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A COMPARISON OF UNIT EFFECTS AND UNIT CORRECTIONS AS USED IN THE GUNNERY PROBLEM

by

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May 1969

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MARYLAND

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ABSTRACT

A comparison is made of the range errors obtained in solving fire problems by using (1) unit effects and (2) unit corrections. Results indicate no significant difference in the two methods, but the use of unit corrections does permit much faster solutions.

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I. INTRODUCTION

Current artillery firing tables present unit corrections for the nonstandard conditions of weather and materiel encountered in gunnery problems. In order to determine if the use of unit effects would introduce less range error into the solution of such problems than unit corrections, a comprehensive comparison of the two methods was made.

The distinguishing characteristics of effects and corrections can be easily shown mathematically. In using effects, one is given a scalar valued function, $F(\bar{x})$, where $\bar{x} = \{x_1, x_2, \ldots, x_n\}$. The object then is to find $F(\bar{x}_0) \ni$

$$F(\bar{x}) = F(\bar{x}_0) + \sum_i F_{x_i}\Big|_{\bar{x}_0} \Delta x_i, \quad \text{where } F_{x_i} = \frac{\partial F}{\partial x_i}. \quad \text{The}$$

equation is to be solved iteratively. In using corrections, one is given $F(\bar{x})$ and then solves directly for

$$F(\bar{x}_0) = F(\bar{x}) - \sum_i F_{x_i}\Big|_{\bar{x}} \Delta x_i.$$

Both methods are exact for linear functions and both are approximate otherwise.

For purposes of the study, 3 weapon systems, 2500 fire problems, and 50 sets of nonstandard conditions were utilized. The problems were solved by each of the two methods and the results compared and analyzed.

II. BASIC CONSIDERATIONS

A. Weapon/Charge Combinations

The following weapon/charge combinations were considered:

Weapon	Charges
105mm How., M108	3, 6, 7
155mm How., M109	3, 5, 7, 8
175mm Gun, M107	1, 2, 3

The charges were selected so as to provide a representative sample of the velocity levels for each weapon.

B. Ranges

Fire problems were solved at 5 target ranges per charge, and consisted of 4 at low angles of elevation, from 50 to 650 mils, and 1 at a high angle of 1150 mils.

C. Parameters

In this study, range was considered to be of the form

$$R = F(\Phi, p_1, p_2, p_3, p_4)$$

where Φ is the quadrant elevation and $p_1, \ldots, p_4$ are the parameters muzzle velocity, air density, air temperature, and range wind.

As shown in the following table, the parameters were divided into two groups according to the type of distribution assumed. (Choice of parametric values and the assumptions made relative to their type of distribution were based primarily on data from Honest John Rocket troop firings.) The table also lists applicable means, standard deviations, and bounds.

NORMAL DISTRIBUTION		
PARAMETER	MEAN	STANDARD DEVIATION
Air Density	95.4 % of ICAO Standard (1962)	± 6.6 %
Air Temperature	100.4 % of ICAO Standard (1962)	± 3.0 %
Wind Speed	13.4 Knots	± 9.1 Knots
UNIFORM DISTRIBUTION		
PARAMETER	BOUNDS	
Muzzle Velocity	0 - 100 % Remaining Tube Life	
Wind Direction	0 - 6400 Mils	

Fifty random samples of density, temperature, and wind speed were taken from normally distributed populations based on the above means and standard deviations. The wind speeds were then resolved into range and cross wind components using a random selection of angles from 0 to 6400 mils to determine the azimuth of fire. Finally, 50 random samples of muzzle velocity deviations were computed using tube wear data from the appropriate firing table and assuming a uniform distribution in tube life. All of these values were combined to create 50 distinct sets of data for each weapon. In forming these combinations, the parameters were considered to be independently distributed in accordance with a report by W.G. Dotson.* Lists of the combinations are to be found in Tables I, II, and III.

D. Effects and Corrections

Using the current technique, i.e., the secant-slope method, tables of plus and minus unit effects and unit corrections were computed for each of the weapon/charge combinations.

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* W.G. Dotson, "The Optimization of Unit Effects for Artillery Firing Tables", BRL Report No. 1210 (AD423230), 1963.

Unit effects for each range were generated using the formula:

$$\frac{\Delta R(\Phi, p_1, \ldots, p_4)}{\Delta p_i} = \frac{R(\Phi, p_i \pm \Delta p_i) - R(\Phi, p_1, \ldots, p_4)}{\Delta p_i}, i = 1, 2, 3, \text{or } 4$$

where Δp_i = constant change in parameter p_i along entire trajectory,

$R(\Phi, p_1, \ldots, p_4)$ = standard range,

$R(\Phi, p_i \pm \Delta p_i)$ = range achieved using the standard elevation to hit $R(\Phi, p_1, \ldots, p_4)$ under the perturbation $\pm \Delta p_i$,

$\frac{\Delta R(\Phi, p_1, \ldots, p_4)}{\Delta p_i}$ = unit range effect for p_i at $R(\Phi, p_1, \ldots, p_4)$.

Unit range corrections were computed using the formula:

$$\frac{\Delta R(\Psi, p_i \pm \Delta p_i)}{\Delta p_i} = \frac{R(\Psi, p_1, \ldots, p_4) - R(\Psi, p_i \pm \Delta p_i)}{\Delta p_i}, i = 1, 2, 3 \text{ or } 4$$

where Δp_i = constant change in parameter p_i along entire trajectory,

$R(\Psi, p_i \pm \Delta p_i) = R(\Phi, p_1, \ldots, p_4)$,

$R(\Psi, p_1, \ldots, p_4)$ = range achieved under the standard conditions using the elevation, Ψ, required to hit $R(\Phi, p_1, \ldots, p_4)$ under the perturbation $\pm \Delta p_i$,

$\frac{\Delta R(\Psi, p_i \pm \Delta p_i)}{\Delta p_i}$ = unit range correction for p_i at $R(\Psi, p_i \pm \Delta p_i)$.

Note that $R(\Psi, p_i \pm \Delta p_i) = R(\Phi, p_1, \ldots, p_4)$ is the range to be hit when dealing with unit corrections, whereas $R(\Phi, p_1, \ldots, p_4)$ must be determined if unit effects are being utilized.

The perturbations, Δp_i, used to generate both the unit effects and unit corrections were ± 15 m/s in muzzle velocity, ± 10% in both air density and temperature, and ± 50 knots in range wind.

III. DETERMINATION OF RANGE ERRORS

To determine the range errors resulting from the application of unit effects (corrections), 2500 fire problems were solved using the unit effects (corrections) corresponding to each weapon/charge/range combination and the 50 sets of nonstandard conditions for the appropriate weapon system. The only sources of error in the problems which were unaccounted for were those due to the unit effects (corrections) themselves and to arithmethic. However, arithmetical errors, such as those produced by interpolation and round off, were considered negligible in the final results. In order to solve fire problems using effects, an iterative process was carried on until the appropriate range and quadrant elevation, Φ, were found such that

$$R(\Phi, p_1, \ldots, p_4) + \sum_{i=1}^{4} \frac{\Delta R(\Phi, p_1, \ldots, p_4)}{\Delta p_i} \Delta p_i = R(\Phi, p_i \pm \Delta p_i).$$

Fire problems using corrections were solved in the normal manner

$$R(\Psi, p_i \pm \Delta p_i) + \sum_{i=1}^{4} \frac{\Delta R(\Psi, p_i \pm \Delta p_i)}{\Delta p_i} \Delta p_i = R(\Psi, p_1, \ldots, p_4),$$

where Ψ is the quadrant elevation required to hit the target range under the particular set of nonstandard conditions.

The errors present in unit effects (corrections) were now reflected as errors in predicted quadrant elevations. Thus to find the range errors caused by the use of unit effects (corrections) in solving fire problems, trajectories were computed with these elevations and

nonstandard conditions. The resultant ranges were then subtracted from the target ranges.

A certain number of fire problems were unsolvable because a plus or minus unit correction was not computed near maximum range. Solutions to still others could not be obtained because the predicted range exceeded maximum range for that charge. Finally, problems employing high angle fire had no solution if the maximum angle was exceeded or if a change in the mode of fire, from high angle to low angle, was required. A listing of all of these appears in Table IV.

IV. ANALYSIS OF DATA

For each weapon/charge/range combination, the mean and standard deviation caused by all 50 sets of nonstandard conditions were found. The results are to be seen in Table V.

The above means and standard deviations were then statistically combined with the probable errors in range, described below, to convert the range errors into a corresponding decrease in the percent of rounds falling within plus and minus 1 and plus and minus 2 probable errors. If there were no aiming errors, 50% of all rounds would fall within plus and minus 1 probable error and 82.3% within plus and minus 2 probable errors. Probable errors of .3% and .6% of range were used to describe the round to round dispersion about the target range and a normal distribution of rounds about those ranges was assumed. Tables VI and VII list these percents for all weapon/charge/range combinations.

As noted in Section III, a certain number of fire problems could not be solved. Analysis of the data showed that 35 problems using unit effects had no solution because, as previously stated, the predicted

range exceeded the maximum range for that charge; or, when in high angle fire, the predicted quadrant elevation exceeded the maximum listed elevation; or a change in the mode of fire was required. The use of unit corrections failed to solve 34 of these problems for the same reasons.

Another 54 problems employing unit corrections were unsolvable because they involved ranges beyond those for which the firing table had corrections listed for range wind. There is no comparable deficiency with firing tables presenting unit effects.

This lack of unit corrections only prevents the successful completion of a mission if the top charge is being used. For example, 36 of the 54 fire problems mentioned above were encountered near maximum range in charges 1 and 2 of the 175mm Gun. By using the next higher charge, these missions could have been completed. Only those 18 missions lying in charge 3, the highest charge for this weapon, would have had to have been canceled. A forthcoming report entitled "Standard Conditions for Cannon Artillery Firing Tables" shows that by optimizing the standards used in current firing tables the number of listed ranges near maximum range, which lack unit corrections, can be substantially reduced, and thus permit the solving of more fire problems than is presently possible.

V. SUMMARY OF RESULTS

Weapon	The Percent of Rounds Falling Within Plus and Minus One Probable Error		Two Probable Errors	
	Effects	Corrections	Effects	Corrections
	For a Probable Error Equal to .3% of Range			
105mm	48.28	46.59	80.48	78.65
155mm	46.86	47.45	78.91	79.58
175mm	47.26	47.77	79.37	79.85
	47.41	47.29	79.52	79.38
	For a Probable Error Equal to .6% of Range			
105mm	49.55	49.09	81.81	81.33
155mm	49.15	49.32	81.39	81.57
175mm	49.27	49.37	81.52	81.62
	49.31	49.27	81.56	81.51

Note: If there were no errors caused by using unit effects or unit corrections, then 50% of the rounds would fall within 1 probable error and 82.3% within 2 probable errors.

VI. CONCLUSIONS

1. Examination of the summary of results shows that there is no appreciable difference, in terms of range errors, between those fire problems solved with unit corrections and those solved with unit effects.

2. The adoption of either unit effects or unit corrections should be considered in relation to their use in a manual backup system in the post-1970 time frame. The fact that fire problems can be solved approximately three times faster using corrections rather than effects, because the corrections are listed at a known range (target range), is

a distinct advantage in any such back-up system.

3. The absence of unit corrections near maximum range prevents the solution of fire problems for ranges in this area, if the top charge is being used.

Table I. NONSTANDARD CONDITIONS FOR 105MM HOW., M108

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
97.1	99.8	- .3	- 7.6	1
107.3	99.1	- 2.3	- 1.9	2
88.2	103.1	- 8.7	- 7.4	3
110.1	104.6	- 16.6	- 10.4	4
92.0	96.9	10.6	- 2.0	5
95.7	98.7	.2	- 0.2	6
100.0	107.2	- 13.3	- 2.7	7
92.5	99.6	14.1	- 6.7	8
94.9	101.5	8.8	- 6.8	9
94.8	98.1	2.2	- 0.2	10
99.7	101.9	9.3	- 1.2	11
99.8	99.4	- 18.0	- 5.7	12
91.4	103.2	.5	- 1.8	13
101.9	95.8	19.6	- 4.7	14
87.3	98.9	- 6.1	- 10.1	15
98.0	97.7	3.2	- 9.2	16
78.7	107.2	9.8	- 5.8	17
88.3	99.8	- 2.8	- 1.3	18
102.9	104.7	- 11.3	- 3.0	19
89.9	100.8	- .5	- 4.4	20
94.0	103.1	8.0	- 10.1	21
105.6	102.1	21.5	- 3.4	22
95.0	96.0	1.4	- 7.3	23
84.0	99.8	.3	- 5.9	24
97.2	106.6	- 2.4	- 6.9	25

Table I. NONSTANDARD CONDITIONS FOR 105MM HOW., M108
(Continued)

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
90.8	95.1	18.3	- 1.1	26
86.4	101.2	- 12.5	- 7.8	27
97.4	106.3	- 8.2	- 5.3	28
88.4	102.0	9.6	- 0.6	29
83.9	103.4	6 6	- 9.5	30
97.3	97.1	24.0	- 10.3	31
95.9	95.6	- 1.2	- 2.3	32
98.9	99.6	6.3	- 6.5	33
90.7	99.7	21.1	- 3.7	34
98.9	103.1	2.8	- 1.8	35
99.6	98.9	19.2	- 3.3	36
94.5	99.6	- 16.6	- 9.1	37
88.3	99.6	9.2	- 5.2	38
97.0	102.3	2.1	- 0.7	39
88.3	100.6	3.1	- 6.0	40
95.1	100.6	.5	- 6.8	41
96.7	94.1	- 6.8	- 2.1	42
88.8	101.2	1.2	- 2.3	43
93.5	100.8	- 11.0	- 9.7	44
98.1	101.4	.8	- 7.8	45
87.3	101.2	- 11.2	- 1.2	46
91.4	99.8	7.4	- 1.8	47
92.3	103.2	24.8	- 7.7	48
94.6	95.3	7.4	- 1.1	49
88.7	100.3	- 17.2	- 6.6	50

Table II. NONSTANDARD CONDITIONS FOR 155MM HOW., M109

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
97.1	99.8	- .3	- 13.6	1
107.3	99.1	- 2.3	- 5.7	2
88.2	103.1	- 8.7	- 13.5	3
110.1	104.6	- 16.6	- 16.2	4
92.0	96.9	10.6	- 6.1	5
95.7	98.7	.2	- 1.2	6
100.0	107.2	- 13.3	- 7.5	7
92.5	99.6	14.1	- 12.6	8
94.9	101.5	8.8	- 12.9	9
94.8	98.1	2.2	- 1.0	10
99.7	101.9	9.3	- 4.3	11
99.8	99.4	- 18.0	- 11.6	12
91.4	103.2	.5	- 5.6	13
101.9	95.8	19.6	- 10.2	14
87.3	98.9	- 6.1	- 16.1	15
98.0	97.7	3.2	- 15.4	16
78.7	107.2	9.8	- 11.6	17
88.3	99.8	- 2.8	- 4.4	18
102.9	104.7	- 11.3	- 8.0	19
89.9	100.8	- .5	- 9.8	20
94.0	103.1	8.0	- 16.0	21
105.6	102.1	21.5	- 8.6	22
95.0	96.0	1.4	- 13.4	23
84.0	99.8	.3	- 11.8	24
97.2	106.6	- 2.4	- 12.9	25

Table II. NONSTANDARD CONDITIONS FOR 155MM HOW., M109
(Continued)

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
90.8	95.1	18.3	- 3.2	26
86.4	101.2	- 12.5	- 13.8	27
97.4	106.3	- 8.2	- 11.0	28
88.4	102.0	9.6	- 2.2	29
83.9	103.4	6.6	- 15.5	30
97.3	97.1	24.0	- 16.2	31
95.9	95.6	- 1.2	- 7.0	32
98.9	99.6	6.3	- 12.5	33
90.7	99.7	21.1	- 9.0	34
98.9	103.1	2.8	- 5.6	35
99.6	98.9	19.2	- 8.4	36
94.5	99.6	- 16.6	- 15.2	37
88.3	99.6	9.2	- 10.9	38
97.0	102.3	2.1	- 2.4	39
88.3	100.6	3.1	- 12.0	40
95.1	100.6	.5	- 12.8	41
96.7	94.1	- 6.8	- 6.5	42
88.8	101.2	1.2	- 6.9	43
93.5	100.8	- 11.0	- 15.7	44
98.1	101.4	.8	- 13.8	45
87.3	101.2	- 11.2	- 4.2	46
91.4	99.8	7.4	- 5.5	47
92.3	103.2	24.8	- 13.7	48
94.6	95.3	7.4	- 4.1	49
88.7	100.3	- 17.2	- 12.6	50

Table III. NONSTANDARD CONDITIONS FOR 175MM GUN, M107

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
97.1	99.8	- .3	- 16.8	1
107.3	99.1	- 2.3	- 0.1	2
88.2	103.1	- 8.7	- 16.3	3
110.1	104.6	- 16.6	- 19.4	4
92.0	96.9	10.6	- 0.1	5
95.7	98.7	.2	- 0.0	6
100.0	107.2	- 13.3	- 0.3	7
92.5	99.6	14.1	- 11.6	8
94.9	101.5	8.8	- 12.3	9
94.8	98.1	2.2	- 0.0	10
99.7	101.9	9.3	- 0.1	11
99.8	99.4	- 18.0	- 7.5	12
91.4	103.2	.5	- 0.1	13
101.9	95.8	19.6	- 3.3	14
87.3	98.9	- 6.1	- 19.1	15
98.0	97.7	3.2	- 17.9	16
78.7	107.2	9.8	- 7.6	17
88.3	99.8	- 2.8	- 0.1	18
102.9	104.7	- 11.3	- 0.6	19
89.9	100.8	- .5	- 2.3	20
94.0	103.1	8.0	- 19.1	21
105.6	102.1	21.5	- 0.9	22
95.0	96.0	1.4	- 16.0	23
84.0	99.8	.3	- 8.4	24
97.2	106.6	- 2.4	- 12.4	25

Table III. NONSTANDARD CONDITIONS FOR 175MM GUN, M107
(Continued)

DENSITY %	TEMPERATURE %	RANGE WIND knots	MUZZLE VELOCITY m/s	NO.
90.8	95.1	18.3	- 0.0	26
86.4	101.2	- 12.5	- 17.2	27
97.4	106.3	- 8.2	- 5.6	28
88.4	102.0	9.6	- 0.0	29
83.9	103.4	6.6	- 18.2	30
97.3	97.1	24.0	- 19.3	31
95.9	95.6	- 1.2	- 0.1	32
98.9	99.6	6.3	- 10.7	33
90.7	99.7	21.1	- 1.1	34
98.9	103.1	2.8	- 0.1	35
99.6	98.9	19.2	- 0.8	36
94.5	99.6	- 16.6	- 17.7	37
88.3	99.6	9.2	- 5.3	38
97.0	102.3	2.1	- 0.0	39
88.3	100.6	3.1	- 8.6	40
95.1	100.6	.5	- 12.2	41
96.7	94.1	- 6.8	- 0.1	42
88.8	101.2	1.2	- 0.1	43
93.5	100.8	- 11.0	- 18.6	44
98.1	101.4	.8	- 17.3	45
87.3	101.2	- 11.2	- 0.1	46
91.4	99.8	7.4	- 0.1	47
92.3	103.2	24.8	- 16.9	48
94.6	95.3	7.4	- 0.1	49
88.7	100.3	- 17.2	- 11.2	50

Table IV

Wpn	Chg	Range Meters	Number of Fire Problems Which Could Not Be Solved			
			Group A		Group B	
			Effects	Corrections	Effects	Corrections
105mm	7	8200	1			
155mm	3	5800	3	3		
	8	16900	1	1		18
175mm	1	14300	1	1		18
	1	12600	1	1		
	2	20900	1	1		18
	2	19100	12	12		
	3	30200	1	1		
	3	30000	14	14		

NOTE: Group A includes those fire problems which could not be solved because the predicted range exceeded maximum range, the predicted elevation exceeded maximum elevation, or the mode of fire required changing.

Group B includes those fire problems which could not be solved because a plus or minus unit correction was lacking at the required range.

Table V

Wpn	Chg	Range Meters	Mean Range Error In Meters		Standard Deviation In Meters		No. of Cases
			Effects	Corrections	Effects	Corrections	
105mm	3	1300	- .890	2.574	.832	1.310	50
		2600	- 1.286	5.568	1.804	2.548	50
		3900	- 2.822	8.702	3.664	4.483	50
		4000	- 2.660	9.070	3.781	4.720	50
		3900	- 3.274	7.420	5.669	4.480	50
	6	2400	- 4.634	- 2.118	2.819	2.390	50
		4800	- 7.520	.114	4.055	5.501	50
		7200	- 6.818	5.544	4.418	9.992	50
		8000	- 6.792	6.832	4.896	11.716	50
		6800	- 1.082	6.758	7.201	10.312	50
	7	2900	- .892	1.318	1.792	1.899	50
		5800	- 6.964	- 1.296	4.738	7.367	50
		8600	- 8.420	4.070	5.869	13.678	50
		10400	- 8.102	9.462	7.569	20.702	50
		8200	- 4.159	4.490	7.353	10.624	49

Table V (Continued)

Wpn	Chg	Range Meters	Mean Range Error In Meters		Standard Deviation In Meters		No. of Cases
			Effects	Corrections	Effects	Corrections	
155mm	3	1600	- 1.224	1.804	1.005	1.630	50
		3200	- 2.956	4.914	3.203	2.933	50
		4800	- 5.286	7.076	6.326	5.178	50
		5800	- 6.377	13.232	8.229	5.761	47
		4500	- 5.502	6.608	9.191	4.973	50
	5	2500	- 7.374	- 4.124	4.708	5.796	50
		5000	-10.012	- .478	5.865	6.489	50
		7500	-10.366	4.822	7.680	7.456	50
		9000	-10.660	7.786	10.788	10.271	50
		7000	- 6.458	5.028	12.961	9.780	50
	7	3600	- 2.874	1.476	2.768	2.752	50
		7300	-10.366	- 1.664	8.245	7.504	50
		11000	-14.320	2.578	10.481	15.009	50
		13200	-14.994	9.272	12.857	22.826	50
		10200	-10.562	3.158	13.789	11.870	50
	8	4500	- .048	3.872	2.396	4.016	50
		9000	- 9.804	2.148	8.755	9.237	50
		13500	-16.418	.466	14.746	19.930	50
		16900	-15.631	9.934	17.286	26.529	31
		16900	-15.253*	-	15.573*	-	49
		15400	-17.010	1.220	22.114	14.084	50

*NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

Table V (Continued)

Wpn	Chg	Range Meters	Mean Range Error In Meters		Standard Deviation In Meters		No. of Cases
			Effects	Corrections	Effects	Corrections	
175mm	1	3800	- 2.356	.974	2.731	3.302	50
		7600	-10.184	- 3.050	10.742	6.484	50
		11300	-14.946	- 2.054	14.109	13.591	50
		14300	-15.955	1.632	13.615	17.808	31
		14300	-15.059*	-	13.676*	-	49
		12600	-10.478	3.355	18.644	11.582	49
	2	5500	- 1.016	2.028	3.333	4.120	50
		11100	- 7.632	4.470	10.376	13.155	50
		16600	-21.102	- 4.874	23.545	23.766	50
		20900	-22.574	- 3.326	25.689	34.375	31
		20900	-20.569*	-	24.483*	-	49
		19100	-26.124	.795	31.537	19.597	38
	3	8200	- 3.440	.940	6.321	5.328	50
		16400	- 9.908	4.718	15.786	20.907	50
		24500	-22.776	9.132	45.063	50.196	50
		30200	-42.884	56.153	52.852	96.151	49
		30000	-52.267	20.483	36.719	41.463	36

* NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

Table VI

Wpn	Chg	Range Meters	For a Probable Error Equal to .3% of Range The Percent of Rounds Falling within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
105mm	3	1300	49.07	45.11	81.31	77.09
		2600	49.23	44.53	81.48	76.46
		3900	48.54	43.90	80.76	75.74
		4000	48.61	43.71	80.83	75.52
		3900	47.19	45.15	79.30	77.11
	6	2400	45.00	48.17	76.95	80.37
		4800	46.77	48.63	78.89	80.86
		7200	48.66	47.47	80.89	79.61
		8000	48.84	47.14	81.08	79.25
		6800	48.80	46.76	81.03	78.83
	7	2900	49.49	49.32	81.75	81.58
		5800	47.82	48.29	80.01	80.49
		8600	48.51	47.26	80.73	79.37
		10400	48.80	45.48	81.04	77.38
		8200	48.89	47.98	81.12	80.16

Table VI (Continued)

Wpn	Chg	Range Meters	For a Probable Error Equal to .3% of Range The Percent of Rounds Falling within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
155mm	3	1600	48.96	47.63	81.21	79.80
		3200	48.09	46.75	80.28	78.87
		4800	47.05	46.64	79.16	78.74
		5800	46.81	43.94	78.89	75.81
		4500	44.76	46.61	76.55	78.70
	5	2500	39.52	42.92	70.42	74.35
		5000	44.74	48.26	76.66	80.46
		7500	47.00	48.54	79.13	80.76
		9000	47.14	47.90	79.27	80.08
		7000	45.91	47.52	77.87	79.66
	7	3600	48.71	49.20	80.94	81.45
		7300	46.70	48.84	78.79	81.07
		11000	47.34	48.04	79.50	80.23
		13200	47.70	46.60	79.88	78.64
		10200	47.10	48.50	79.21	80.71
	8	4500	49.70	48.40	81.96	80.62
		9000	47.81	48.84	79.99	81.07
		13500	47.29	47.79	79.43	79.96
		16900	48.04	47.20	80.23	79.32
		16900	48.28*	-	80.48*	-
		15400	46.75	49.11	78.83	81.35

*NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

Table VI (Continued)

Wpn	Chg	Range Meters	For a Probable Error Equal to .3% of Range The Percent of Rounds Falling Within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
175mm	1	3800	49.05	49.13	81.29	81.38
		7600	46.28	49.06	78.31	81.31
		11300	46.70	48.47	78.79	80.68
		14300	47.79	48.39	79.97	80.59
		14300	47.92*	-	80.10*	-
		12600	47.13	49.04	79.24	81.28
	2	5500	49.57	49.26	81.83	81.51
		11100	48.60	48.38	80.82	80.59
		16600	46.43	47.83	78.48	80.00
		20900	47.30	47.28	79.44	79.40
		20900	47.62*	-	79.78*	-
		19100	45.60	48.90	77.53	81.13
	3	8200	49.19	49.54	81.43	81.79
		16400	48.65	48.25	80.88	80.44
		24500	45.93	45.87	77.90	77.82
		30200	45.20	39.54	77.07	70.01
		30000	45.55	47.60	77.53	79.75

*NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

Table VII

Wpn	Chg	Range Meters	For a Probable Error Equal to .6% of Range The Percent of Rounds Falling Within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
105mm	3	1300	49.76	48.69	82.03	80.93
		2600	49.80	48.53	82.07	80.76
		3900	49.62	48.34	81.88	80.57
		4000	49.64	48.28	81.90	80.50
		3900	49.25	48.70	81.50	80.93
	6	2400	48.65	49.53	80.88	81.78
		4800	49.16	49.65	81.40	81.91
		7200	49.66	49.33	81.92	81.58
		8000	49.71	49.24	81.97	81.49
		6800	49.69	49.13	81.95	81.38
	7	2900	49.87	49.83	82.14	82.09
		5800	49.44	49.56	81.69	81.81
		8600	49.62	49.27	81.88	81.52
		10400	49.69	48.75	81.96	80.98
		8200	49.72	49.47	81.98	81.73

Table VII (Continued)

Wpn	Chg	Range Meters	For a Probable Error Equal to .6% of Range The Percent of Rounds Falling Within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
155mm	3	1600	49.74	49.38	82.00	81.64
		3200	49.50	49.15	81.76	81.40
		4800	49.22	49.11	81.47	81.36
		5800	49.15	48.37	81.39	80.59
		4500	48.53	49.10	80.75	81.35
	5	2500	46.89	47.93	79.01	80.11
		5000	48.58	49.55	80.81	81.81
		7500	49.21	49.62	81.46	81.88
		9000	49.25	49.45	81.50	81.71
		7000	48.88	49.34	81.11	81.60
	7	3600	49.67	49.80	81.93	82.06
		7300	49.13	49.70	81.37	81.96
		11000	49.31	49.49	81.56	81.75
		13200	49.40	49.08	81.66	81.32
		10200	49.23	49.61	81.48	81.87
	8	4500	49.92	49.59	82.19	81.85
		9000	49.43	49.70	81.69	81.96
		13500	49.29	49.42	81.54	81.67
		16900	49.49	49.26	81.75	81.50
		16900	49.55*	-	81.81*	-
		15400	49.13	49.77	81.38	82.04

*NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

Table VII (Continued)

Wpn	Chg	Range Meters	For a Probable Error Equal to .6% of Range The Percent of Rounds Falling within Plus and Minus			
			One Probable Error		Two Probable Errors	
			Effects	Corrections	Effects	Corrections
175mm	1	3800	49.76	49.78	82.02	82.04
		7600	49.00	49.76	81.24	82.02
		11300	49.12	49.60	81.37	81.86
		14300	49.43	49.58	81.68	81.84
		14300	49.46*	-	81.72*	-
		12600	49.24	49.75	81.49	82.02
	2	5500	49.89	49.81	82.16	82.08
		11100	49.64	49.58	81.90	81.84
		16600	49.04	49.43	81.28	81.69
		20900	49.29	49.28	81.54	81.53
		20900	49.38*	-	81.63*	-
		19100	48.79	49.72	81.03	81.98
	3	8200	49.79	49.88	82.06	82.15
		16400	49.65	49.54	81.91	81.80
		24500	48.89	48.87	81.12	81.10
		30200	48.67	46.67	80.90	78.72
		30000	48.80	49.37	81.04	81.62

*NOTE: Includes data for 18 additional fire problems that were solved using unit effects.

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13. ABSTRACT

A comparison is made of the range errors obtained in solving fire problems by using (1) unit effects and (2) unit corrections. Results indicate no significant difference in the two methods, but the use of unit corrections does permit much faster solutions.

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