462.00	0.00	0.00	462.10	462.00	460.20P	461.57
5	464.00	0.00	0.00	463.60	464.10	462.20	463.48
6	465.00	0.00	0.00	464.60	464.90	463.10P	464.40
7	465.00	0.00	0.00	465.10	465.00	463.30P	464.60
8	464.70	0.00	0.00	464.60	464.60	463.20P	464.28
9	464.30	0.00	0.00	464.10	464.10	462.40P	463.73
10	462.30	0.00	0.00	462.60	462.40	460.80P	462.03
11	463.70	0.00	0.00	463.60	463.60	462.10P	463.25
12	462.70	0.00	0.00	462.60	462.60	461.60P	462.38
13	463.70	0.00	0.00	463.60	463.60	462.10P	463.25
14	463.00	0.00	0.00	462.60	463.00	461.40	462.50
15	463.00	0.00	0.00	462.60	462.70	461.70	462.50
16	463.30	462.20	0.00	463.10	463.10	461.60P	462.78
17	0.00	0.00	0.00	463.60	462.60	461.10	0.00
18	463.70	461.00	0.00	463.60	464.00	461.40P	463.18
19	463.00	0.00	0.00	462.60	463.00	461.30	462.48
20	465.70	0.00	0.00	465.60	0.00	0.00	0.00

MEAN 463.43  
 VARIANCE 0.948  
 STND DEV 0.974  
 PROB ERR 0.657

GRAND MEAN= 462.999 AVERAGE VARIANCE= 0.9189 STND DEV= 0.9586 PROB ERR= 0.6466

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

4 INSTRUMENTS WITH 16 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL 08RYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 6M ROUNDS 741-760, GE = 1111 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E	XMR F
M36-1	0.0000	0.0000	0.0000	0.9186	0.9208	0.8249
DELETED M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED GE-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED GE-2	0.9186	0.0000	0.0000	0.0000	0.9405	0.7979
NM-87	0.9208	0.0000	0.0000	0.8239	0.7979	0.0000
XMR	0.8249	0.0000	0.0000	2.6630	2.6592	2.4467
COV INCLD INST	2.6643	0.0000	0.0000	2.5436	2.5674	2.7799
COV EXCLD INST	2.5623	0.0000	0.0000	0.0657	0.0181	0.0813
EST (SIGMA E1)	0.0261	0.0000	0.0000	0.25638	0.13435	0.28511
EST (SIGMA E1)	0.16162	0.00000	0.00000			
PRECISION RANK	2	0	0	3	1	4
TOTAL COVARIANCE =		5.2266			0.871	PARAM STD DEV. = 0.9333

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRAL ORRYON

NORMALIZED DATA 155MM HOWITZER, M109, ZONE 74, ROUNDS 761 - 780, QE = 319 MILS

DATA POINT	M36-1 DELFTEN	M36-2 DELFTEN	GE-1 DELFTEN	GE-2 n	M4-87 E	XMR F	MEAN
DELFTEN 1	0.00	0.00	0.00	551.70	0.00	560.00	0.00
DELFTEN 2	0.00	0.00	0.00	563.00 I	563.50	562.60	563.03
DELFTEN 3	0.00	0.00	0.00	566.50	566.50	559.90	0.00
DELFTEN 4	0.00	0.00	0.00	535.10	566.00	564.90	0.00
DELFTEN 5	0.00	0.00	0.00	564.00	565.60	563.50	0.00
DELFTEN 6	0.00	0.00	0.00	565.00	565.60	564.60	565.07
DELFTEN 7	0.00	0.00	0.00	566.10	560.90	565.00	564.00
DELFTEN 8	0.00	0.00	0.00	566.20	579.00	563.50	562.23
DELFTEN 9	0.00	0.00	0.00	545.00	566.40	565.50	0.00
DELFTEN 10	0.00	0.00	0.00	553.00	564.10	563.50	0.00
DELFTEN 11	566.90	0.00	0.00	566.00	566.30	565.30	565.87
DELFTEN 12	564.40	0.00	0.00	547.40	0.00	562.50	0.00
DELFTEN 13	565.40	0.00	0.00	565.50	565.60	564.00	565.33
DELFTEN 14	436.00	0.00	0.00	560.20	565.50	565.20	0.00
DELFTEN 15	0.00	0.00	0.00	566.00	566.50	565.50	566.00
DELFTEN 16	0.00	0.00	0.00	566.80	540.40	0.00	0.00
DELFTEN 17	0.00	0.00	0.00	565.00	552.40	564.50	0.00
DELFTEN 18	0.00	0.00	0.00	565.00	565.40	564.00	564.80
DELFTEN 19	545.00	0.00	0.00	565.50	557.10	565.00	562.53
DELFTEN 20	500.00	0.00	0.00	566.00	566.20	565.70	565.97
MEAN	0.00	0.00	0.00	565.23	563.61	564.61	564.61
VARIANCE	0.000	0.000	0.000	0.900	11.601	0.943	0.943
STND DEV	0.000	0.000	0.000	0.900	3.406	0.971	0.971
PROR FR	0.000	0.000	0.000	0.668	2.207	0.655	0.655
GRAND MEAN	564.483	AVERAGE VARIANCE =	4.5081	STND DEV =	2.1232	PROR FR =	1.4321

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

3 INSTRUMENTS WITH 10 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT STILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORAYON  
 NORMALIZED DATA 155MM HOWITZER, M109, ZONE 74, ROUNDS 761 - 780, OF = 319 MILS

COVARIANCE MATRIX

	M3A-1 A	M3A-2 B	GF-1 C	RE-2 D	NH-R7 E	YMR F
DELETED M3A-1	DELETED	DELETED	DELETED	0.0000	0.0000	0.0000
DELETED M3A-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DELETED GF-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RE-2	0.0000	0.0000	0.0000	0.0000	0.7597	0.9274
NH-R7	0.0000	0.0000	0.0000	0.7597	0.0000	0.9399
YMR	0.0000	0.0000	0.0000	0.9274	0.9399	0.0000
COV INCLD INST	0.0000	0.0000	0.0000	1.6871	1.6996	1.8673
COV EXCLD INST	0.0000	0.0000	0.0000	0.9399	0.9274	0.7597
EST (SIGMA E1)	0.0000	0.0000	0.0000	0.2320	10.8289	-0.1644
EST (SIGMA E1)	0.00000	0.00000	0.00000	0.48259	3.29073	0.00000
PRECISION RANK	0	0	0	2	3	1

TOTAL COVARIANCE = 2.6270    PARAMETER VARIANCE = 0.876    PARAM STD DEV. = 0.9358



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A. JULY-AUGUST 73, BPL ORRYON  
 NORMALIZED DATA 175MM GUN, M107, ZONE I, ROUNDS 971-995, QE = 306 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NH-87 E	XMR F	MEAN
1	DELETED	500.60	499.80	500.20	500.40	0.00	500.25
2	500.00	500.60	501.30	500.20	500.40	0.00	500.63
3	501.40	504.60	503.30	502.20	502.50	0.00	503.15
4	501.10	500.60	501.60P	500.70	500.60	0.00	500.94
5	503.10	501.70	501.80	502.20	502.20	0.00	501.94
6	0.00	503.60	503.30	502.20	0.00	0.00	0.00
7	0.00	501.60	501.30	501.20	501.40	500.00	501.37
8	0.00	502.60	501.60	502.20	503.40	0.00	502.50
9	0.00	503.30	503.30	503.20	502.50P	0.00	503.07
10	0.00	504.60	505.30	500.20P	504.30	0.00	503.60
11	0.00	502.30	501.70	501.70	501.90	0.00	501.90
12	0.00	0.00	503.30	503.30	503.30	0.00	0.00
13	0.00	500.40	500.30	500.20	500.50	0.00	500.35
14	0.00	0.00	500.30	500.70	500.60	0.00	0.00
15	0.00	375.60	503.30	503.20	503.20	0.00	0.00
16	0.00	497.50	496.70 I	496.30 I	496.70 I	0.00	496.80
17	0.00	503.60	503.30	502.70	503.20	0.00	503.20
18	0.00	478.60	498.20	497.30	498.00	0.00	498.03
19	0.00	502.90	502.30	501.70	502.20	0.00	502.27
20	0.00	502.60	502.30	501.70	502.10	0.00	502.18
21	0.00	503.30	503.20	503.20	502.60P	0.00	503.13
22	0.00	502.90	501.70	502.70	502.30	0.00	502.40
23	0.00	504.90	503.70	504.70	504.30	0.00	504.40
24	0.00	502.30	501.70	501.70	501.40	0.00	501.77
25	0.00	505.30P	503.20	502.70	502.80	0.00	503.50
MEAN	0.00	502.23	501.81	501.38	501.72	0.00	
VARIANCE	0.000	4.034	3.639	3.691	3.395	0.000	
STND DEV	0.000	2.009	1.908	1.921	1.843	0.000	
PROR ERR	0.000	1.355	1.267	1.296	1.243	0.000	
GRAND MEAN	501.783	AVERAGE VARIANCE =	3.6409	STND DEV =	1.9209	PROR ERR =	1.2957

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

4 INSTRUMENTS WITH 21 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A.: JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 175MM GUN, M107, ZONE 1, ROUNDS 971-995, 9E = 306 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	9E-1 C	9E-2 D	NM-87 E	XMR F
DELETED	DELETED	0.0000	0.0000	0.0000	0.0000	DELETED
M36-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
M36-2	0.0000	0.0000	3.5572	3.2482	3.4439	0.0000
9E-1	0.0000	3.5572	0.0000	2.9022	3.3093	0.0000
9E-2	0.0000	3.2482	2.9022	0.0000	3.0805	0.0000
NM-87	0.0000	3.4439	3.3093	3.0805	0.0000	0.0000
XMR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
COV INCLD INST	0.0000	10.2494	9.7688	9.2309	9.8337	0.0000
COV EXCLD INST	0.0000	9.2920	9.7726	10.3105	9.7077	0.0000
EST (SIGMA E1)	0.0000	0.2986	0.3839	0.9738	0.0757	0.0000
EST (SIGMA E1)	0.0000	0.54642	0.61963	0.98680	0.27513	0.00000

PRECISION RANK 0 2 3 4 1 0  
 TOTAL COVARIANCE = 19.5414 PARAMETER VARIANCE = 3.257 PARAM STD DEV. = 1.8047

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A. JULY-AUGUST 73, SRL ORRYON  
 NORMALIZED DATA 175MM GUN, M107, ZONE 2, ROUNDS 941-96,  $\sigma = 325$  MILS

DATA POINT	M36-1 A	M36-2 R	GE-1 C	GE-2 n	NM-87 E	XMR F	MEAN
DELETED 1	710.70	709.40	100.50	109.50	710.60	0.00	0.00
DELETED 2	703.60	0.00	702.80	103.00	704.40	701.20	0.00
DELETED 3	707.10	0.00	706.30	706.80	707.10	704.70	0.00
DELETED 4	701.60	650.16	700.80	707.30	701.40	699.00	0.00
DELETED 5	707.10	0.00	706.30	706.30	706.50	704.30	0.00
DELETED 6	698.90	692.30	700.30	700.30	700.50	0.00	0.00
7	704.00	704.60	703.30	703.30	703.80	701.50	703.80
8	704.60	704.90	703.80	703.80	704.00	0.00	704.22
9	706.80	706.70	705.80	706.30	699.20P	704.50	704.80
10	701.30	701.90	700.80	701.30	696.40PI	0.00	700.34
11	707.40	707.40	707.30	706.80	706.70	0.00	707.12
12	704.00	704.60P	703.80	703.80	703.80	0.60	704.00
13	705.30	705.00P	705.30	705.80	705.40	0.00	705.16
14	705.00	705.60	705.30	704.80	704.90	0.00	705.12
15	707.40	707.40	707.30	706.80	706.00	0.00	707.16
16	703.60	704.00	703.80	703.30	703.40	0.06	703.62
17	703.60	703.60	703.80	703.30	703.40	0.00	703.54
18	705.60	706.30	705.30	705.80	705.60	0.00	705.72
19	705.30	705.60	705.80	704.80	705.00	0.00	705.30
20	706.00	706.70	707.80	707.30	273.80	0.00	0.00
21	707.70	708.40	706.80	707.30	707.40	0.00	707.52
22	701.60	703.30	702.80	702.80	702.40	0.00	702.54
23	707.40	708.00	706.80	707.30	707.50	0.00	707.40
24	704.00	704.30	703.30	703.80	703.80	0.00	703.84
25	706.30	707.40	706.30	706.30	706.70	0.00	706.60
MEAN	705.01	705.44	704.86	704.86	704.24	0.00	
VARIANCE	3.537	3.345	3.173	3.114	9.018	0.000	
STND DEV	1.881	1.829	1.781	1.745	2.832	0.000	
PROB FOR	1.269	1.234	1.202	1.100	1.910	0.000	
GRAND MEAN	704.880	AVERAGE VARIANCE	4.2375	STND DEV	2.0585	PROB ERR	1.3085

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 \* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)  
 5 INSTRUMENTS WITH 10 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL DARYOM  
 NORMALIZED DATA 175MM GUN, M107, ZONE 2, ROUNDS 941-965, QE = 325 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 R	QE-1 C	QE-2 n	NM-87 E	XMR F
M36-1	0.0000	3.2639	3.2173	3.2085	3.9545	DELETED
M36-2	3.2639	0.0000	3.0033	3.0150	3.6323	0.0000
QE-1	3.2173	3.0033	0.0000	3.0261	3.8448	0.0000
QE-2	3.2085	3.0150	3.0261	0.0000	3.5507	0.0000
NM-87	3.9545	3.6323	3.8448	3.5507	0.0000	0.0000
DELETED	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
COV INCLD INST	13.6442	12.9144	13.0915	12.8003	14.9822	0.0000
COV EXCLD INST	20.0722	20.8019	20.6248	20.9160	18.7341	0.0000
EST (SIGMA E1)	0.0603	0.3547	0.0649	0.2002	3.6491	0.0000
EST (SIGMA F1)	0.2455A	0.59559	0.25479	0.44745	1.91025	0.00000
PRECISION RANK	1	4	2	3	5	0

TOTAL COVARIANCE = 33.7163      PARAMETER VARIANCE = 3.372      PARAM STN DEV. = 1.8362

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRVON

NORMALIZED DATA 175MM GUN, M107, ZONE 3, ROUNDS 901-930, QE = 500 MILS

DATA POINT	M36-1 A	M36-2 H	GE-1 C	GE-2 N	NM-87 E DELETED	XMR F DELETED	MEAN
DELETED 1	0.00	914.50	1000.50	914.90	915.60	0.00	0.00
2	915.10	914.50	915.90	914.90	914.60	0.00	915.10
3	917.90	917.90	917.40	917.40	910.40	0.00	917.65
DELETED 4	0.00	0.00	917.90	917.40	917.40	914.90	0.00
5	916.10	915.20	915.40	915.40	915.80	913.00	915.52
6	916.50	916.90	917.90	917.90	918.20	915.60	917.30
7	916.10	916.90	917.90	917.90	917.20	914.80	916.95
8	913.40	914.80	915.40	914.40	914.80	912.20	914.50
9	916.10	915.20	915.90	914.90	0.00	0.00	915.52
10	914.50	917.60	917.90	917.40	917.80	915.00	917.85
11	914.80	901.10	914.40	0.00	914.80	912.10	0.00
12	905.00	0.00	1000.50	915.40	915.00	913.40	0.00
DELETED 13	914.40	0.00	915.40	914.40	0.00	911.90	0.00
14	916.90P	915.80	915.90	915.90	916.20	913.60	916.12
15	915.40	914.80	915.90	914.90	915.80	912.60	915.25
16	915.10	914.20	914.40	914.40	914.80	912.10	914.52
17	914.50	919.30	916.90	917.40	917.20	0.00	918.02
DELETED 18	914.90	665.80	913.90	914.40	562.80	911.70	0.00
19	917.20	917.90	915.90	916.40	916.00	914.80	916.85
20	914.80	915.80	914.90	915.40	915.00	912.80	913.23
21	902.90 I	901.30 I	911.40 I	911.90	904.60	909.40	906.88
DELETED 22	860.20	847.40	913.90	914.40	873.00	912.10	0.00
23	915.80	916.90	914.40	914.90	297.10	912.30	915.50
24	895.10	886.00	913.90	913.40	288.60	0.00	0.00
25	908.30	915.50	913.00	913.90	913.80	911.40	912.90
DELETED 26	836.50	541.00	916.90	916.90	869.00	0.00	0.00
DELETED 27	809.00	923.80	910.40	910.90	911.00	908.40	0.00
28	916.80	915.50	915.90	916.40	915.80	913.80	916.15
29	906.30	908.40	914.40	914.90	914.60	912.60	911.00
DELETED 30	913.40	695.70	913.40	913.90	913.60	911.30	0.00

MEAN	914.62	914.97	915.66	915.56	0.00	0.00	0.00
VARIANCE	17.671	15.942	2.594	2.224	0.000	0.000	0.000
STND DEV	4.204	3.993	1.610	1.491	0.000	0.000	0.000
PROB ERR	2.035	2.693	1.088	1.006	0.000	0.000	0.000
GRAND MEAN	915.201	AVERAGE VARIANCE	9.6077	STND DEV	3.0996	PROB ERR	2.0907

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 \* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)  
 4 INSTRUMENTS WITH 19 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FJRT SILL, CONDUCTED BY F.A.: JULY-AUGUST 73, ORL ORRYOM  
 NORMALIZED DATA 175MM GUN, M107, ZONE 3, ROUNDS 901-930, OE = 500 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E	XMR F
M36-1	0.0000	14.8789	5.4623	4.9085	0.0000	DELETED
M36-2	14.8789	0.0000	4.9671	4.5497	0.0000	0.0000
GE-1	5.4623	4.9671	0.0000	2.2200	0.0000	0.0000
GE-2	4.9085	4.5497	2.2200	0.0000	0.0000	0.0000
NM-87	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
XMR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
COV INCLD INST	25.2496	24.3957	12.6494	11.6782	0.0000	0.0000
COV EXCLD INST	11.7368	12.5908	24.3370	25.3082	0.0000	0.0000
EST (STIMA E1)	4.7506	3.8754	2.2730	2.8743	0.0000	0.0000
EST (STIMA E1)	2.17950	1.96661	1.50764	1.69537	0.00000	0.00000
PRECISION RANK	4	3	1	2	0	0
TOTAL COVARIANCE =	36.9865	PARAMETER VARIANCE =	6.164	PARAM STD DEV. =	2.4828	

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A. JULY-AUGUST 73, ORL OBRVOM

NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 2, ROUNDS 601-620, OE = 598 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	MM-67 E	XMR F	MEAN
1	273.00 I	DELETED	273.40	272.70 I	273.60 I	272.30 I	273.16
2	269.10	233.30	269.90	268.70	269.50	268.70	269.18
3	269.40	269.50	269.90	268.70	269.50	268.60	269.22
4	271.10	269.20	271.40	270.20	270.90	270.30	270.78
5	270.40	0.00	269.90	269.70	270.40	269.20	269.92
6	270.40	0.00	269.40	269.20	270.00	269.40	269.68
7	269.80	0.00	269.40	268.20	268.90	268.30	268.72
8	270.40	263.40	269.40	269.20	270.00	269.00	269.66
9	270.10	0.00	269.40	269.20	270.00	270.50	269.58
10	271.10	0.00	271.40	270.20	271.10	270.50	270.66
11	269.80	0.00	269.70	268.70	269.70	268.80	269.32
12	269.80	0.00	269.70	268.70	269.20	267.80	269.04
13	271.10	270.90	271.20	270.20	270.90	270.10	270.70
14	270.80	270.50	271.20	270.20	270.60	269.60	270.48
15	270.40	270.20	269.70	269.70	270.40	269.60	269.96
16	270.10	268.50	269.40	269.20	269.90	268.80	269.48
17	271.80	271.50	271.70	270.70	271.40	270.60	271.24
18	271.40	0.00	271.70	270.70	271.40	270.20	271.08
19	271.80	0.00	271.70	270.70	271.40	270.50	271.22
20	271.80	0.00	271.70	270.70	271.40	270.40	271.20

MEAN 270.67  
 VARIANCE 1.303  
 STND DEV 1.142  
 PROB ERR 0.770

GRAND MEAN= 270.221 AVERAGE VARIANCE= 1.1980 STND DEV= 1.0945 PROB ERR= 0.7363

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

• INSTRUMENTS WITH 20 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRON  
 NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 2, ROUNDS 601-620, SE = 598 MILS

COVARIANCE MATRIX

	M36-1	M36-2	SE-1	SE-2	NM-87	XMR
	A	B	C	D	E	F
M36-1	0.0000	DELETED	1.1877	1.1813	1.1944	1.1188
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SE-1	1.1877	0.0000	0.0000	1.1400	1.1449	1.0868
SE-2	1.1813	0.0000	1.1400	0.0000	1.1180	1.0504
NM-87	1.1944	0.0000	1.1449	1.1180	0.0000	1.0790
XMR	1.1188	0.0000	1.0868	1.0504	1.0790	0.0000
COV INCLD INST	4.6822	0.0000	4.5593	4.4897	4.5363	4.3348
COV EXCLD INST	6.6100	0.0000	6.7419	6.8114	6.7648	6.9663
EST (SIGMA E1)	0.0653	0.0000	0.1992	0.0029	-0.0002	0.0721
EST (SIGMA E1)	0.25563	0.00000	0.44629	0.05352	0.00000	0.26643
PRECISION RANK	3	0	5	2	1	4

TOTAL COVARIANCE = 11.3011      PARAMETER VARIANCE = 1.130      PARAM STD DEV. = 1.0631



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL OSRYON

NORMALIZED DATA 8-INCH MUNITZER, M110, ZONE 3, ROUNDS 641-660, OE = 1130 MILS

DATA POINT	M36-1 A	M36-2 R	OE-1 C	OE-2 D	NM-87 E	XMR F	MEAN
1	302.80	302.30	303.20	301.70	302.50	301.50	302.33
2	303.40	303.00	303.70	302.70	303.20	302.30	303.05
3	304.40	304.40	303.70	303.70	304.40	303.70	304.05
4	303.40	303.00	303.70	302.20	303.10	302.10	302.92
5	309.20	306.10	287.20	303.70	309.20	306.60	0.00
6	303.80	303.30	303.70	302.70	303.40	302.50	303.23
7	0.00	0.00	303.20	303.20	304.10	303.00	0.00
8	304.80	304.70	305.20	303.70	304.90	304.20	304.56
9	303.80	303.30	303.20	302.70	303.50	302.50	303.17
10	304.20	304.00	303.20	303.20	304.00	306.50P	304.18
11	303.90	303.60	303.20	302.70	303.70	302.40	303.25
12	304.60	236.30	303.70	303.20	304.20	302.90	0.00
13	305.00	302.00	305.20	303.70	304.60	305.60	304.35
14	304.30	304.10	303.20	303.20	304.00	302.90	303.62
15	305.30	305.10	305.20	303.70	304.90	303.50	304.62
16	304.30	304.10	303.20	303.20	304.00	304.80	303.93
17	303.90	278.20	303.20	302.70	303.60	302.50	0.00
18	304.30	304.10	303.20	303.20	303.90	302.70	303.57
19	303.90	303.60	303.20	303.20	303.80	0.00	0.00
20	305.00	304.50	305.20	303.70	304.60	303.40	304.40

MEAN	304.18	303.70	303.87	303.07	303.91	303.37	
VARIANCE	0.469	0.773	0.738	0.374	0.486	1.929	
STND DEV	0.685	0.879	0.859	0.611	0.697	1.388	
PROB ERR	0.462	0.593	0.579	0.412	0.470	0.937	
GRAND MEAN=	303.683	AVERAGE VARIANCE=	0.7947	STND DEV=	0.6915	PROB ERR=	0.6013

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY 1 OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 1 INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY;

6 INSTRUMENTS WITH 15 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRVOM  
 NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 3, ROUNDS 641-660, SE = 1130 MILD

COVARIANCE MATRIX

	M36-1 A	M36-2 B	SE-1 C	SE-2 D	MH-67 E	XMR F
M36-1	0.0000	0.3650	0.4214	0.3971	0.4660	0.5730
M36-2	0.3650	0.0000	0.1750	0.3357	0.4014	0.2557
SE-1	0.4214	0.1750	0.0000	0.3274	0.4226	0.3546
SE-2	0.3971	0.3357	0.3274	0.0000	0.4126	0.5533
MH-67	0.4660	0.4014	0.4226	0.4126	0.0000	0.6054
XMR	0.5730	0.2557	0.3546	0.5533	0.6054	0.0000
COV INCLD INST	2.2226	1.5329	1.7012	2.0262	2.3080	2.3422
COV EXCLD INST	3.8440	4.5337	4.3653	4.0403	3.7585	3.7243
EST (BIOMA E1)	-0.0358	0.6131	0.4942	-0.0326	-0.0616	1.3648
EST (BIOMA E1)	0.00000	0.78299	0.70296	0.00000	0.00000	1.16824
PRECISION RANK	2	5	4	3	1	6

TOTAL COVARIANCE = 6.0665      PARAMETER VARIANCE = 0.404      PARAM STD DEV. = 0.6360

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A. JULY-AUGUST 73, BRL OBRVON  
 NORMALIZED DATA 8-INCH MORTAR, M110, ZONE 4, ROUNDS 21-640, OE = 335 MILS

DATA POINT	M36-1 A	M36-2 B	OE-1 C	OE-2 D	NH-27 E	XMR F	MEAN
1	347.40	DELETED	345.20	345.20	346.40	345.60	345.96
2	346.40	0.00	345.20	344.20	345.40	343.90	345.02
3	346.00	0.00	345.20	343.70	345.30	343.90	344.82
4	346.70	0.00	345.70	344.70	345.80	344.50	345.48
5	347.40	0.00	345.20	344.70	346.30	345.60	345.84
6	347.40	0.00	345.20	345.20	346.40	345.40	345.92
7	348.10	0.00	347.20	345.70	347.10	346.10	346.84
8	347.40	0.00	345.20	344.70	346.10	345.10	345.70
9	346.40	0.00	345.20	343.70	345.30	344.00	344.92
10	347.00	0.00	345.20	344.70	346.10	345.10	345.62
11	347.60	300.00	345.20	345.20	0.00	348.00	0.00
12	348.60	348.10	347.70	346.70	347.00	346.30	347.42
13	348.60	348.10	347.70	346.20	347.70	0.00	0.00
14	346.20	346.40	345.20	343.70	345.10	344.70	344.98
15	348.60	348.50	347.20	346.70	348.00	351.30	348.36
16	347.20	347.20	345.70	345.20	346.40	345.40	345.98
17	347.60	347.40	0.00	0.00	347.10	350.40	0.00
18	346.80	346.00	345.20	344.70	346.10	345.00	345.56
19	347.90	350.90	347.20	345.70	347.20	346.10	346.82
20	347.60	321.10	345.70	345.70	346.40	345.40	346.16

GRAND MEAN= 345.965 AVERAGE VARIANCE= 1.1526 STND DEV= 1.0736 PROB ERR= 0.7241

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

5 INSTRUMENTS WITH 17 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OBRVON  
 NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 4, ROUNDS 621-640, OE = 335 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	OE-1 C	OE-2 D	NM-87 E	XMR F
M36-1	0.0000	DELETED	0.5649	0.6871	0.6347	1.0053
M36-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OE-1	0.5649	0.0000	0.0000	0.6756	0.6463	0.9462
OE-2	0.6871	0.0000	0.6756	0.0000	0.7482	1.1462
NM-87	0.6347	0.0000	0.6463	0.7482	0.0000	1.1450
XMR	1.0053	0.0000	0.9662	1.1662	1.1450	0.0000
COV INCLD INST	2.8520	0.0000	2.8529	3.2971	3.1743	4.3027
COV EXCLD INST	5.3675	0.0000	5.4065	4.9624	5.0852	3.9566
EST (SIGMA E1)	0.0536	0.0000	0.2945	0.0241	-0.0365	1.2975
EST (SIGMA E1)	0.2316	0.0000	0.54265	0.15934	0.00000	1.13906
PRECISION RANK	3	0	4	2	1	5

TOTAL COVARIANCE = 8.2595      PARAMETER VARIANCE = 0.026      PARAM STD DEV. = 0.9088

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL OBRON

NORMALIZED DATA 8-INCH MORTAR, M110, ZONE 5G, ROUNDS 801-820, OE = 1110 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E	KMR F	MEAN
DELETED 1	0.00	415.50	417.80	416.30	0.00	415.70	0.00
2	416.30	415.80	415.80	415.30	416.00	414.80	415.67
3	415.80	415.10	415.80	414.30	415.40	414.80	415.17
DELETED 4	415.30	414.80	415.30	414.80	0.00	413.80	0.00
5	415.60	415.10	415.60	414.30	415.10	413.90	414.97
6	416.10	415.50	415.80	414.30	415.40	414.70	415.30
7	415.60	415.50	415.80	414.30	415.40	414.20	415.13
DELETED 8	415.60	415.10	415.80	414.80	0.00	414.10	0.00
9	415.60	415.50	415.80	414.30	415.40	414.00	415.03
10	415.90	415.10	415.80	414.30	415.40	414.30	415.35
11	415.60	415.80	415.80	414.80	415.30	414.30	414.83
12	415.90	415.10	415.30 I	414.30	414.90	413.80	415.42
13	415.90	415.50	415.80	414.80	415.80	414.90	416.10
14	416.40	416.50	415.80	415.60	416.50	415.40	415.65
15	416.30	415.80	415.80	415.30	416.00	414.70	0.00
DELETED 16	0.00	415.50	415.80	414.30	415.20	414.00	0.00
DELETED 17	0.00	415.50	415.80	414.80	415.80	414.20	0.00
DELETED 18	0.00	416.10	415.80	417.80	416.30	415.70	0.00
19	416.90	416.50	415.80	415.80	416.50	415.60	416.18
20	416.60	416.10	415.80	414.30	416.10	414.80	415.62

MEAN 416.05 VARIANCE 0.209 STND DEV 0.458 PROB ERR 0.309  
 GRAND MEAN= 415.417 AVERAGE VARIANCE= 0.2305 STND DEV= 0.4801 PROB ERR= 0.3239

MEASUREMENTS FOUND TO BE OUTLIER'S AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

• INSTRUMENTS WITH 13 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, SPL OBRYN  
 NORMALIZED DATA 1/2-INCH MUNITZER, M110, ZONE 56, ROUNDS 601-620, GE = 1110 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NM-87 E	XMR F
M36-1	0.0000	0.2135	0.0186	0.2061	0.2128	0.2096
M36-2	0.2135	0.0000	0.0228	0.2394	0.2337	0.2221
GE-1	0.0186	0.0228	0.0000	0.0192	0.0324	0.0337
GE-2	0.2061	0.2394	0.0192	0.0000	0.2490	0.2462
NM-87	0.2128	0.2337	0.0324	0.2490	0.0000	0.2427
XMR	0.2096	0.2221	0.0337	0.2462	0.2427	0.0000
COV INCLD INST	0.8606	0.9315	0.1266	0.9599	0.9706	0.9542
COV EXCLD INST	1.5411	1.4703	2.2751	1.4418	1.4312	1.4475
EST (SIGMA E1)	0.0192	0.0238	0.1961	0.1128	0.0068	0.0638
EST (SIGMA E1)	0.13661	0.15426	0.4283	0.33561	0.08251	0.25264
PRECISION RANK	2	3	6	5	1	4

TOTAL COVARIANCE = 2.4017      PARAMETER VARIANCE = 0.160      PARAM STD DEV. = 0.4001

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL 08RYON  
 NORMALIZED DATA 8-INCH MUNITZER, M110, ZONE 5W, ROUNDS 021-840, QE = 518 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 D	M4-07 F	XMR F	MEAN
DELETED 1	421.50	421.40	DELETED	DELETED	420.20	0.00	0.00
2	422.00	422.40	417.00	0.00	421.50	422.50	422.30
3	421.50	421.00	280.70	0.00	420.50	420.60	420.90
4	421.20	421.00	0.00	0.00	420.50	421.00	420.93
5	420.80	420.70	395.00	475.10	419.60P	420.80	420.48
6	421.80	421.40	0.00	363.10	420.20	420.10	420.67
7	422.00	422.70	0.00	0.00	421.80	426.50	0.00
8	421.50	421.00	486.00	386.10	420.20	422.80	421.38
9	421.20	421.40	0.00	395.10	421.00	421.00	421.15
10	417.40 1	420.40	468.00	535.00	420.10	421.10	419.75
11	423.20	422.70	462.00	0.00	421.90	422.80	422.55
12	0.00	421.00	0.00	0.00	419.80	420.90	0.00
13	421.20	421.00	0.00	0.00	420.10P	421.00	420.82
14	421.20	419.00	380.10	0.00	419.60	0.00	0.00
15	421.50	420.40	0.00	0.00	420.00	420.60	420.78
16	0.00	421.40	418.00	461.10	419.40	420.80	0.00
17	421.50	421.40	443.50	0.00	420.20P	421.60	421.18
18	423.20	422.70	490.00	391.20	421.60	421.90	422.35
19	420.20	420.00	402.10	355.00	419.50	419.80	419.87
20	421.80	422.00	407.60	402.10	421.10	421.70	421.65
MEAN	421.30	421.34	0.00	0.00	420.53	421.29	
VARIANCE	1.908	0.638	0.000	0.000	9.530	0.841	
STND DEV	1.381	0.799	0.000	0.000	0.728	0.917	
PROR ERR	0.032	0.530	0.000	0.000	0.491	0.619	
GRAND MEAN	421.137	AVERAGE VARIANCE=	0.9704	STND DEV=	0.9896	PROR ERR=	0.6675

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P. OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

4 INSTRUMENTS WITH 15 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL OARYON  
 NORMALIZED DATA 8-INCH WHITZER, M110, ZONE SW, ROUND 821-R40, GE = 518 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C	GE-2 D	NH-87 E	XMR F
M36-1	0.0000	0.8891	DELETED	DELETED	0.6598	0.5898
M36-2	0.8891	0.0000	0.0000	0.0000	0.5393	0.5006
GE-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GE-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NH-87	0.6598	0.5393	0.0000	0.0000	0.0000	0.4555
XMR	0.5898	0.5006	0.0000	0.0000	0.4555	0.0000
CON INCLD INST	2.1387	1.9290	0.0000	0.0000	1.6545	1.5459
CON EXCLD INST	1.4953	1.7050	0.0000	0.0000	1.9795	2.0882
EST (SIGMA F1)	0.9810	-0.0794	0.0000	0.0000	0.0863	0.5067
FSY (SIGMA F1)	0.99046	0.00000	0.00000	0.10000	0.29385	0.71185
PRECISION RANK	4	1	0	0	2	3

TOTAL COVARIANCE = 3.6340      PARAMETER VARIANCE = 0.606      PARAM STD DEV. = 0.7783



CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A. JULY-AUGUST 73, BRL OBRYON  
 NORMALIZED DATA 8-INCH HOWITZER, M10, ZONE 5M, ROUNDS R81-R90 OF = 518 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C DELETED	GF-2 D DELETED	NM-87 F DELETED	XMR F	MEAN
DELETED 1	423.80	423.40	0.00	0.00	0.00	0.00	0.00
DELETED 2	423.20	422.70	0.00	0.00	0.00	0.00	0.00
DELETED 3	423.50	423.70	333.90	379.10	421.83	0.00	0.00
4	422.50	421.40	458.00	430.20	0.00	422.20	422.03
5	422.20	422.40	407.40	407.10	0.00	422.30	422.30
6	424.20	424.00	420.30	473.00	0.00	423.50	423.90
7	423.80	423.30	0.00	0.00	0.00	423.70	423.60
8	423.20	422.70P	0.00	0.00	0.00	423.20	423.03
9	426.20	421.70	389.80	419.30	0.00	421.40	421.10
10	422.80	423.00	0.00	0.00	0.00	422.50	422.77
MEAN	422.70	422.64	0.00	0.00	0.00	422.69	
VARIANCE	1.710	0.816	0.000	0.000	0.000	0.671	
STND DEV	1.308	0.903	0.000	0.000	0.000	0.819	
PROB ERR	0.882	0.609	0.000	0.000	0.000	0.553	
GRAND MEAN	422.676	AVERAGE VARIANCE =	1.0650	STYD DEV =	1.0324	PROB ERR =	0.6964

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P  
 I INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF OTHER DATA POINTS BY THE SAME INSTRUMENT.  
 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)  
 3 INSTRUMENTS WITH 7 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

COVARIANCE MATRIX

	M36-1 A	M36-2 B	GE-1 C DELETED	GF-2 D DELETED	NM-87 E DELETED	XMR F
M36-1	0.0000	0.9250	0.0000	0.0000	0.0000	1.0133
M36-2	0.9250	0.0000	0.0000	0.0000	0.0000	0.6074
GE-1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GF-2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NM-87	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
YMR	1.0133	0.6074	0.0000	0.0000	0.0000	0.0000
COV INCLD INST	1.9383	1.5324	0.0000	0.0000	0.0000	1.6207
COV EXCLD INST	0.6074	1.0133	0.0000	0.0000	0.0000	0.9250
EST (SIGMA FI)	0.3790	0.2971	0.0000	0.0000	0.0000	-0.0243
EST (SIGMA FI)	0.61567	0.54511	0.00000	0.00000	0.00000	0.00000
PRECISION RANK	3	2	0	0	0	1
TOTAL COVARIANCE =	2.5457	PARAMETER VARIANCE =	0.649	PARAM STD DEV. =	0.9212	

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 8-INCH HDWITZER, M10, ZONE 6W, ROUNDS 841-860, QF = 382 MILS

DATA POINT	M36-1 A	M36-2 B	GE-1 C	GE-2 n	NM-87 F	XMR P	MEAN
DELETED 1	505.90	0.00	499.80	499.80	500.30	500.20	0.00
2	501.80	500.60	501.80	500.30	501.10	501.10	501.12
3	500.70	500.30	499.80	499.80	500.10	499.90	500.10
4	501.70	501.60	501.30	500.60	501.30	500.20	501.15
5	502.10	501.30	501.30	501.30	501.80	500.30	501.35
6	500.70	500.30	501.30	499.80	500.40	499.40	500.32
7	500.40	497.90P	499.80	499.80	500.00	499.70	499.52
8	500.10	499.90	499.30	498.80	499.60	499.50	499.53
9	501.40	500.90	501.80	500.30	500.90	499.90	500.87
10	500.70	500.30	499.80	499.30	500.20	500.10	500.07
11	500.70	500.30	503.30	499.80	500.40	498.50	500.50
12	501.70	501.30	501.80	500.30	501.10	499.70	500.98
13	500.10	499.10	499.80	499.30	499.90	498.20	499.40
14	499.10	498.90	499.30	498.90	498.90	497.20P	498.62
15	499.70	499.80	499.30	498.80	499.60	497.90P	499.08
16	503.50 I	503.40 I	503.80	502.30 I	503.00 I	501.10	502.85
17	501.10	500.60	501.30	500.30	500.70	498.60P	500.43
18	500.70	500.60	499.80	499.30	500.20	498.30	499.82
19	501.10	500.90	501.30	499.80	500.60	498.70	500.40
20	500.10	499.90	499.30	498.80	499.50	497.40	499.17

MEAN 500.92  
 VARIANCE 0.981  
 STND DEV 0.991  
 PROB ERR 0.668

GRAND MEAN= 500.277 AVERAGE VARIANCE= 1.2267 STND DEV= 1.1076 PROB ERR= 0.7471

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P  
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 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

\* INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

6 INSTRUMENTS WITH 19 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL DRYON  
 NORMALIZED DATA 9-INCH HOWITZER, M10, ZONE CW, ROUNDS 841-860, OF = 382 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 R	GE-1 C	GE-2 n	NM-87 E	XMR F
M36-1	0.0000	0.9955	1.0778	0.9246	0.9130	0.9246
M36-2	0.9955	0.0000	1.1361	0.9360	0.9284	0.7537
GE-1	1.0778	1.1361	0.0000	1.0694	1.0389	0.8472
GE-2	0.9246	0.9360	1.0694	0.0000	0.8864	0.8382
NM-87	0.9130	0.9284	1.0389	0.8864	0.0000	0.8286
XMR	0.9246	0.7537	0.8472	0.8382	0.8286	0.0000
COV INCLD INST	4.8353	4.7497	5.1694	4.6545	4.5953	4.1923
COV EXCLD INST	9.2630	9.3486	8.9288	9.4437	9.5030	9.9060
EST (SIGMA F1)	-0.0264	0.3711	0.6862	0.0124	-0.0179	0.6957
FST (SIGMA F1)	0.00000	0.60916	0.82838	0.11129	0.00000	0.83410

PRECISION RANK 1 4 5 3 2 6

TOTAL COVARIANCE= 14.0983 PARAMETER VARIANCE = 0.940 PARAM STD DEV. = 0.9695

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, BRL ORRYON  
 NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 7M, ROUNDS 861-8A0, QF = 277 MILS

DATA POINT	M36-1 A	M38-2 R	GE-1 C	GE-2 D	NM-87 F	XMR F	MEAN
1	594.90	594.60	593.80	593.80	594.30	592.10P	593.92
2	592.60	593.60	593.80	593.30	593.90	591.80	593.22
3	508.80	597.70	593.30	596.80	597.70	595.60	597.25
DELETED 4	593.30	0.00	593.30	592.30	592.80	590.10	0.00
5	596.00	596.00	595.80	594.80	595.60	592.90P	595.18
DELETED 6	594.60	594.20	593.80	593.80	594.30	0.00	0.00
7	596.00	596.00	595.30	594.80	595.60	593.60	595.22
8	593.20	592.90	593.30	591.80	592.80	590.70	592.45
9	596.30	596.30	595.30	595.30	595.00	593.80	595.48
10	592.20	596.70	591.80	590.80	591.60	588.60	591.95
11	590.90	590.90	589.80	589.80	590.40	586.10P	589.65
12	596.40	596.00	595.30	595.30	595.90	590.90P	594.97
13	596.00	595.70	595.30	595.30	596.50	592.70P	595.25
14	594.60	594.20	593.80	593.30	594.10	590.00P	593.48
15	592.60	592.60	591.80	591.30	592.20	589.20P	591.62
16	594.90	594.90	595.30	593.80	594.60	591.60P	594.18
17	595.40	593.60	595.30	593.80	594.70	590.90P	593.95
18	593.30	593.20	593.30	592.30	592.70	589.60P	592.40
19	591.60	585.10 I	591.30	590.38	592.50	587.80	589.78
20	593.30	592.60	591.80	591.80	592.50	588.50P	591.75

MEAN 594.37  
 VARIANCE 4.005  
 STND DEV 2.001  
 PROB ERR 1.350

GRAND MEAN= 593.428 AVERAGE VARIANCE= 4.8847 STND DEV= 2.2011 PROB ERR= 1.4846

MEASUREMENTS FOUND TO BE OUTLIERS AT A 95% CONFIDENCE LEVEL ARE FOLLOWED BY I OR P.  
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 P INDICATES THE MEASUREMENT WAS FOUND TO BE AN OUTLIER WHEN COMPARED TO MEASUREMENTS OF THE SAME DATA POINT BY OTHER INSTRUMENTS.

• INDICATES AN OUTLIER WHEN CONSIDERING THE DIFFERENCE BETWEEN INSTRUMENTS. (TWO INSTRUMENT CASE ONLY)

6 INSTRUMENTS WITH 18 DATA POINTS EACH WERE USED IN THIS ANALYSIS.

CUSTOMER SERVICE TEST AT FORT SILL, CONDUCTED BY F.A., JULY-AUGUST 73, ORL OBRON  
 NORMALIZED DATA 8-INCH HOWITZER, M110, ZONE 7W, ROUNDS 851-880, QE = 277 MILS

COVARIANCE MATRIX

	M36-1 A	M36-2 R	RE-1 C	GE-2 N	NM-87 E	XMR F
M36-1	0.0000	4.0576	3.6755	3.8275	3.6806	4.2182
M36-2	4.0576	0.0000	3.8500	4.1000	3.4068	4.7112
RE-1	3.6755	3.8500	0.0000	3.6944	3.5686	4.2814
GE-2	3.8275	4.1000	3.6944	0.0000	3.7225	4.3560
NM-87	3.6806	3.4068	3.5686	3.7225	0.0000	4.2000
XMR	4.2182	4.7112	4.2814	4.3560	4.2000	0.0000
CONV INCLD INST	19.4594	20.1256	19.0699	19.7013	18.5785	21.7676
CONV EXCLD INST	39.4918	39.2256	40.2813	39.6499	40.7727	37.5836
FST (SIGMA F1)	0.2101	3.9362	0.1910	-0.0070	0.3344	0.6631
FST (SIGMA F1)	0.45839	1.08397	0.43704	0.00000	0.57826	0.81429

PRECISION RANK 3 6 2 1 4 5

TOTAL COVARIANCE = 59.3512 PARAMETER VARIANCE = 3.957 PARAM STD DEV. = 1.9892

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73  
105MM HOWITZER M102

EST ISTGMA FII SUMMARY		POINTS		MEAN	M3A-1		M3A-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
1	6	19	184	66053	0.23702	0.14259	0.35109	0.03674	0.07446	0.24401	0.00000	200-220	1	350
2	5	20	235	63209	0.14917	0.34635	0.24670	0.13547	0.00000	0.00000	0.00000	243-263	3	1250
3	4	19	270	72018	0.00235	0.03714	0.21283	0.31834	0.01749	0.07666	0.00000	221-231	4	180
4	5	19	316	78316	0.00000	0.03750	0.17411	0.34002	0.00594	0.19319	0.00000	260-284	5	200
5	3	10	406	10333	0.00000	0.00000	0.22667	0.00000	0.00000	0.00000	0.00000	301-310	7	1095
6	5	6	484	83000	1.43130	-0.01094	0.58428	0.16659	0.00000	0.00000	0.32372	311-320	7	1077
7	4	5	486	86000	0.17074	0.01725	0.17325	-0.00175	0.00725	0.00725	0.00000	322-326	7	405
8	3	17	545	42941	0.00000	4.17464	-0.00224	0.51979	0.00000	0.00000	0.00000	327-345	7	405 (R&P)

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73  
155MM HOWITZER M109

EST ISTGMA FII SUMMARY		POINTS		MEAN	M3A-1		M3A-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
1	5	16	199	79750	0.07142	0.00000	0.00000	0.17739	0.06731	0.17977	0.33272	401-420	1	460
2	4	16	276	55606	0.00000	0.00000	0.00000	0.24175	0.01185	0.00440	0.10303	481-500	3G	1219
3	5	16	315	71000	0.00000	0.07720	0.35509	0.03016	0.78984	0.06549	0.00000	421-440	4G	237
4	5	20	375	64300	0.17495	0.00000	0.14739	0.21085	0.00591	0.19335	0.00000	701-720	5G	680
5	5	14	280	78429	0.00000	0.14000	0.02196	0.02923	0.01311	0.00000	0.00000	441-460	3W	300
6	4	19	321	44079	0.00000	0.00000	0.06732	0.21591	1.14121	0.17302	0.00000	461-480	4W	229
7	4	20	377	72500	0.09457	0.00000	0.52760	0.20784	0.04564	0.00000	0.00000	721-740	5W	675
8	4	18	465	99861	0.02812	0.00000	0.00000	0.06573	0.01805	0.00129	0.00000	741-760	6W	1111
9	3	10	545	48333	0.00000	0.00000	0.00000	0.23289	10.82880	-0.16444	0.00000	761-780	7W	319

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73  
175MM GUN, M107

EST ISTGMA FII SUMMARY		POINTS		MEAN	M3A-1		M3A-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
1	4	21	501	78333	0.00000	0.29854	0.00000	0.38394	0.92377	0.07570	0.00000	971-995	1	306
2	4	19	704	68000	0.06031	0.35472	0.00000	0.04492	0.20021	3.44907	0.00000	941-965	2	325
3	4	19	915	20132	4.75066	3.67543	0.00000	2.27797	2.47429	0.00000	0.00000	901-930	3	500

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73  
8 INCH HOWITZER, M110

EST ISTGMA FII SUMMARY		POINTS		MEAN	M3A-1		M3A-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
1	5	20	270	22100	0.06535	0.00000	0.00000	0.19917	0.00285	-0.00019	0.07200	601-620	2	509
2	4	15	303	69333	-0.03574	0.00000	0.00000	0.49415	-0.03283	-0.06185	1.36480	641-660	3	1150
3	4	17	345	66471	0.05364	0.00000	0.00000	0.29447	0.02413	-0.03351	1.29744	621-640	4	355
4	4	13	415	41667	0.01921	0.02379	-0.07937	0.19610	0.11277	0.00681	0.00000	801-820	5G	1110
5	4	15	421	13667	0.08102	-0.00000	0.00000	0.00000	0.00000	0.00685	0.50673	821-840	5W	518
6	3	7	422	67619	0.37905	0.29714	0.00000	0.00000	0.00000	-0.02429	0.00000	881-890	5W	518
7	4	19	500	27719	-0.02643	0.37107	0.00000	0.68822	0.01239	-0.01792	0.69572	841-860	6	382
8	5	18	593	42770	0.21012	3.93615	0.00000	0.19100	-0.00704	0.33439	0.66306	861-880	7	277

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73

EST (SIGMA E11) SUMMARY

2

16.5 INCH HOWITZER M102

INST	POINTS	MEAN	M36-1	M36-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
6	10	164.6653	0.23782	0.14759	0.35109	0.03676	0.07446	0.24801	200-220	1	350
5	20	235.63200	0.16917	0.34635	0.44670	0.13547	0.00000	0.07575	243-263	3	1250
4	19	270.22018	0.09235	0.01714	0.21283	0.31838	0.00000	0.07666	231-241	4	130
3	19	316.78316	0.00000	0.03750	0.19411	0.34002	0.00596	0.15119	269-284	5	200
3	10	486.19333	0.00000	0.00000	0.22667	0.34000	0.00000	0.01600	301-310	7	1093
4	6	484.83000	1.43133	-0.01094	0.09428	0.16639	0.00000	0.32372	311-320	7	1077
4	6	486.88000	0.17975	0.01725	-0.08175	0.00725	0.00725	0.00725	322-326	7	405
3	17	545.42041	0.00000	4.17464	-0.08224	0.31479	0.00000	0.00000	327-345	7	405 (NCP)

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73

EST (SIGMA E11) SUMMARY

2

155MM HOWITZER M109

INST	POINTS	MEAN	M36-1	M36-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
5	16	109.70750	0.07142	0.00000	0.17749	0.06731	0.17977	0.33272	401-420	1	460
4	14	276.58806	0.00000	0.00000	0.24175	0.41145	0.00440	0.18303	431-500	3G	1219
5	13	315.71000	0.00000	0.07720	0.35509	0.03016	0.28066	0.06549	421-440	4G	237
5	20	370.08300	0.17695	0.00000	0.14734	0.21045	0.00591	0.19335	701-720	5G	680
5	14	260.78420	0.00000	0.14600	0.19071	0.02195	0.02923	0.01311	461-460	3W	300
4	4	321.42079	0.00000	0.00000	0.06732	0.21571	1.04121	0.17302	461-480	4W	229
4	28	377.72500	0.00000	0.00000	0.00000	0.32760	0.23724	0.04564	481-490	5W	675
4	18	462.98861	0.02612	0.00000	0.00000	0.06573	0.01805	0.08129	741-760	6W	1111
3	10	564.48333	0.00000	0.00000	0.00000	0.23289	10.02089	-0.16444	761-780	7W	319

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73

EST (SIGMA E11) SUMMARY

2

175MM GUN, M107

INST	POINTS	MEAN	M36-1	M36-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
4	21	501.78333	0.00000	0.29859	0.38394	0.02377	0.02570	0.00000	971-995	1	306
5	14	704.88000	0.00000	0.35472	0.04492	0.20021	3.64907	0.00000	941-965	2	325
4	10	915.20132	4.75000	3.87543	2.27297	2.37429	0.00000	0.00000	901-930	3	500

Customer Service Test, at Fort Sill by Frankford Arsenal July-Aug 73

EST (SIGMA E11) SUMMARY

2

8 INCH HOWITZER, M110

INST	POINTS	MEAN	M36-1	M36-2	GE-1	GE-2	M4-A7	XMR	ROUNDS	ZONE	QE
5	20	270.22100	0.06535	0.00000	0.19917	0.00285	-0.00019	0.07206	601-620	2	508
4	15	303.68333	-0.03574	0.61308	0.49415	-0.03263	-0.06185	1.36480	641-660	3	1130
4	17	345.06471	0.05164	0.00000	0.29447	0.02413	-0.03451	1.20748	621-640	4	335
4	13	415.41667	0.03021	0.02379	0.14510	0.11277	0.00681	0.06383	801-820	5G	1110
3	15	421.15007	0.06102	-0.07637	0.00000	0.00000	0.08635	0.50623	821-840	5W	518
4	7	425.67515	3.37905	0.29714	0.00000	0.00000	-0.00000	-0.02429	881-890	5W	518
4	10	500.27719	-0.02643	0.37107	0.68622	0.01239	-0.01792	0.69572	841-860	6	382
6	18	503.42778	0.21012	3.93615	0.19100	-0.00704	0.33439	0.66306	861-880	7	277

APPENDIX C  
Correspondence - BRL to FA, AMXBR-EB-FT, 11 January 1974



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AMXBR-EB-FT

11 January 1974

SUBJECT: Customer Service Test Results of Chronographs,  
Fort Sill, Oklahoma, July-August 1973

Commander  
Frankford Arsenal  
ATTN: SARFA-FCF-E  
Bridge & Tacony Streets  
Philadelphia, PA 19137

1. References:

- a. Frankford Arsenal (FA) Customer Service Test conducted at Fort Sill, July-August 1973.
- b. Telecons with Mr. F. Richter, FA, during period June-December 1973.
- c. Letter from FA dated 19 July 1973, to BRL, subject: Customer Service Test of Chronographs, Fort Sill, Oklahoma.
- d. Letter to ARMCOM dated 3 July 1973, subject: Customer Service Test of Chronographs, Fort Sill, Oklahoma

2. As requested by reference 1.c., BRL has analyzed the data of the referenced customer service test using methodology adopted by the U.S. and other NATO nations as the most efficient and unbiased means of estimating and comparing relative chronograph performance when two or more instruments are used to make simultaneous measurements of gun muzzle velocities. STANAG 4114 and ARDC TN 12 (AD732428) provide the rationale for the discussion and results that follow.

3. The data gathered at Fort Sill during this test were presented to the BRL in three different forms. First, the raw velocity observations were given. These velocities simply reflect what numbers were found on the display



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readouts directly from the chronographs themselves. From this set of data, a second set which was corrected for frequency was generated. The third and final set of data that was given to the BRL was a set of "normalized" data. These data were obtained by feeding the chronograph readings corrected for frequency into the FADAC computer and letting the FADAC program routine compute muzzle velocity. This last set of data was used as the basis for all of the performance estimates to follow. It must be pointed out here that one very vital part of the data reduction process was omitted from the test results and this was correction for parallax. Unlike magnetic coils and most sky screens, doppler chronographs typically must be offset from the trajectory to avoid destruction by the shot and also, as in the case where several chronographs are being used at one time, the logistics of chronograph placement caused some to be farther away from the trajectory line than others. The importance of these parallax corrections has already been discussed with FA as well as the vital bearing that they have on our data analysis, however, due to lack of time and complexity in re-reducing all data tapes, BRL was asked to make chronograph estimates based on the normalized data provided. Four different models of chronographs were used in the test. There were two M36 doppler radars (M36-1, M36-2), two General Electric doppler radars (GE-1, GE-2), a Norwegian doppler radar (NM-87) and a Frankford Arsenal doppler radar prototype (XMR).

4. Missing data, maverick readings, and outliers had to be considered in this data analysis since a matrix with entries in every cell was necessary to obtain performance estimates properly.

a. Where a chronograph was turned off, intentionally or unintentionally, and failed to obtain a reading, either the data from all chronographs for that specific round were deleted or consideration of other readings from that same chronograph for that specific weapon/zone/QE were also deleted, thereby maintaining a full matrix of observations.

b. Where maverick readings (obviously extremely far from true) were encountered, these were treated as missing data.

c. The computer program contains an outlier test which is designed to detect values which are statistically not part of the same population in which they are found. Two different

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analyses were performed. The first looked at possible outlying observations within each round fired (i.e., did one chronograph record a significantly different reading than all other chronographs simultaneously looking at the same round). This test was performed on every round from every weapon contained in the service test. The second outlier test looked at possible outliers for each chronograph over each group of projectiles fixed at every initial condition (weapon/zone/QE combination). These tests were performed at the 99 percent level of confidence and data points were deleted only when they were detected as outliers by both tests.

5. Detecting a small constant bias in velocity measurement has always been a problem in chronograph tests. It is for this reason that the BRL, in its letter to ARMCOM on 3 July 1973 suggested that methods independent of doppler radar be used to observe velocity. Methods such as sky screens (optical) or coils (electromagnetic) were suggested as techniques which should also be used in this test since independent detection modes not dependent on doppler radar techniques would minimize the possibility of bias errors remaining undetected. This suggestion was not acted upon due to a number of reasons, and, hence, only the doppler method of velocity observation is common to all six devices. With no independent measurement being available, we must, therefore, assume that the real (unbiased true), velocity falls somewhere midway between all observations of the doppler radars.

6. The measurement related to successive shots, but produced by the same instrument, differs not only by the value of the instrumental error of the chronograph but, also, and often to a considerably greater degree, by the value of the random deviation of the velocity of each successive shell. Hence, traditional analysis of variance techniques could not be applied effectively to determine the accuracy and precision of the instrumentation since projectile velocity is not, in itself, a repeatable phenomenon. The methodology used by BRL takes into account these problems and computes unbiased estimates of random errors of measurement for each chronograph. These estimates are contained in Inclosure 1. Below is a brief summary of some of the terms found in these data.

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"Mean" - simple arithmetic mean

"Variance" - variance of all observations in  
column appearing immediately above  
(except deleted data)

"stnd dev" - standard deviation (square root of  
variance)

"prob err" - .6745 of standard deviation

"grand mean" - mean of all data considered

"average variance" - arithmetic average of variances  
from all instruments considered

"covariance matrix" - included simply as computational  
information

"cov incld inst" - included simply as computational  
information

"cov excld inst" - included simply as computational  
information

\*"est ( $\sigma_{e_1}^2$ )" - unbiased estimate of variance  
in random precision error (est  $\sigma_{e_1}^2$ )

\*"est ( $\sigma_{e_1}$ )" - (est  $\sigma_{e_1}$ )

"precision rank" - a simple numerical ranking of  
size of each precision estimate  
with smallest being ranked 1

"total covariance" - included simply for computational  
information

"parameter variance" - estimate of the real round-to-  
round muzzle velocity variance  
due to propellant and tube  
influences but free of chronograph  
precision errors

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The quantities marked with an asterisk (\*) above occasionally are negative due to the statistical approach used. There is no reason for alarm when these estimates become negative since (a) they are best estimates of precision and because, in some cases, the precisions are very small numerically, the estimates do occasionally fall into the negative region and, (b) these negative numbers are only slightly negative and can be treated as zero. If more information on this is desired, volume 43, pp 243-264 of the June 1948 edition of the journal of the American Statistical Association gives a comprehensive explanation.

7. Chronograph performance is dependent upon many factors including

- a. velocity level being measured,
- b. quadrant elevation (QE) of weapon,
- c. shell cross-sectional area and surface irregularities,
- d. baseline length,
- e. blast and muzzle flash,
- f. weather conditions,
- g. skill of chronograph operators.

Looking at the test in light of each of these factors, we can make the following observations.

a. Although the test encompassed a velocity span of approximate 730 m/s (185 m/s to 915 m/s), a linear least squares fit of precision versus velocity showed significance in the first order term only for the 175mm gun over zones 1, 2 and 3. Other systems generally showed little degradation in precision due to changing velocity levels.

b. Since only one true replication is included (shell, weapon, and zone identical with only QE altered), that being the 105mm howitzer, zone 7, firing both at 1077 and 1093 mils, no conclusive statement can be made. Past studies have shown that doppler radar chronographs are much less affected by elevation change than instruments dependent on optical techniques.

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c. Caliber size did not seem to affect the ability of any chronograph to lock on and measure. The RAP shell which possess a very irregular base which fosters poor reflectivity did cause problems for some of the systems, the 105mm RAP caused erratic behavior patterns for the M36-1 as well as the XMR system. Unfortunately NM87 was turned off during the 105 RAP firing, but the reason for this has not been noted on the data sheets submitted to BRL. Only five (5) 155mm RAP projectiles were fired and of these five shell, no chronograph obtained a reading for every shot. The GE-2 unit and the NM87 obtained readings for four out of these five however, there is no way of determining which unit, if either, was reading precisely. As the result of studying the test plan drawn up by Frankford Arsenal in June, which included a small number of RAP shell to be fired, BRL recommended shortly before the test that "these hollow base shell be part of the test plan since recent tests have shown that radar tracking of these shell is more difficult due to irregularities of reflection from shell base." Since these types of shell will be encountered in the field in increasing numbers in the years just ahead, it is unfortunate that only 24 out of the approximately 800 shell expended in the subject test were from the RAP family.

d. None of the chronograph systems possessed a particularly long or short baseline so no discussion will be made of the effects of baselength.

e. The influence of blast and muzzle flash was a major factor in this test. The 8-inch howitzer, zone 5, white bag, because of its internal ballistic burning behavior, produces a large muzzle flash pattern. Looking at the results of the two occasions fired at this zone, it is immediately obvious that the flash caused serious degradation in the performance of both GE units. Not only were 50 percent of the data lost completely but the other data gathered for the most part were erroneous. The M36 units did not seem to encounter a significant data loss, but their precision errors did increase and were significantly higher than the lower zones measured. The NM87 performance and precision was good for the first data set (rounds 821-840), however, later, under identical conditions with the second set (rounds 881-890), the same unit became erratic. This is not consistent with past performance of the unit and it is suspected that the data omissions in the second data set do not reflect the instrument's true ability and typical behavior. The XMR unit was quite consistent in obtaining readings but,

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in this case, was not as precise as the NM87 ( $\sigma_{eNM87}^2 = .08635$   
vs  $\sigma_{eXMR}^2 = .50673$ ). Although the 175mm gun did not exhibit

the muzzle flash that the 8-inch howitzer, zone 5W, displayed, the blast (shock or overpressure) from the 175mm gun zone 3 was the maximum encountered during the test. The effects of muzzle flash caused sizeable data loss for some chronographs. Blast overpressure, on the other hand, although it caused some random data loss, caused precision to degrade also. The pooled variance in precision error for the M36 and GE systems (the only systems in the 175mm matrix) was approximately 3.4 m/s. The XMR experienced a cracked wave guide as a result of this overpressure.

f. Weather conditions are often a consideration in chronograph operation. No data on prevailing weather was submitted to BRL as part of the data package and since normalization (extrapolation thru prevailing weather) was performed on the data by means of a FADAC computer by Frankford Arsenal, no meaningful comment on weather influences can be made.

g. Operators familiar with their equipment were present at the test site. A total of five trained soldiers were operating the two M36 systems. General Electric had an instrumentation van with two skilled operators highly trained in the usage of their systems. Frankford Arsenal had an instrumentation van which was manned by people familiar with the XMR from its inception. The only system which did not have its own trained crew was the NM87 which is foreign made. This system was mounted on top of an excess M36 tripod. Past results of the NM87 with trained crews and developers operating it showed highly of the NM87 with trained crews and developers operating it showed highly successful and reliable results. ( $\sigma_{e1} \approx .05\% \bar{V}$ ). Hence, the results shown in this

test for the NM87, although not bad, are not necessarily representative of the system's capabilities given a crew with the equivalent familiarity as the other systems used in this test.

8. Inclosure 2 is a summary sheet displaying the precision estimates of all of the systems tested. Two sets of data, 155mm howitzer, zone 7 RAP (rounds 781-785) and the 8-inch

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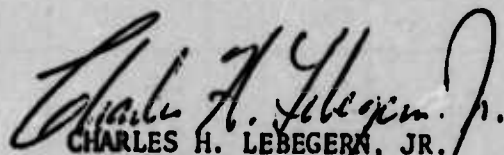
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howitzer, zone 5W (881-890), were not computed since data omissions prevented a large enough data matrix to determine meaningful precision estimates. Overall, no single system possessed a significantly better or worse precision than the others. On the basis of the test data alone, all that can be said concerning precision is that the pooled precision error of all systems for all conditions was held at approximately .15 percent of average velocity. It is unfortunate that the data given to BRL for analyses was not corrected for parallax since, for example, a projectile which is being tracked in a 50 foot gate beginning 25 feet from the gun by a chronograph located four feet laterally from the muzzle could experience velocity errors of the order of .4 percent. If all gating were over the same distance and triggering dependent only on distance for on-off, the errors would only be bias errors which would not affect precision estimates, however, since baselengths vary between chronographs and some have fixed gates in time (M36 and XMR), the precision estimates made are affected by parallax.

9. The summary to accompany this data analysis which will be prepared by Frankford Arsenal will hopefully elaborate on the specific reasons for data omissions throughout the test. The conclusions of the BRL regarding this test is that the data gap problem, i.e., lack of obtaining a reading, was a more serious problem than the precision of the reading itself. In the field application, consistent readings are of vital importance and data gaps regardless of the reason are intolerable.

FOR THE DIRECTOR:

2 Incls  
as

  
CHARLES H. LEBEGERN, JR.  
Chief, Firing Tables Branch  
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RIA, Attn: AMSAR-RDT, Dr. E. J. Haug

APPENDIX D  
 Test Data - Yuma Proving Ground, Yuma, Arizona - 29 March 1974

8 inch RD NO	HOWITZER PROJ	CHARGE	PROJECTOR		DATA REDUCTION		
			NM 87	FA	NM 87	FA	
912	M106	7	12976	564.2 2	621.5 35	621.9 22	
913	M106	9	19294	000.0 99	418.0	—	
914	XM650E3	9	13932	717.9 8	573.8	791.4 28	
915			10155	000.0 99	794.1	—	
916			10558	721.1 2	763.8	794.9 28	
917			13225	716.3 10	442.5	789.6 140	
918			10810	000.0 99	746.0	—	
919			18222	000.0 99	442.5	—	
920			18796	717.9 9	429.0	791.4 126	
921			18377	719.8 2	438.8	793.5 28	
922			14337	000.0 99	562.5	—	
923			10214	723.1 2	789.5	797.1 28	
924			16042	717.7 9	502.7	791.2 126	
925			12303	000.0 99	655.5	—	
926			12524	000.0 99	643.9	—	
927			10461	721.5 2	710.9	795.4 28	
928			18995	000.0 99	424.5	—	
			(A)	(B)	(C)	(D)	(E)
						(F)	(G)
							740329 (YPG)

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## DATA REDUCTION METHODOLOGY

### 1. Legend

- A = NM87 Chronograph Readout ( $.25 \times 10^{-6}$  seconds)  
B = FA Processor Readout (meters/second)  
C = FA Processor Gate Number  
D = NM87 calculated velocity (meters/second)  
E = NM87 Range (35 meters - fixed)  
F = FA Processor calculated velocity (meters/second)  
G = FA Processor Range (meters)

### 2. Sample Calculation: Round Number 912

#### a. NM87

$$\begin{aligned}\text{Velocity} &= \frac{\text{Base length}}{\text{Chronograph readout}} \\ &= \frac{2.016 * 4.0 * 10^{-6}}{\text{Chronograph readout (A)}} \\ &= \frac{8.064 * 10^{-6}}{12976} \\ &= 621.5 \text{ meters/second}\end{aligned}$$

#### b. FA Processor

$$\text{Velocity} = K * \text{FA Processor Readout (B)}$$

where K is the correction factor for the transmitter frequency difference between the NM87 Radar Chronograph Set and the FA Processor<sup>1</sup>

$$\begin{aligned}K &= \frac{10.500}{9525} = 1.10236 \\ \text{Velocity} &= 1.1024 * 564.2 \\ &= 621.9 \text{ meters/second}\end{aligned}$$

$$\text{Range} = \text{Velocity (F)} * \text{Gate Number (C)} * \text{GW}$$

where GW is gate width of FA Processor = .0178 seconds.

$$\begin{aligned}&= 621.9 * 2 * .0178 \\ &= 22 \text{ meters}\end{aligned}$$

<sup>1</sup> The FA Processor was developed by the Systems Development Division at Frankford Arsenal.

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