TECHNICAL REPORT

MEMORANDUM REPORT

M61-30-1

SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL

by

Ira I. Goldberg
and
S. Sorin

Ordnance Project TW-407
DA Project 5W13-02-062

May 1961

REPORT M61-30-1

FRANKFORD ARSENAL

338 000

PHILADELPHIA 37, PA

Requests for copies are to be made to ASTIA (Armed Services Technical Information Agency).

Frankford Arsenal
Philadelphia 37, Pa.

Memorandum Report M61-30-1
May 1961
Ord Proj TW-407
DA Proj 5W13-02-062

SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL

Prepared by: Ira I. Goldberg
IRA I. GOLDBERG
Electronics Engineer

S. Sorin
S. SORIN
Systems Engineer

Reviewed by: E. Roffman
E. ROFFMAN
Chief, Electronics Branch

W. Sperling
W. SPERLING
Chief, Development Engineering Branch

Approved by: John J Cummings
JOHN J. CUMMINGS
Chief, Engineering Support Division

W. T. Abell
W. T. ABELL
Chief, Fire Control Division
Research and Development Group

ABSTRACT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (CONT'D)

INTRODUCTION

The lack of accurate meteorological information over a battle theater was not, until recently, of particularly great significance for tank warfare. The reason for this was that errors affecting tank gunfire from sources other than surface winds were of such magnitude as to overshadow this effect. However, recent technological advances in the field of fire control and armament have resulted in a sharp reduction of some of the major sources of gunnery errors. Consequently, errors introduced by failure to correct for crosswind have assumed relatively large importance, and have become one of the limiting factors in tank gunnery accuracy.

The problem of obtaining accurate surface wind data applicable to tank operations is not a simple task and to date has not been satisfactorily resolved. The complexities and uncertainties of predicting surface winds due to the many factors affecting their behavior has made a theoretical approach to the subject extremely complex and difficult. To date currently available methods of surface wind measurement are totally inadequate because of the extreme variability of surface winds and the need for obtaining the velocity along the projectile trajectory.

A method for reducing surface wind information, whenever a satisfactory system of wind measurement is developed, to a wind component (crosswind) perpendicular to the gun tube is suggested in this report. This method will always yield the crosswind component regardless of surface wind shifts, tank maneuvers or turret rotation.

In the following discussion, the effect of surface wind correction in the improvement of tank gunnery accuracy is shown; an attempt to focus attention and generate greater appreciation for the difficulties involved in analyzing surface wind behavior is made; and a method for determining crosswind relative to the gun tube is presented.

DISCUSSION

A. Effect of Crosswind on Tank Gunnery Accuracy

Errors affecting tank gunfire accuracy may be classified into three general categories (Reference 1):

1. Fixed Biases
2. Variable Biases
3. Random Errors

Fixed biases of a weapons system are those considered constant at a given target range. They are fixed by system design and operational use, and comprise drift, inherent fire control design characteristics, jump, and parallax. Drift bias is due to differences between drift at target range for projectile used and the drift at zeroing range of the zeroing projectile. Inherent fire control system design characteristic errors are the biases introduced into the system because of design compromises, such as for system simplicity, low cost, etc. Jump bias is due to differences in mean jumps between the zeroing projectiles and projectiles fired for effect. Parallax bias results from the offset between gun tube and the optical axis of the direct fire sight.

Variable biases of a weapons system are those which may be considered constant during the firing of a single shot group, but which may vary considerably from group to group, or from occasion to occasion. These include cant, fire control non-repeatability, jump variation, crosswinds, and zeroing. Cant errors will occur when a tank does not fire from a level position and has no means for compensating for these errors. Fire control non-repeatability, as the name indicates, is a measure of the non-repeatability of the fire control system. Jump variations are caused by day to day variations in jump. Crosswind errors are introduced by occasion to occasion variation in mean crosswind velocity. This differs from wind gustiness which contributes to round to round dispersion. Zeroing errors arise from the variability of group center of impact due to the fact that the zeroing center of impact must be estimated from a definite number of rounds, variability of observation of center of impact (crew must observe C.I. from firing position), and effect upon zeroing of the variability of cant, jump, fire control characteristics, and crosswind.

Random errors of a weapons system are those which vary in magnitude and direction from round to round during the firing of a single shot group or during a single firing occasion. These include round to round impact variations within a shot group and random variations in laying the gun.

The effectiveness of a weapons system may be represented by its percentage of first round hit probability. This is a measure of hit performance which may be achieved by a weapons system and, therefore, can be used to measure its effectiveness.

The percentage of first round hit probability for a specific type of ammunition, at a specified range, can be computed for a particular weapons system by taking into account the individual contribution of the errors mentioned above. Thus, if the individual contribution of each source of error is known, the percentage of first round hit probability is $P_T = P_H \times P_V$, where P_H is the horizontal component of the percentage of first round hit probability, and P_V is the vertical component of the percentage of first round hit probability. The horizontal component, P_H, can be computed by obtaining the square root of the sum of the squares of the individual errors. Then, assuming a Gaussian distribution and using known target dimensions, $P_H = 2A_{th}$, where A_{th} is obtained by consulting a normal probability table, and is the value corresponding to $t_h = L \pm C.I./\sigma$. C.I. is the center of impact in mils; L the value in mils, corresponding to half the target width at the specified range; and σ is the square root of the sum of the squares of the individual error contributions in mils. The vertical component of the percentage of first round hit probability can be computed in a similar manner.

There are three types of test conditions to be considered in evaluating the effectiveness of a weapons system (Reference 1). These are:

1. Idealized Test Conditions
2. User Test Conditions
3. Quasi-Combat Test Conditions

Idealized test condition tests are performed under specific, rigidly controlled conditions, and the standard deviation of the wind velocity assumed here is 3.3 ft/sec, which is that of a relatively calm day. User test condition tests are conducted under prevalent average proving ground test conditions. It is, therefore, assumed that weather conditions are those for average proving ground firings, or 6.5 ft/sec for wind velocity standard deviation. Quasi-Combat Test conditions are tests which are conducted, as far as possible, under simulated combat conditions. A variety of weather conditions may, therefore, be encountered, and a standard deviation for wind velocity of 11.0 ft/sec is assumed.

Because of recent technological advances, other errors in tank fire control systems have been reduced to the point where the relative error introduced by crosswind has become considerable. In order to show this effect, a comparison is made here between first round hit probabilities obtained with crosswind corrected and uncorrected for the 90mm gun, Tank M48. The test conditions used are those for Quasi-Combat Test conditions. These conditions reflect to a greater degree actual possible combat conditions and, for this reason, were chosen for this comparison. Tables I, II and III, and figures 1, 2 and 3 show the comparison between corrected and uncorrected crosswind data for three different velocity ammunitions, using two different types of range finders, the M13 and the T57. Computations were based on a system having a full solution computer, a muzzle boresight device, and a muzzle velocity correction device. It can reasonably be expected that such a sophisticated system would also have a wind correction device if it were available.

It is realized that the relative improvement in system effectiveness due to crosswind correction will depend upon the system components and the values assumed for the errors. However, the increases in first round hit probability given here may be considered as general illustrations of the improvement to be expected if crosswind correction is introduced.

Table IV and figure 4 show the percent improvement to be expected in first round hit probability with each different velocity ammunition. This data shows that beyond the range of 1,000 yards, the percent improvement in first round hit probability is considerable, especially at 2,000 and 2,500 yards. Table IV and figure 4 also show that although the absolute increase in hit probabilities at the longer ranges is 15 percent (3825 ft/sec ammunition at 2000 yds), the percent improvement in first round hit probability is as high as 47 percent (absolute improvement 10 percent) for 2,400 ft/sec ammunition at 2,500 yards. This data also shows that the improvement is not only dependent on projectile time of flight, but also on muzzle velocity. The error contributed by crosswind is computed below (Reference 1):

$$CW = 1000\sigma_w/3R \left| t - 3R/V_{oa} \right|, \text{ where}$$

CW = standard deviation of crosswind error in mils

R = range in yards

σ_w = standard deviation of the crosswind velocity in ft/sec

t = projectile time of flight in seconds

V_{oa} = muzzle velocity in ft/sec

From Table IV and figure 4 it can be noticed that the percent improvement in first round hit probability, due to crosswind correction, is greatest for the 2,400 ft/sec ammunition, for the 3,825 ft/sec ammunition next, and for the 3,000 ft/sec ammunition least. From the above formula it can be seen that at any particular range, the standard deviation of the crosswind error, CW, varies with different speed ammunitions because of variations in time of flight, (t), and in muzzle velocity, (V_{oa}), as expressed in $t - \frac{3R}{V_{oa}}$. The value of $t - 3R/V_{oa}$ is relatively large for low velocity ammunitions. As the speed of ammunition is increased this quantity will decrease to a minimum value, and then increase with increasing ammunition velocity because of the interrelationship of time of flight, t, and the term $\frac{3R}{V_{oa}}$ which depends on muzzle velocity, V_{oa}. For the lower velocity ammunitions the time of flight increases faster than $\frac{3R}{V_{oa}}$ so that the quantity $t - \frac{3R}{V_{oa}}$ is large. At very high ammunition velocities the time of flight is small, but the smallness of $\frac{3R}{V_{oa}}$ causes $t - \frac{3R}{V_{oa}}$ to be larger than at some intermediate values of ammunition velocity. This then, explains why there is a greater improvement in first round hit probability with 3,825 ft/sec ammunition than with the 3,000 ft/sec ammunition. It can be seen, therefore, that crosswind correction is particularly important for very low and very high velocity ammunitions.

The order of accuracy required to measure the crosswind velocity is shown in Table V and figure 5. They show the percentage of first round hit probability with a crosswind of 7.5 miles per hour (Quasi-Combat Test Conditions) entirely corrected (no crosswind error), and the degradation in first round hit probability for an error of 1/2 mile per hour and of 1 mile per hour in crosswind velocity measurement. An uncorrected crosswind curve is also given for comparison. The 2,400 ft/sec ammunition data was chosen because it showed the largest

Table I. COMPARISON OF FIRST ROUND HIT PROBABILITY FOR CROSSWIND CORRECTED AND UNCORRECTED DATA (M13 AND T57 RANGE FINDERS)

First Round Hit Probability (in percent)
MV = 2,400 ft/sec

Range in Yards	First Rd. Hit Prob. Crosswind Corrected	First Rd. Hit Prob. Crosswind Not Corrected	Improvement in % 1st Rd. Hit Probability $\frac{\text{COR-UNCOR}}{\text{COR}} \times 100$	Improvement in % 1st Rd. Hit Probability COR-UNCOR
		M13 - Range Finder		
500	98.2	97.6	.6	.6
1000	89.7	84.0	6.4	5.7
1500	68.7	55.8	18.8	12.9
2000	41.9	27.7	33.9	14.2
2500	21.5	11.4	47.0	10.1
		T57 - Range Finder		
500	96.2	95.6	.6	.6
1000	76.7	71.9	6.3	4.8
1500	45.1	37.7	16.4	7.4
2000	19.1	14.0	26.7	5.1
2500	8.4	5.2	38.1	3.2

Table II. COMPARISON OF FIRST ROUND HIT PROBABILITY FOR CROSSWIND CORRECTED AND UNCORRECTED DATA (M13 AND T57 RANGE FINDERS)

First Round Hit Probability (in percent)
MV = 3,000 ft/sec

Range in Yards	First Rd. Hit Prob. Crosswind Corrected	First Rd. Hit Prob. Crosswind Not Corrected	Improvement in % 1st Rd. Hit Probability $\frac{\text{COR-UNCOR}}{\text{COR}} \times 100$	Improvement in % 1st Rd. Hit Probability COR-UNCOR
		M13 - Range Finder		
500	98.4	98.0	.4	.4
1000	91.5	88.1	3.7	3.4
1500	75.4	66.0	12.5	9.4
2000	53.4	41.3	22.7	12.1
2500	32.9	22.3	32.2	10.6
		T57 - Range Finder		
500	96.6	96.2	.4	.4
1000	80.2	76.9	4.1	3.3
1500	53.8	47.7	11.3	6.1
2000	29.9	24.2	19.1	5.7
2500	15.2	11.1	27.0	4.1

Table III. COMPARISON OF FIRST ROUND HIT PROBABILITY FOR CROSSWIND CORRECTED AND UNCORRECTED DATA (M13 AND T57 RANGE FINDERS)

First Round Hit Probability (in percent)
MV = 3,825 ft/sec

Range in Yards	First Rd. Hit Prob. Crosswind Corrected	First Rd. Hit Prob. Crosswind Not Corrected	Improvement in % 1st Rd. Hit Probability $\frac{\text{COR-UNCOR}}{\text{COR}} \times 100$	Improvement in % 1st Rd. Hit Probability COR-UNCOR
		M13 - Range Finder		
500	98.2	97.7	.5	.5
1000	90.1	85.3	5.3	4.8
1500	73.4	62.0	15.5	11.4
2000	52.0	36.5	29.8	15.5
2500	34.0	19.6	42.4	14.4
		T57 - Range Finder		
500	96.4	96.0	.4	.4
1000	78.8	74.7	5.2	4.1
1500	54.3	46.8	13.8	7.5
2000	31.3	23.8	24.0	7.5
2500	16.6	10.7	35.5	5.9

Table IV. IMPROVEMENT IN FIRST ROUND HIT PROBABILITY DUE TO CROSSWIND CORRECTION (M13 AND T57 RANGE FINDERS)

Muzzle Velocity ft/sec	(Range (in yards) 500 %	500 Δ	1000 %	1000 Δ	1500 %	1500 Δ	2000 %	2000 Δ	2500 %	2500 Δ
M13 - Range Finder										
2400	.6	.6	6.4	5.7	18.8	12.9	33.9	14.2	47.0	10.1
3000	.4	.4	3.7	3.4	12.5	9.4	22.7	12.1	32.2	10.6
3825	.5	.5	5.3	4.8	15.5	11.4	29.8	15.5	42.4	14.4
T57 - Range Finder										
2400	.6	.6	6.3	4.8	16.4	7.4	26.7	5.1	38.1	3.2
3000	.4	.4	4.1	3.3	11.3	6.1	19.1	5.7	27.0	4.1
3825	.4	.4	5.2	4.1	13.8	7.5	24.0	7.5	35.5	5.9

$$\%\ \text{Improvement (or Degradation)} = 100 \times \frac{\text{First Rd Hit Prob, Crosswind Cor - First Rd Hit Prob, No Crosswind Cor}}{\text{First Rd Hit Prob, Crosswind Cor}}$$

Δ = First Rd Hit Prob, Crosswind Cor - First Rd Hit Prob, No Crosswind Cor

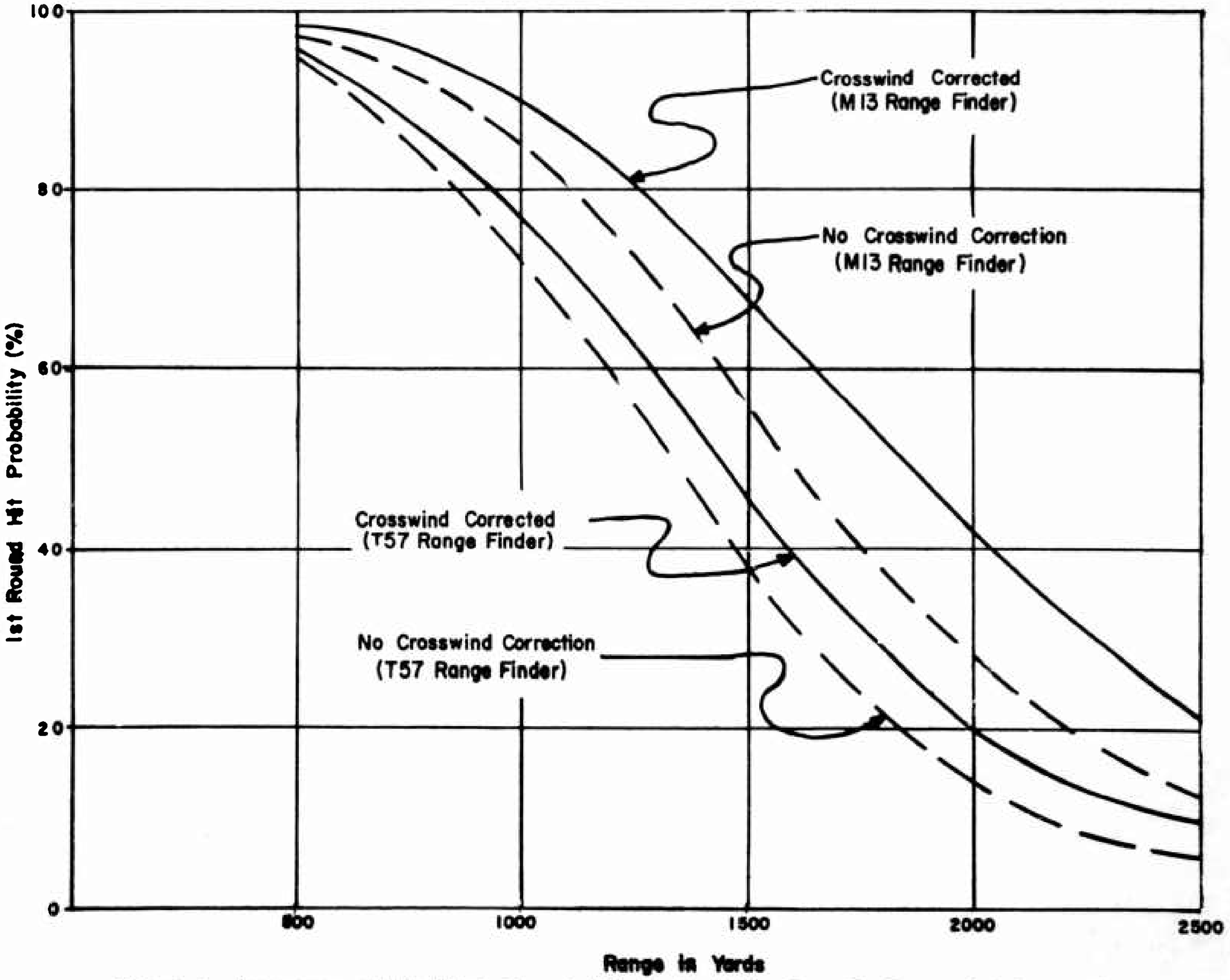


Figure I. Improvement In First Round Hit Probability Due To Crosswind Correction (M13 And T57 Range Finders) Muzzle Velocity = 2,400 ft/sec.

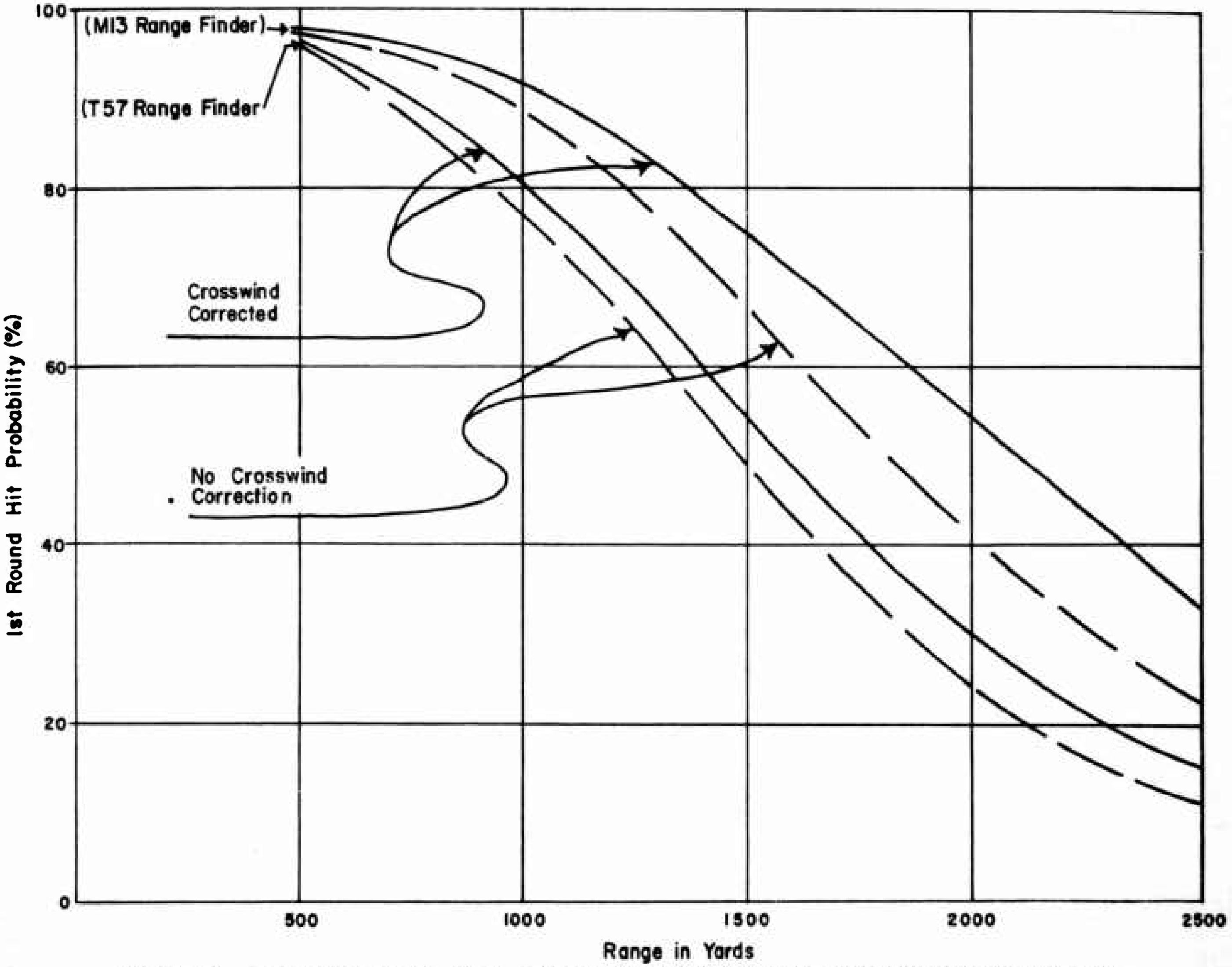


Figure 2. Improvement In First Round Hit Probability Due To Crosswind Correction (M13 And T57 Range Finders) Muzzle Velocity = 3,000 ft/sec.

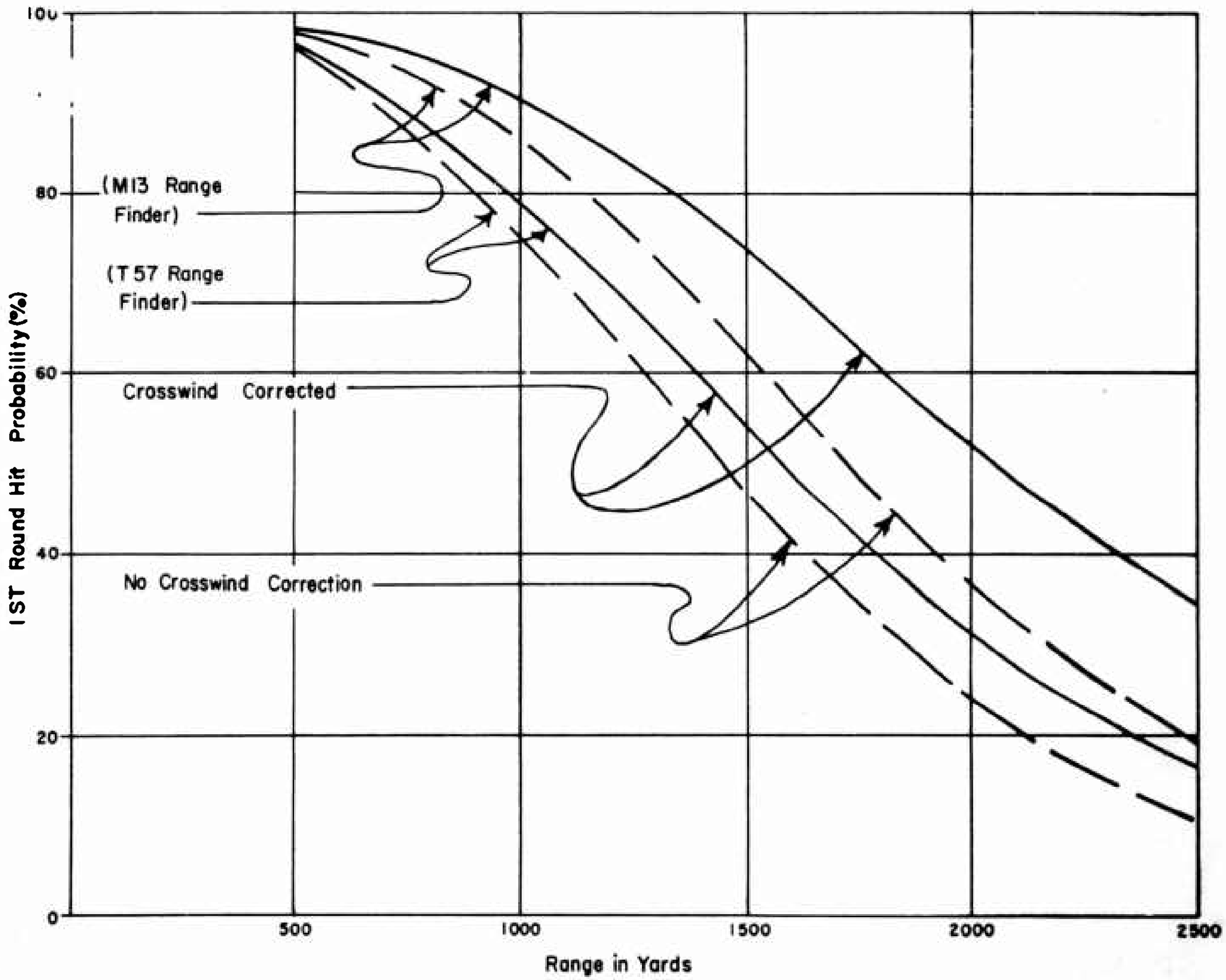


Figure 3. Improvement In First Round Hit Probability Due To Crosswind Correction (M13 And T57 Range Finders) Muzzle Velocity= 3,825 ft/sec.

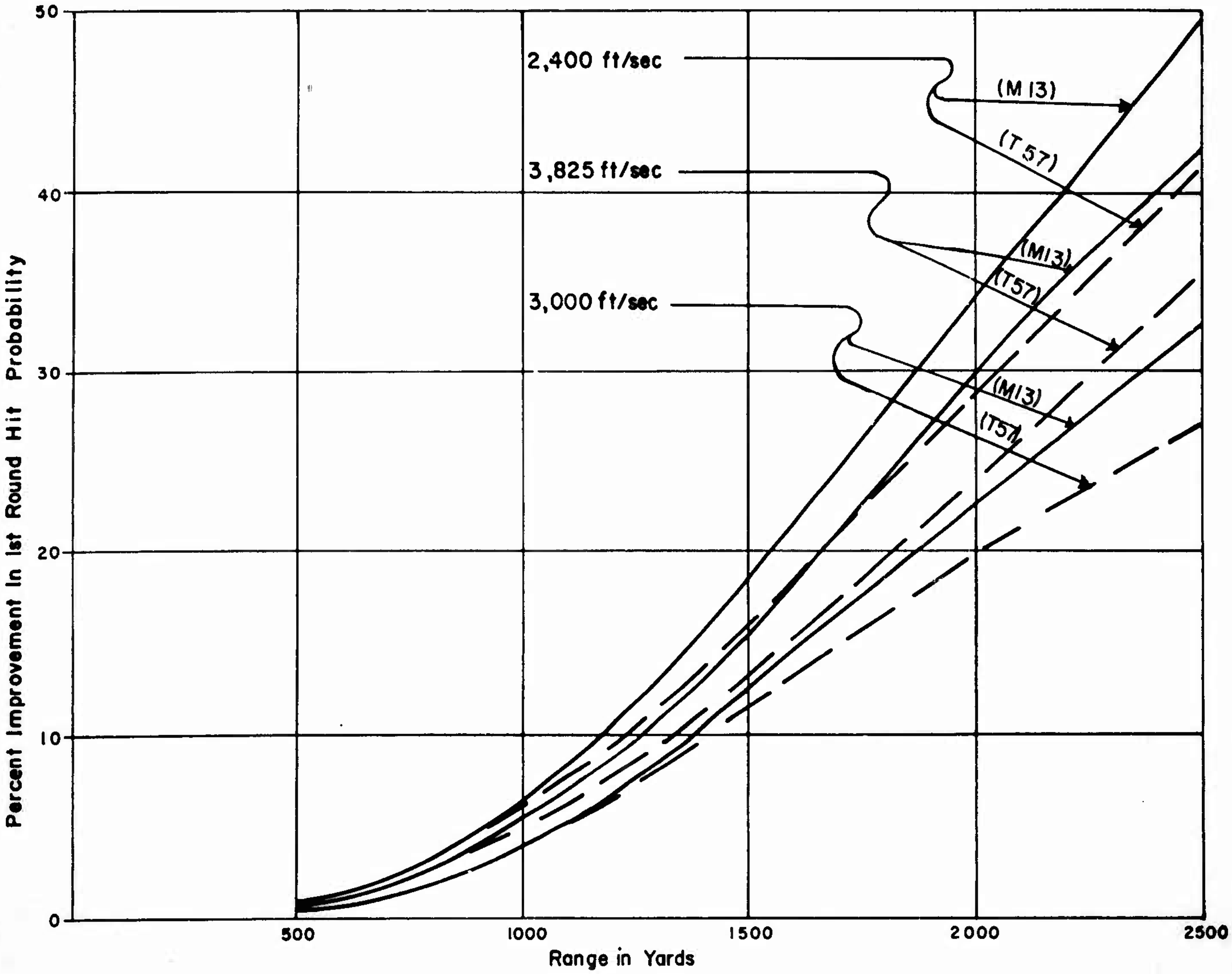


Figure 4. Percent Improvement In First Round Hit Probability Vs Range For Crosswind Corrected Data With Three Different Velocity Amunitions

Table V. DEGRADATION OF FIRST ROUND HIT PROBABILITY WITH A 1/2 MPH AND A 1 MPH ERROR IN CROSSWIND MEASUREMENT (M13 AND T57 RANGE FINDERS)

First Round Hit Probability (in percent)
MV = 2,400 ft/sec

Range in yards	First Round Hit Probability			
	With Crosswind		With Error in Crosswind Meas.	
	Corrected	Not Corrected	1/2 MPH	1 MPH
		M13 Range Finder		
500	98.2	97.6	98.1	98.0
1000	89.7	84.0	88.5	87.4
1500	68.7	55.8	66.2	63.8
2000	41.9	27.7	39.0	36.7
2500	21.5	11.4	19.4	17.7
		T57 Range Finder		
500	96.2	95.6	96.2	96.0
1000	76.7	71.9	75.7	74.7
1500	45.1	37.7	43.7	42.4
2000	19.1	14.0	19.4	18.4
2500	8.4	5.2	8.3	7.8

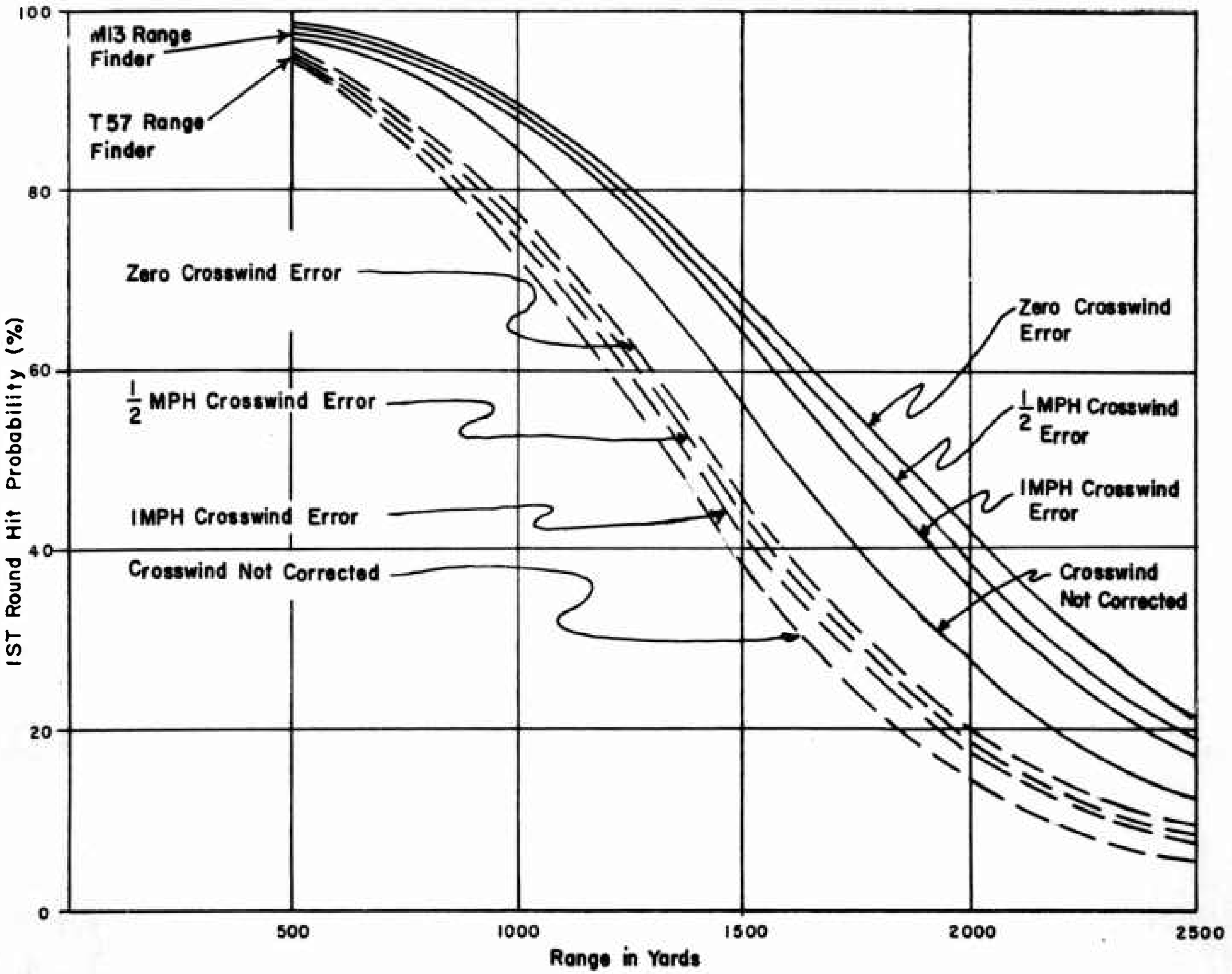


Figure 5. Effect Of 1/2 MPH And 1MPH Error In Crosswind Measurement On First Round Hit Probability (M13 And T57 Range Finders) Muzzle Velocity = 2,400 ft/sec.

crosswind error of the three velocity ammunitions and, therefore, would yield the largest degradation in first round hit probability. It is seen from this data that a 1 mile per hour crosswind measurement error introduces a maximum first round hit probability degradation in the M13 range finder data of approximately 5.2%, while a 1/2 mile per hour crosswind error introduces a maximum degradation of approximately 2.9% in first round hit probability (no crosswind first round hit probability - 1/2 MPH or 1 MPH crosswind first round hit probability = degradation in first round hit probability). The percent of degradation in first round hit probability,

$$100 \times \frac{\text{First Rd. Hit Prob., No Crosswind - First Rd Hit Prob 1/2 or 1 MPH Crosswind}}{\text{First Rd. Hit Prob. No Crosswind}}$$

is 12.4% and 6.9% respectively.

Presently used wind measuring devices, such as wind-driven generator anemometers, do not actually measure the surface wind at the desired location, which is along the trajectory of the projectile, between tank and target. Measurement of the wind at the tank is not very satisfactory, as the tank is either concealed behind an obstacle, such as a house or hill, which will alter the speed and direction of the wind, or is standing in open country, in which case its hull will change the characteristics of the surface wind in the immediate vicinity of the vehicle. As will be subsequently shown, because of surface wind peculiarities, even if wind could be measured at the tank accurately with simple equipment and with minimum difficulty, a reading at the tank cannot be extrapolated along the desired trajectory without introducing large errors in surface wind measurement. Several methods have been proposed to measure the surface wind, or its effect, along a desired path. Some of these methods include the use of spotting ammunition, and an ultrasonic wind measuring system. However, each of these schemes contains its own peculiar disadvantages, such as time delay involved, disclosure of position to enemy, quantity and complexity of required equipment, etc. Therefore, a truly satisfactory method for surface wind measurement along the trajectory of a projectile still remains to be attained.

B. Some Aspects of Surface Wind Behavior

The advantages to be derived from crosswind correction have been shown in the previous discussion. Some aspects of surface wind behavior will now be examined in order that the difficulties involved in surface wind measurement may become more apparent.

The atmosphere over any area of the earth contains well-defined dynamic systems in which air motion is mostly determined by horizontal gradients of pressure and temperature. Depending, however, on the height above the ground, air motion may be primarily influenced by other causes, such as surface friction, air density gradients, coriolis forces due to rotation of the earth, etc.

To facilitate discussion of atmospheric air flow, it is convenient to divide the atmosphere into three layers:

1. Surface Boundary Layer, extending to a height of approximately 100 meters above the ground.

2. Friction Layer, or Planetary Boundary Layer, which envelops the lower layer, and extends to a height of approximately 1,000 meters above the ground.

3. Free Atmosphere Layer, which extends above the height of 1,000 meters from the ground.

Winds in the Surface Boundary Layer are primarily determined by the nature of the terrain and the vertical gradient of temperature. Thus, air motion in this layer is affected to a greater extent by local variations in air density than by the effect of the main pressure field, and is practically insensitive to the effect of the earth's rotation.

The Planetary Boundary Layer is a zone of transition from the disturbed flow of the surface layer to the smooth, placid flow of the free atmosphere. Winds in this layer are primarily determined by surface friction, pressure and density gradients, and the effect of the rotation of the earth (Coriolis Effect).

The Free Atmosphere Layer exhibits frictionless, laminar air flow, and is the region of the geostrophic wind. This is a theoretical wind, the velocity of which is calculated under the assumptions that the atmosphere is incompressible and frictionless. This calculation is based on the assumption that air adjusts its speed to maintain a balance involving only the forces arising from the pressure gradient and the earth's rotation.

Of the above three categories the most difficult dynamic problems, by far, are found in the Surface Boundary Layer. One reason for this difficulty is that because of the proximity of the boundary, air flow of surface winds in this region is turbulent. This immediately involves treatment of the most difficult aspects of fluid dynamics. Another difficulty is that strict mathematical representation of the lower boundary is impossible because of the extreme variability of the earth's surface. However, the greatest difficulty of all is that the layers of air in contact with the ground often exhibit extreme variations in density gradient over a 24-hour period. This affects the whole pattern of surface air flow in a complicated manner.

Because interest is primarily centered on the behavior of low level surface winds in this report, some of the more detailed aspects of the surface boundary layer will be examined.

When a Dines pressure tube anemometer capable of indicating instantaneous values of wind speed was placed at a height of 13 meters over downland in clear summer weather, a typical record of wind velocity versus time over a 24-hour period (figure 6) resulted (Reference 2, pages 14 to 18). It can be noticed in this graph that the wind velocity shows rapid fluctuations, and that the amplitude of these oscillations changed considerably with time, being greatest at noon, decreasing in amplitude at sunset, and being least at night. Mean wind velocity can be observed to be least at night, increasing to a maximum at midday. The fluctuations in wind velocity are referred to as gustiness; these fluctuations occur in wind direction as well as in velocity. A convenient measure of gustiness is the root-mean-square value of the ratio of the oscillations to the mean wind, $\sqrt{V1^2/V_m^2}$, where V1 is the eddy velocity of the fluctuations and V_m is the mean wind velocity. If a coordinate system is established with the x axis along the direction of the mean wind, the y axis crosswind, and the z axis vertical, the gustiness component of each axis, g_x, g_y, g_z may be computed by using the component eddy velocity of the fluctuations in each axis. Thus, $g_x = \sqrt{V_x^2/V_m^2}$, $g_y = \sqrt{V_y^2/V_m^2}$, and $g_z = \sqrt{V_z^2/V_m^2}$, where V_x, V_y and V_z are the component eddy velocities of the fluctuations in the x, y, and z axis, and V_m is the velocity of the mean wind. (Reference 2). Studies have shown that the three components of gustiness, although different from each other in the first few meters above the ground, are of the same order of magnitude and exhibit the same 24-hour period fluctuations in clear weather.

Examination of records of wind velocity measurements made for windy, overcast days and nights, and those made for clear skies, reveals that gustiness remains at a relatively constant value day and night for the former, while it exhibits large variations in gustiness for

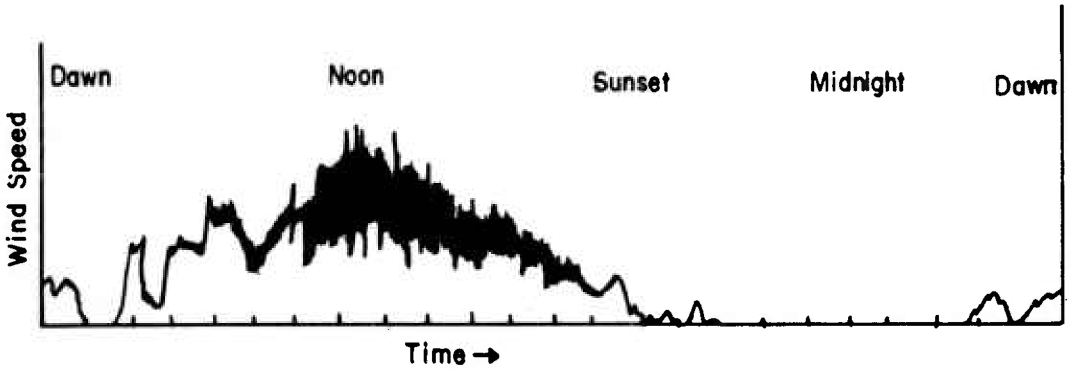


Figure 6. Typical Record Of Wind Speed Vs Time For A 24-Hour Period In Clear Weather (13 Meters Height)

the latter. This observation connects the diurnal variations in air turbulence with the variations in the temperature of the ground, since a cloud cover tends to prevent radiation from entering or leaving the ground. Figure 7 shows a record made of the differences in temperature between heights of 1 and 17 meters over a 24-hour period. This graph indicates a 24-hour variation in temperature of the same general characteristics as that for wind gustiness. Figure 7 also shows that the lapse rate, which is the rate of fall of temperature with height, increases as the sun rises and approaches noon, when the lapse rate reaches a maximum. As the sun descends and sunset approaches, the lapse rate decreases and becomes an inversion rate, which is the rise of temperature with increasing height. As night falls, the inversion rate increases to a peak at approximately midnight and decreases at dawn when the cycle begins again. What takes place is that at dawn, in clear weather, the incoming radiation from the sun starts to warm the ground and the lower layers of air, so that these layers become warmer than those at greater heights. As the sun approaches noon, the lapse rate increases in magnitude to a peak at noon and then decreases as the sun descends, and ground temperatures decrease. After sunset the ground temperature decreases rapidly, and the air layers in contact with it become cooler than the higher layers of air. This inversion continues throughout the night and reverts to a lapse rate after sunrise.

The above discussion clearly indicates why air turbulence varies widely over a 24-hour period during clear weather. A large lapse rate indicates that warmer, less dense air lies below colder, denser air, which is an ideal condition for the formation of convection currents. Any disturbance of the air mass, whether mechanical or thermal, tends to continue and, in fact, become magnified. This is a condition of instability in which air turbulence tends to grow. In an inversion condition, however, a state of stability and equilibrium exists as colder and, therefore, denser air lies beneath warmer, less dense air. Hence, any disturbance of the air mass tends to become damped out with relatively little resulting air movement. Consequently, large lapse rates are followed by large wind oscillations or gustiness, and large inversion rates are followed by undisturbed, laminar air flow.

Another aspect of the Surface Boundary Layer worth examining is the mean wind velocity profile near the ground.

The mean wind profile can be represented in its simplest form by the expression $\overline{U} = \overline{U_1} \ (Z/Z_1)^P$, where $P \leq O$, (Reference 2) and $\overline{u}$ is

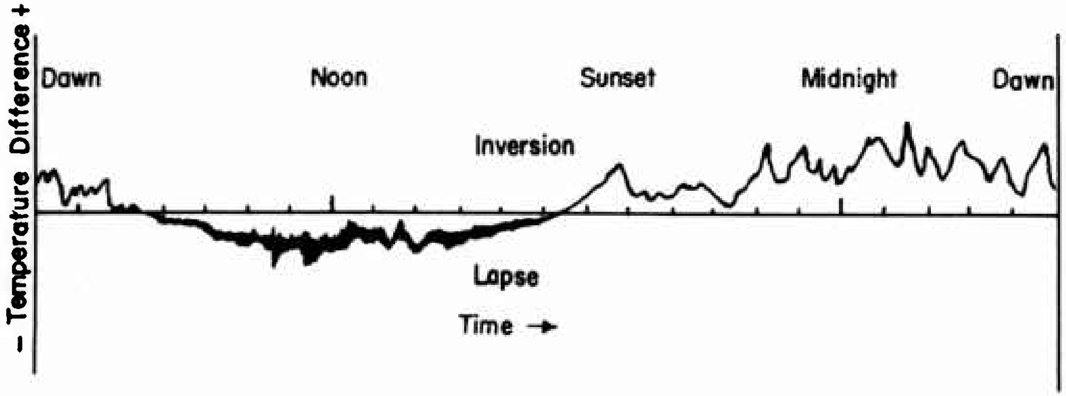


Figure 7. Typical Record Of Temperature Difference Between 1 And 17 Meters Over A 24-Hour Period In Clear Weather

the mean wind velocity at height Z and $\overline{u}_1$ is the mean wind velocity at the constant reference height Z_1. This equation, however, can only be applied to relatively shallow layers near the ground.

It has been shown that the mean wind up to the height of 10 meters over level short grass surfaces, under conditions of neutral equilibrium, is directly proportional to the logarithm of the height. However, under large lapse rates and large inversions the mean wind velocity is no longer strictly proportional to the logarithm of the height. The power law representation above may be used to determine wind speed conditions near the surface. The exponent $\underline{p}$ above varies with the temperature gradient. Observations made by Giblett at Cardington, England, indicate that $\underline{p}$ varies from 0.01 in high lapse rates to 0.62 in a high inversion. Observations made by Frost in 1947 for heights between 1.5 to 120 meters show a variation in $\underline{p}$ from 0.145 to 0.77, under high lapse and inversion rates, respectively. Table VI gives the variation in $\underline{p}$ as a function of temperature gradient, as observed by Frost in 1947.

The condition of the boundary, in this instance the surface of the ground, has considerable effect on the mean wind velocity profile. For turbulent flow over smooth boundaries at relatively high Reynolds numbers, wind-tunnel investigations indicate a profile known as the "seventh-root profile", $\overline{u} = \overline{u}_1 (Z/Z_1)^{1/7}$ near the boundary (Reference 2). At higher Reynolds numbers the exponent changes to 1/8 and sometimes to 1/9. When the boundary is aerodynamically rough, a parameter called the "roughness length" is introduced. This parameter is related to the average size of the obstacles which cover the surface. Investigations by various observers, including Prandtl, Rossby and Montgomery, Deacon, etc., indicate the following relationship for adiabatic temperature gradients: $\overline{u} = (1/K) \; (\tau_0/\rho) \; 1/2 \log (Z/Z_0)$, where $Z \geq Z_0$ (Reference 2). K is a non-dimensional constant known as Karman's constant, which in aerodynamic work has usually a value of 0.4. τ_0 is the shearing stress at the surface, and Z_0 is the roughness length. For non-adiabatic temperature gradients, the following mean wind velocity profile should be used: $\overline{u} = \frac{(\tau_0/\rho)^{1/2}}{K(1-B)} \left[(Z/Z_0)^{1-B} - 1 \right]$ (Reference 2) with $B > 1$ for superadiabatic gradients (high level of turbulence), $B = 1$ for adiabatic lapse rates, and $B < 1$ for inversion rates (low level of turbulence).

From the above, the limiting value of the mean wind velocity profile in very turbulent air is $\overline{u} = \overline{u}_1$ for $p = 0$ and $d\overline{u}/dZ = 0$, and for non-turbulent air, the limiting value is $\overline{u} = \overline{u}_1 (Z/Z_1)$, for $p = 1$ and $\frac{d\overline{u}}{dZ}$ = constant which is different from zero. These limits are never

Table VI. VARIATION OF COEFFICIENT P IN $\bar{U} = AZ^P$ WITH TEMPERATURE DIFFERENCE BETWEEN 350 FT AND 4 FT

Temperature Difference (°F)	-4 to -2	-2.5 to -1.5	-2 to 0	-1 to 1	0 to 2	2 to 4	4 to 6	6 to 8	8 to 10	10 to 12
P, All Observations	.145	.17	.23	.27	.28	.39	.50	.60	.61	.67
P, Excluding Observations at 5 ft	.145	.17	.25	.29	.32	.44	.59	.63	.62	.77

(See Reference 4)

reached in practice, but are approached in large lapse rates and large inversions, respectively.

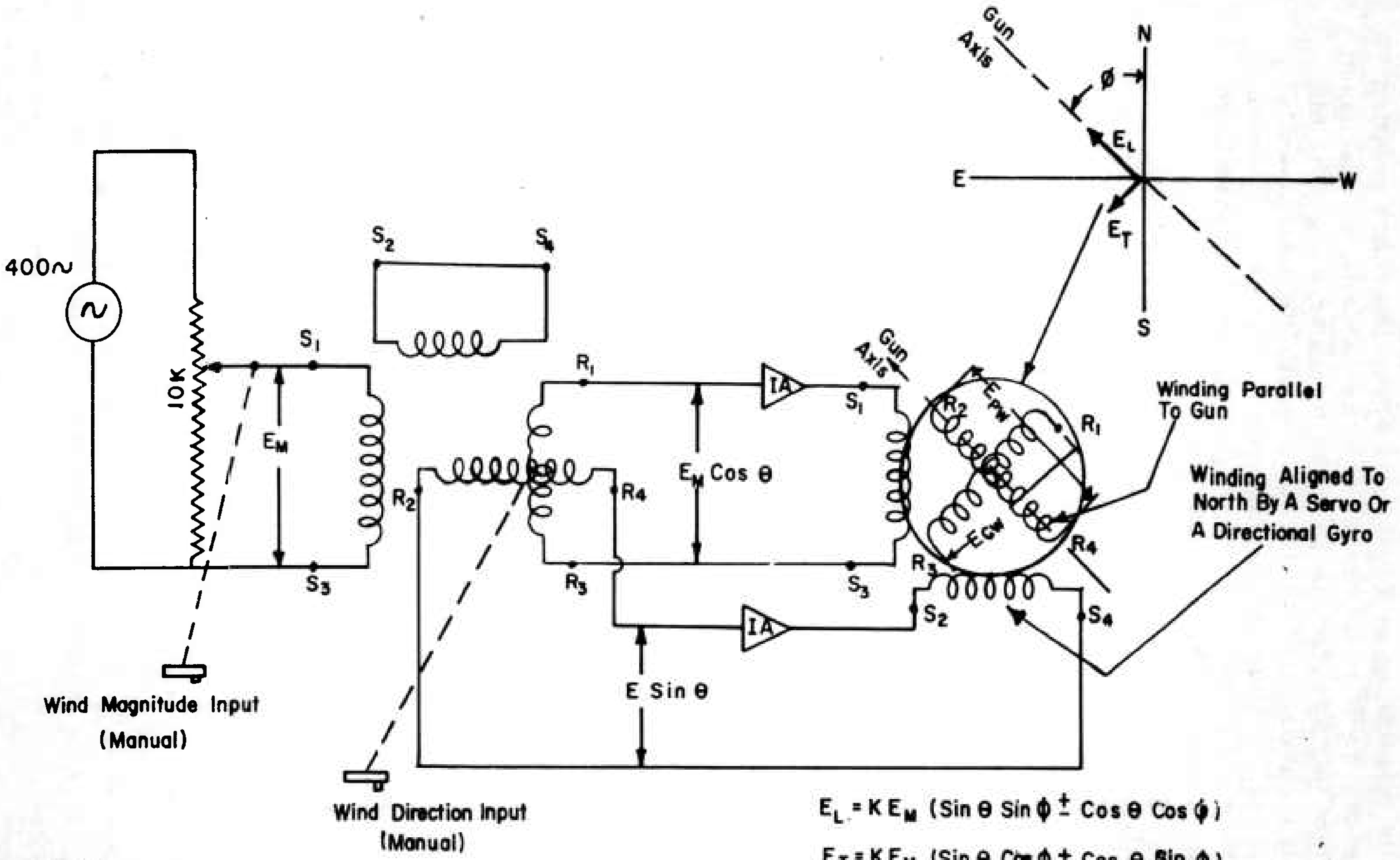
The behavior of low level surface winds is an extremely complex and extensive subject, and only a very small facet of the whole problem has been discussed here. It is however, the purpose of this discussion to point out the complexities involved in order to instill a greater appreciation for the problem of determining low level surface wind characteristics.

C. A Method for Reduction of Crosswind Data

When an acceptable method for accurately obtaining surface wind information is developed, a means for reducing this data into a crosswind component relative to the gun tube will be required. Such a scheme is described in the following discussion.

If wind velocity and direction relative to magnetic north is available, then the circuit shown in figure 8 will yield an output voltage proportional to the velocity of the crosswind component of the surface wind relative to the position of the gun tube. This output voltage will always be proportional to the crosswind component of the surface wind irrespective of tank maneuvers or turret rotation.

The basic scheme is relatively simple and can be used in two versions of the Wind Data Conversion Unit. If it is assumed that wind information is introduced manually by an operator, the unit will then be comprised of a potentiometer, two resolvers, and possibly two isolation amplifiers. Referring to figure 8, it is seen that wind magnitude information is introduced in the potentiometer by manually positioning the slider. Similarly, wind direction information is manually introduced by the operator by turning the shaft, and thus the rotor, of a resolver of 0.05% accuracy (size 15,400 cps). It is seen that the voltage output of the potentiometer, which is proportional to the magnitude of the surface wind velocity, is connected to one of the stator windings of the resolver. This voltage is separated by the resolver into its sine and cosine components with respect to the angle of shaft rotation, which is the angle of the wind direction pertaining to a magnetic north reference. These voltages, appropriately isolated through two isolation amplifiers to prevent loading, are respectively connected to the two stator windings of another resolver. The stator of this



$E_L = K E_M$ (Sin θ Sin $\phi \pm$ Cos θ Cos ϕ)

$E_T = K E_M$ (Sin θ Cos $\phi \pm$ Cos θ Sin ϕ)

Where,

θ = Angle Of Wind From North
ϕ = Angle Of Gun From North
E_M = Wind Magnitude
E_L = Wind Magnitude Parallel To Gun
E_T = Magnitude Of Crosswind

K = Resolver Transformation Ratio

Figure 8. Wind Data Conversion Unit

second revolver is maintained at a magnetic north reference position either by a gyroscope or by means of a servomechanism, as discussed later. The rotor of this resolver is attached to either the gun or the turret proper. It is so oriented as to have one winding permanently positioned parallel to the gun tube, and the other, therefore, perpendicular to it. The desired crosswind voltage output is obtained from the winding perpendicular to the gun tube.

Mathematically,

$$E_T = KE_M (\sin\theta \cos\Phi \pm \cos\theta \sin\Phi), \tag{1}$$

where

E_T = Voltage proportional to magnitude of wind velocity

K = Resolver transformation ratio

E_M = $E \sin wt$ = exciting voltage

θ = Angle of wind direction relative to magnetic north reference

Φ = Angle of gun direction relative to magnetic north reference

From the diagram, figure 9, it can be seen that the crosswind component is $E_T = W \sin(\theta - \Phi) = KE_M \sin(\theta - \Phi)$, or $E_T = KE_M \sin(\theta + \Phi)$, depending on which quadrant θ and Φ lie. Also, from equation (1) by trigonometric identities

$$\sin(\theta \pm \Phi) = \sin\theta \cos\Phi \pm \cos\theta \sin\Phi, \text{ so that} \tag{2}$$

$$E_T = KE_M (\sin\theta \cos\Phi \pm \cos\theta \sin\Phi) \tag{3}$$

$$E_T = KE_M \sin(\theta \pm \Phi) \tag{4}$$

In the system described above, surface wind data may be fed automatically into the Data Conversion Unit, if desired, providing suitable modifications are made. The extent of these modifications will depend on the nature of the wind data input signal available.

The most complex portion of the Wind Data Conversion Unit is its magnetic north reference source. This reference signal can be obtained

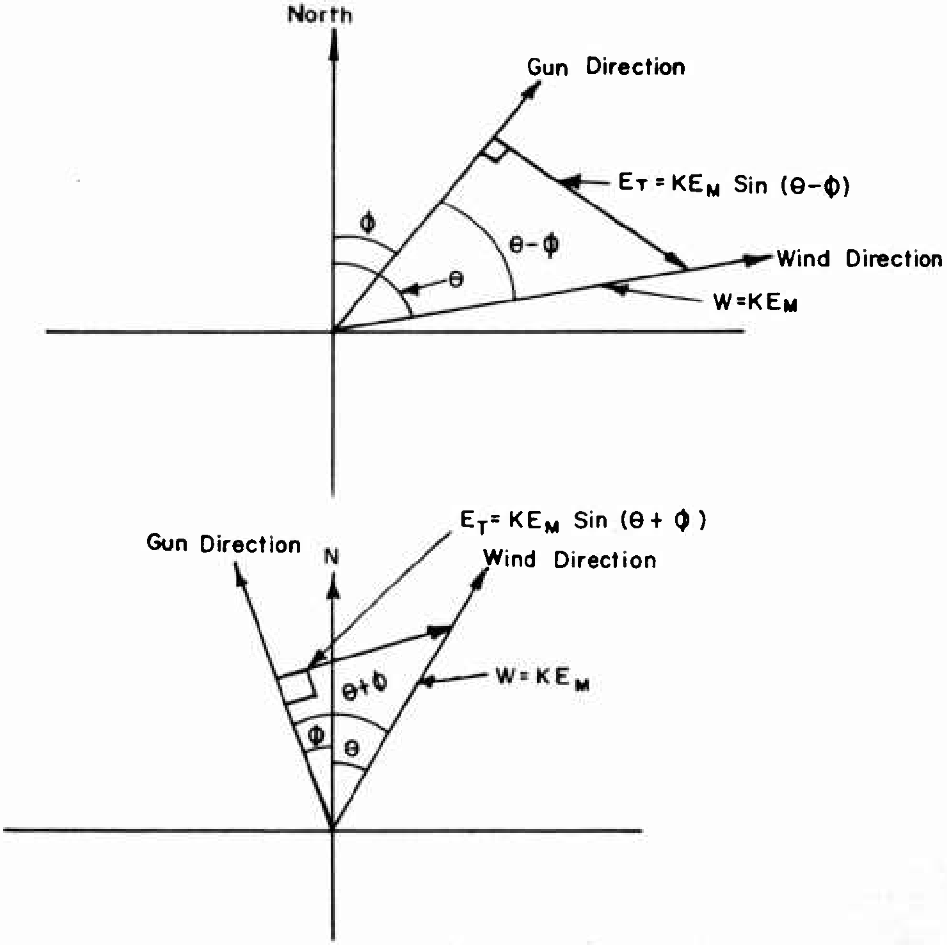


Figure 9. Vector Diagram Showing Relationship Of Crosswind, Gun And Surface Wind Directions

by using a gyroscope-mounted resolver with the stator assembled on the gimbal set on magnetic north and the rotor attached to the gun or turret. It can also be obtained by using a servomechanism directly to keep the stator of the resolver set on magnetic north, while the rotor is similarly attached to the gun or turret. Regardless of which version is used, a magnetic flux valve, such as the one used in the Army's J-2 helicopter Gyro Compass System or in the AN/ASN-13 fixed wing aircraft Gyro Magnetic Compass System, will have to be provided to furnish a magnetic north reference and make available an electrical signal to the gyroscope or to the servomechanism. This signal is used to torque the gimbal of the gyroscope and maintain it on magnetic north, while in the servomechanism the signal is used as a reference to position directly the stator of the resolver on magnetic north.

Because of the large mass of magnetic material in a tank, the earth's magnetic field is greatly distorted both inside and in the immediate vicinity of the tank. It is possible to attach the flux valve to a long cable connected to the gyro torquing circuit and then, periodically,to reset the gyro on magnetic north. Normally, the gyro would operate as a free directional gyro and would only be slaved two or three times a day, when the cable would be stretched to a distance far enough to eliminate the influence of the tank on the earth's magnetic field and the gyro reset. Using gyros with a 2 degree per hour random drift, an accuracy of approximately ± 4 degrees in magnetic north determination could be expected. This error would only be equivalent to an additional 1/2 MPH error in crosswind measurement. Its effect on hit probability can be seen in Table V and figure 5. Another way in which this could be accomplished would be by installing the flux valve at the end of a mast above the tank. This mast could be normally telescoped inside the tank body and erected only to reset the gyro. None of these methods would be satisfactory if a directly coupled servomechanism is used, as this requires a continuous position reference signal for proper operation. A more satisfactory way to obtain such a continuous position reference signal is by a method devised and used by the British in a Centurian Tank (Reference 3). This method uses two flux valves strategically located on the tank hull. By connecting the output signal of the two flux valves in opposition to each other it is possible to null out the effect of the tank hull on the earth's magnetic field, and thus obtain a proper reference signal. The basic principle used is that zones exist near a vehicle, a short distance apart from each other, where there is a constant ratio between the horizontal and vertical components of the magnetic deviation field. Hence, when two flux valves are located in a pair of these zones, the ratio of the magnetic deviation fields between the two zones is fixed regardless of vehicle movements or turret rotation. This ratio varies from 1:2 to 2:3. The above principle is used in the following manner:

The flux valve utilized in the Sperry Gyrosyn Magnetic Compass System provides an output which consists of the resultant sum of three vector voltages at 120° to each other. The amplitude and direction of the resultant vector voltage is dependent on the strength and direction of the magnetic field where the flux valve is located. The strength of the earth's magnetic field is practically constant in the vicinity of the vehicle but the deviation field, due to the magnetic material of the vehicle, decreases with the distance from the vehicle. One flux valve is located at a point on the vehicle where the deviation field strength is KD, where K is a constant, and D the strength of the magnetic deviation field. The other flux valve is located at another point on the vehicle where the deviation field strength is 2/3 KD. If the strength of the earth's magnetic field is denoted by E the voltage output from the first flux valve (V_1) will be proportional to E + KD and the voltage output of the second flux valve (V_2) will be proportional to E + 2/3 KD. Thus,

$$V_1 \propto E + KD \text{ AND } V_2 \propto E + 2/3\ KD.$$

If 2/3 V_1 is subtracted from V_2,

$$V_2 - 2/3\ V_1 \propto E + 2/3\ KD - 2/3\ E - 2/3\ KD, \text{ and}$$

$$V_2 - 2/3\ V_1 \propto 1/3\ E \text{ (Reference 3).}$$

The resultant voltage is, therefore, a vector quantity proportional only to the earth's magnetic field, and this voltage can be used as a magnetic north reference signal.

As a prerequisite to the installation of a two flux valve system a preliminary magnetic survey of the vehicle must first be conducted to determine the zones which exhibit the magnetic relationships outlined above. Each type of vehicle has its own characteristics, so that individual magnetic surveys should be conducted in each case.

The Wind Data Conversion Unit, as has been stated previously, can be built using either a gyroscope or a servomechanism to hold the stator of a resolver on magnetic north. Several proposed approaches have so far been considered; however, at this time, it is believed that

the scheme using the servomechanism to position the resolver stator according to a magnetic north reference signal is the most satisfactory from the standpoint of simplicity and cost.

CONCLUSIONS AND RECOMMENDATIONS

From the data given in the above discussion, the following conclusions can be made:

1. It has been shown that surface winds behave in an unpredictable and complex manner, and that the most important factors governing their behavior are the nature of the terrain and the temperature gradient of the atmosphere. As the terrain and temperature gradient vary from location to location, it can be concluded that surface wind information taken 10 to 20 miles from a particular location one to two hours before, such as provided by the standard metro-message will not be very useful, except under extraordinary circumstances.

2. Present wind measuring devices and proposed methods utilizing extrapolation of surface wind measurements obtained at the tank are not satisfactory. Investigation has shown that a system, suitable for installation in a tank, which would measure wind velocity between the tank and targets would be difficult to develop and possibly beyond the present state of the art.

3. At this time, it is debatable whether the increase in hit probability would warrant the cost and effort of a research and development program to provide accurate wind correction, especially since equipment developed from such a program promises to be complex and costly.

4. If simplified equipment should appear to become feasible, development of a crosswind correction system is recommended. This equipment would be used only on those occasions when the wind velocity is high and gross corrections are desirable. This solution is worthwhile only if simple, inexpensive equipment can be developed for this purpose.

5. For the present, the most logical and recommended course of action is to continuously monitor the state of the art on wind measurement techniques. It is further recommended that when suitable equip-

ment becomes available a magnetic survey of tanks which will employ this system be made, and a unit for converting surface wind into crosswind with respect to the gun tube be developed.

REFERENCES

1. Fire Control Studies, Tank Gunnery Accuracy Evaluation, (U) By Harold Brodkin, F.A. Report 1380A, Feb 1958 (C).

2. Atmospheric Turbulence, O. G. Sutton, John Wiley & Sons, Inc., 1955.

3. Report No. 178, "The Chobham Self-Correcting Magnetic Compass and Navigation System", By G. Harvey, Fighting Vehicle Research and Development Establishment, Ministry of Aviation, England.

4. "The Velocity Profile in the Lowest 400 FT." By R. Frost, The Meteorological Magazine, January 1947.

5. Micrometeorology, O. G. Sutton, McGraw-Hill Book Co., Inc. 1953.

6. "Variation of Wind Velocity and Gusts With Height in the Lower 250 FT." By R. H. Sherlock, American Society of Civil Engineers, Proceedings, V. 76, Sep. No. 128, April 1952.

DISTRIBUTION

28 - Commanding Officer
Frankford Arsenal
Philadelphia 37, Pa.
Attn: Thru: Chief, R&D Group, 1000
Dep. Chief, R&D Group, 1000 (1)
Thru: Chief, Dev. Office, 1100
Chief, 1130 (1)
Thru: Chief, 1500
Chief, 1510 (1)
1510, Paul Marasco (1)
1510, S. Sorin (5)
Thru: Chief, 1700
Chief, 1740 (1)
1742, S. Torrey (1)
1742, Ira I. Goldberg (5)
Thru: Senior Scientist, 0100
Library, 0270 (1)
Chief, 1205 (1)
1252 (10)

1 - Office, Chief of Ordnance
Department of the Army
Washington 25, D. C.
Attn: ORDTW

2 - Attn: ORDTT

1 - Attn: ORDTB

3 - Commanding General
Ordnance Tank-Automotive Command
Detroit, Michigan
Attn: ORDMC-RC.2

1 - Commandant
U. S. Army Armor School
Fort Knox, Ky.

1 - Commanding General
Aberdeen Proving Ground
Maryland
Attn: ORDBG-BRL
Mr. D. Hardison

1 - Attn: D & PS
Mr. E. D. Sissom

1 - Headquarters
CONARC
Fort Monroe, Va.
Attn: ATDEV-2

10 - Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Va.
Attn: TIPDR

AD-   ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN
TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl
illust, tables, and references (DA Proj 5W13-02-062,
Ord Proj TW-407)   UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD-   ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN
TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl
illust, tables, and references (DA Proj 5W13-02-062,
Ord Proj TW-407)   UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD-   ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN
TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl
illust, tables, and references (DA Proj 5W13-02-062,
Ord Proj TW-407)   UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD-   ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN
TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl
illust, tables, and references (DA Proj 5W13-02-062,
Ord Proj TW-407)   UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD- ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl illust, tables, and references (DA Proj 5W13-02-062, Ord Proj TW-407) UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD- ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl illust, tables, and references (DA Proj 5W13-02-062, Ord Proj TW-407) UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD- ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl illust, tables, and references (DA Proj 5W13-02-062, Ord Proj TW-407) UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

AD- ACCESSION NO.
M61-30-1
Frankford Arsenal, Philadelphia 37, Pa.
SURFACE WIND CORRECTION CONSIDERATIONS IN TANK FIRE CONTROL by Ira I. Goldberg, S. Sorin.

Memorandum Report M61-30-1, May 1961, 33 pp, incl illust, tables, and references (DA Proj 5W13-02-062, Ord Proj TW-407) UNCLASSIFIED REPORT

This report discusses the importance of appropriate surface wind correction for conventional tank gunnery, the complexities involved in estimating surface wind behavior, and a suggested method for converting surface wind data into crosswind relative to the gun tube. Development of a simple gross crosswind correction system is recommended as an interim solution for use on those occasions when the wind velocity is high and gross corrections are desirable.

The conclusion is drawn that further work on a precise system should await the development of an accurate method for determining wind velocity along the trajectory of a projectile.

UNCLASSIFIED

1. Tank Gunnery Accuracy Evaluation
2. Fire Control Development-Combat Vehicles
3. Hit Probability
4. Surface Wind Behavior

I. Goldberg, Ira I.
II. Sorin, S.
III. Ord Proj TW-407

DISTRIBUTION LIMITATION:
None, obtain copies from ASTIA.

UNCLASSIFIED

UNCLASSIFIED

UNCLASSIFIED