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SIMPLIFIED BLAST NUISANCE PREDICTIONS FOR SMALL EXPLOSIONS*

Jack W. Reed
Sandia Laboratories
Albuquerque, New Mexico

ABSTRACT

Explosive demolition activities at Tooele Army Depot, Utah, occasionally brought complaints of noise and minor damage to residences in communities 5 to 10 miles distant. A method is provided to use local surface temperature and wind observations, plus upper air data from the National Weather Services at Salt Lake City, to determine whether propagation conditions are weak or strong. With weak propagations calculated toward both Tooele and Grantsville, 5000 lb explosions can often be conducted without audible detection in those neighboring communities.

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INTRODUCTION

Demolition of obsolete or defective munitions has caused complaints about the noise from neighbors of a number of military installations. Airblast propagation, nuisance, and complaints from these relatively small explosions are often strongly dependent on atmospheric conditions. In this paper a simple calculation procedure is described for predicting and limiting this nuisance at Tooele Army Depot, Utah.

Their normal operation is limited to demolition of 5000 lbs of chemical explosives, under 10 ft of earth cover. On occasion however, this does cause blast annoyance at Tooele, 9 miles east, and at Grantsville, 7 miles north of the firing site. Some complaints have charged broken windows or plaster cracks which may or may not be valid. These are often difficult to disprove. Certain weather conditions cause most of these scattered troubles, Sandia Laboratories' experience, in predicting airblast from nuclear explosion tests, has been used to develop a method to estimate weather conditions when these firings should be delayed until better circumstances prevail.

The 10-ft dirt cover normally used on 5000-lb high explosives (HE) at Tooele does little to reduce these relatively distant blast effects. Such cover may partially confine the HE and cause a more efficient explosion burn, comparable to a shaped-charge effect. At large distances this yield enhancement may largely overcome the blast attenuation found close-in from this depth of cover. It would take about 20 ft of dirt cover to reduce distant blast pressures by 80%. A 10-ft cover would effectively (80%) attenuate a 1000-lb HE charge.

Atmospheric Effects

The atmosphere may act like an acoustic lens, depending on air temperatures and winds, both along the ground and aloft. Blast propagation to the 5 to 10 mile distances to communities near Tooele Army Depot depends on atmospheric conditions up to about 3000 ft above ground. At that height, above the ground friction boundary layer and Salt Lake sea breezes, winds and temperatures do not change as much as they do near the ground. Balloon measurements made twice daily at Salt Lake City airport, 30 miles away, can be used to estimate upper air conditions over Tooele.

Blast waves travel at about the speed of sound, and that depends on air temperature. Sound travels faster in warm air than it does in cold air. Sounds may also be speeded or retarded by winds. If the temperature and sound speed increases with height (see Figure 1-B), as it may early in the morning, a blast wave travels faster above the ground than it does at ground level. The wave front is turned by refraction toward the ground, causing loud noise at relatively long distances. An increase in temperature with altitude is called an inversion, because temperature is usually lower at higher elevations.

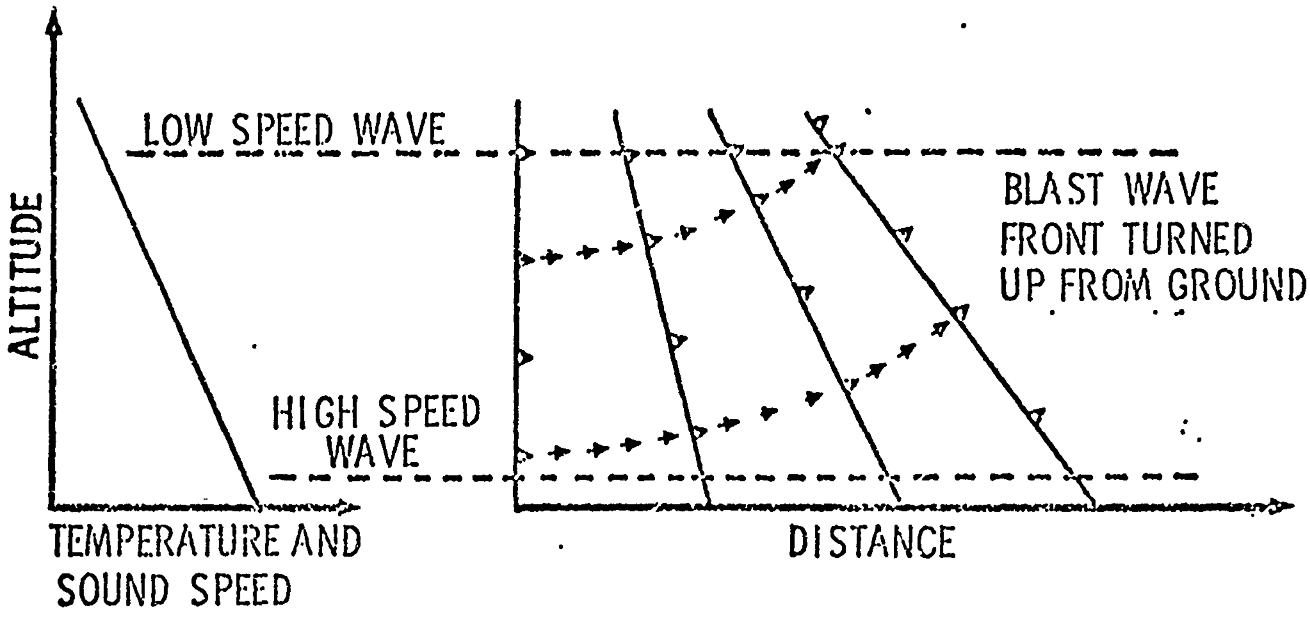
During sunny afternoons, with little wind, temperature is highest at the ground. This turns or refracts the blast wave front upward and into and into the sky (see Figure 1-A). Along the ground, blast pressures are then relatively small and may not even be heard.

Explosions in early afternoon, near the warmest time of day, usually cause the least disturbance. On the other hand, winds (at the surface as well as above ground) may cause strong propagations in spite of good temperature conditions. Surface winds stronger than about 5 knots may also cause strong propagations in the downwind quadrant, independent of refraction.

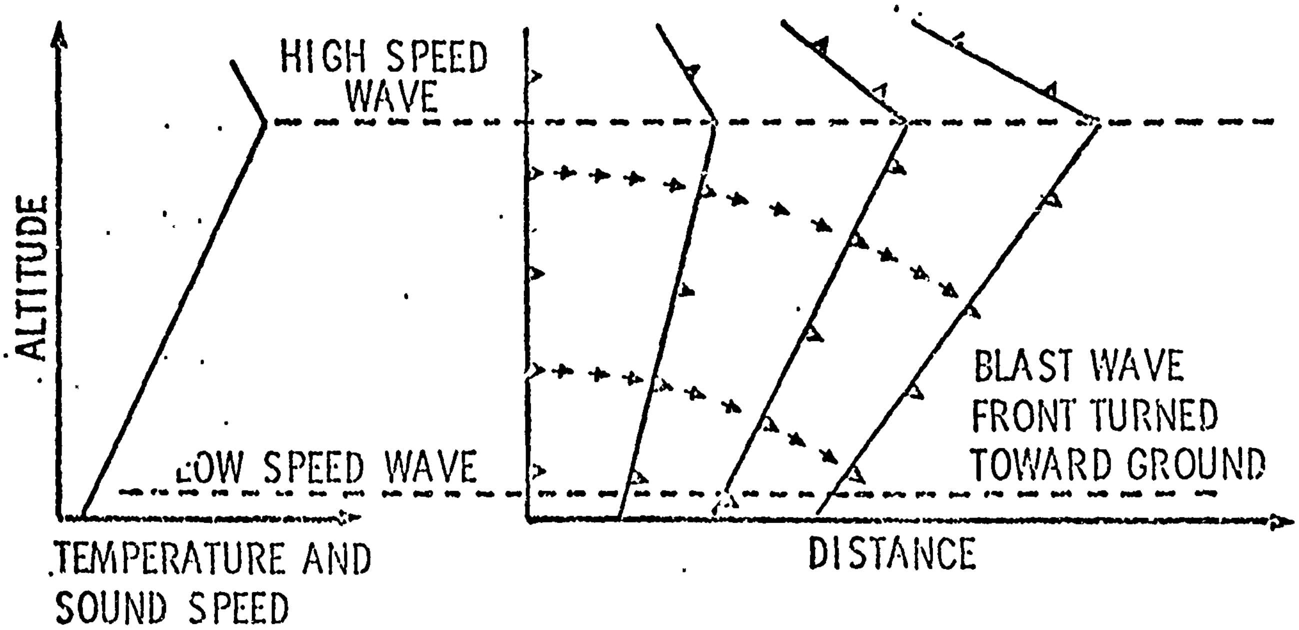
The following calculation is used to determine whether sound velocity (sound speed plus wind) increases (strong propagation) or decreases (weak propagation) with altitude. Calculations are made for directions of concern, toward Grantsville, and Tooele.

Upper Air

Salt Lake upper air weather reports are obtained daily by calling the National Weather Services Office at Salt Lake City Airport. Temperature and wind at 6000 ft MSL (mean sea level altitude) are required. Their balloon observation system, called a rawinsonde, is released daily at 1200Z (Greenwich Time) or 0600 MDT (Mountain Daylight Time) and results are available by about 0800 MDT. These upper air reports are assumed to remain valid throughout the day, unless a storm passes through the area. At Tooele, a cold front passa[illegible] causes more northerly winds and better conditions for reduced airblast propagation. Such abrupt changes there do not lead to unpleasant surprises, as they might at other locations.



A. TEMPERATURE DECREASING WITH ALTITUDE (GRADIENT)



B. TEMPERATURE INCREASING WITH ALTITUDE (INVERSION)

FIGURE I. BLAST WAVE DISTORTIONS CAUSED BY ATMOSPHERIC CONDITIONS

Upper air temperatures are reported in degrees Centigrade and a conversion table is provided to obtain sound speed, in feet per second, from either Fahrenheit or Centigrade air temperatures.

Wind is reported as the direction from which the wind is blowing, in degrees clockwise from True North. A wind from the east would be 090°, from the south 180°, and from northwest 315°. Wind speeds are reported in knots (nautical miles per hour) by National Weather Services for the convenience of aviation navigators. Local surface measurements in statute miles per hour need conversion to knots for use in the following calculations.

Wind vectors (direction and speeds) must be resolved into components toward targets of concern, toward Tooele and Grantsville. Wind components are calculated from a polar coordinate graph, as shown in Figure 2, by following out on the radial line marked with the wind direction to the radius circle that is marked by the wind speed (in knots). Larger scale, cardboard graphs in two colors have been furnished for field use. The component toward Tooele, T_6, in ft/sec. When the temperature is $20^{\circ}C$ ($68^{\circ}F$) the sound speed is 1128 ft/sec.

The sum of $S_6 + T_6$ would give the sound velocity toward Tooele at 6000 ft MSL, but is not recorded. Similarly, $S_6 + G_6$ is the sound velocity toward Grantsville.

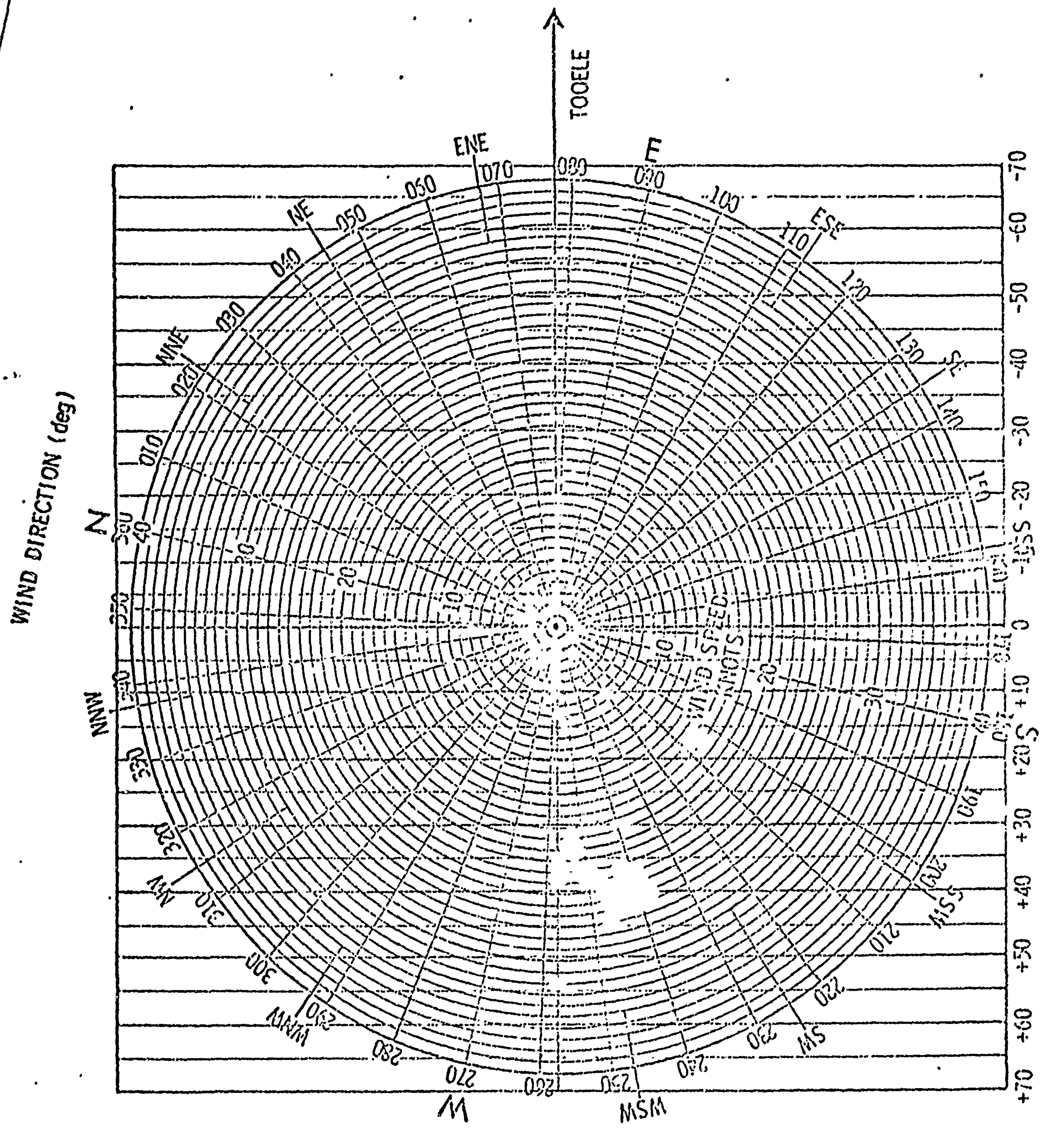


FIGURE 2. COMPUTER FOR WIND COMPONENTS TOWARD TOOELE

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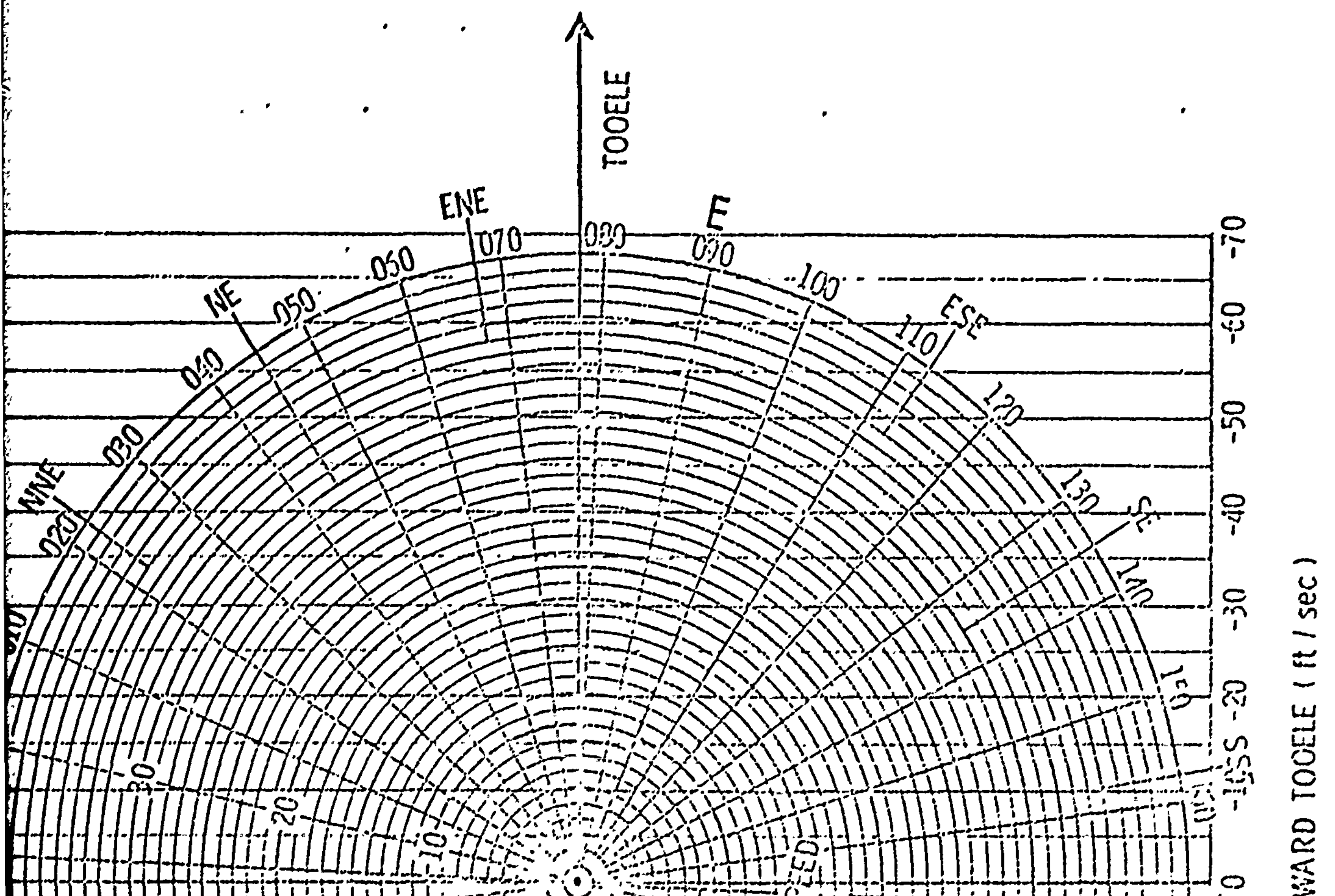

GURE 2. COMPUTER FOR WIND COMPONENTS TOWARD TOOELE

7,

TABLE I. CALCULATIONS FOR BLAST PREDICTIONS DATE:________

I. SALT LAKE CITY UPPER AIR WEATHER REPORT TIME:________

6000FT MSL TEMPERATURE:________°C WIND:____°/____ KNOTS

S_6=________ G_6=______ T_6=______

II. TOOELE SURFACE WEATHER REPORTS

A. TIME:______ TEMPERATURE:______°F WIND:____°/____ KNOTS

S_o=______ G_o=______ T_o=______

$D = S_6 - S_o$______________(-6 limit)

SOUND VELOCITIES:

GRANTSVILLE: $V_G = G_6 - G_o + D =$ ______

TOOELE : $V_T = T_6 - T_o + D =$ ______

B. TIME:______ TEMPERATURE:______°F WIND:____°/____ KNOTS

S_o=______ G_o=______ T_o=______

$D = S_6 - S_o$______________(-6 limit)

SOUND VELOCITIES:

GRANTSVILLE: $V_G = G_6 - G_o + D =$ ______

TOOELE : $V_T = T_6 - T_o + D =$ ______

C. TIME:______ TEMPERATURE:______°F WIND:____°/____ KNOTS

S_o=______ G_o=______ T_o=______

$D = S_6 - S_o$______________(-6 limit)

SOUND VELOCITIES:

GRANTSVILLE: $V_G = G_6 - G_o + D =$ ______

TOOELE : $V_T = T_6 - T_o + D =$ ______

D. TIME:______ TEMPERATURE:______°F WIND:____°/____ KNOTS

S_o=______ G_o=______ T_o=______

$D = S_6 - S_o$______________(-6 limit)

SOUND VELOCITIES:

GRANTSVILLE: $V_G = G_6 - G_o + D =$ ______

TOOELE : $V_T = T_6 - T_o + D =$ ______

If V_G or V_T is greater than +5 : Strong propagation; delay firing.

If V_G or V_T is between -5 and +5: Medium propagation; delay preferable.

If V_G and V_T are both below -5: : Weak propagation; Okay to fire.

Surface Conditions

Surface temperature and wind are obtained from a thermometer and anemometer near the firing site. Sound speed, S_o, is obtained as before, from a conversion table. Wind components T_o and G_o, are likewise calculated from polar coordinate charts. These are entered in appropriate blanks on the form, as well as the difference, D, between sound speeds at altitude and ground level. Note that values below -6 (for example, -8) would be entered as -6. Larger temperature decreases with this particular altitude difference cause very unstable, turbulent air that could not be depended upon to limit propagation. Also if T_o or G_o exceed about +5, downwind propagation could cause nuisance noises.

Sound velocity differences, between 6000 ft MSL and ground, are calculated as shown on the blank form. Values of V_G (toward Grantsville), or V_T (toward Tooele) may be positive (+) or negative (-), depending on whether wave velocities increase or decrease with height. A decrease of temperature and sound speed with height is called a gradient. Strong propagations would result from large positive (+) values; weak propagations result from large negative (-) values, or gradients, as shown by Figure 3.

Strong propagations could occur with velocity differences greater than +5. These could break windows and crack plaster walls. Tooele is more distant than Grantsville, but has the larger population. The net disturbance or damage would, coincidentally, be similar in those two towns.

Intermediate propagation strength, with velocity differences between -5 and +5, could give a loud bang or rumble, but would not be strong enough to break windows or crack plaster. If such waves occurred very often, however, the noise could irritate people to make claims for some damages not really caused by the blast waves.

Best firing conditions come with velocity differences even more negative than -5. With -15 differences the blast would hardly be heard.

Strong propagations calculated in morning hours would usually be reduced considerably by afternoon. If wind effects could be ignored, then the best firing time would be at the warmest time of day, between about 1300 MDT and 1500 MDT.

Note that numerical values in Figure 3 were determined for a particular yield, burst environment, distances to and populations of neighboring towns for Tooele Army Depot operations. Different criteria would apply for other demolition locations and parameters.

Test Procedure

If propagation is calculated to be strong in the morning, extra blanks are provided in the blank form for calculations at later hours with revised surface weather observations. The morning upper air data from Salt Lake City is used during the whole day. It is not expected to change very much and there is no later balloon run until evening. Check calculations from surface observations about once each hour should show whether there is a trend toward improving or worsening conditions.

Onc caution here: Both surface temperatures and winds should be averaged

PROPAGATION

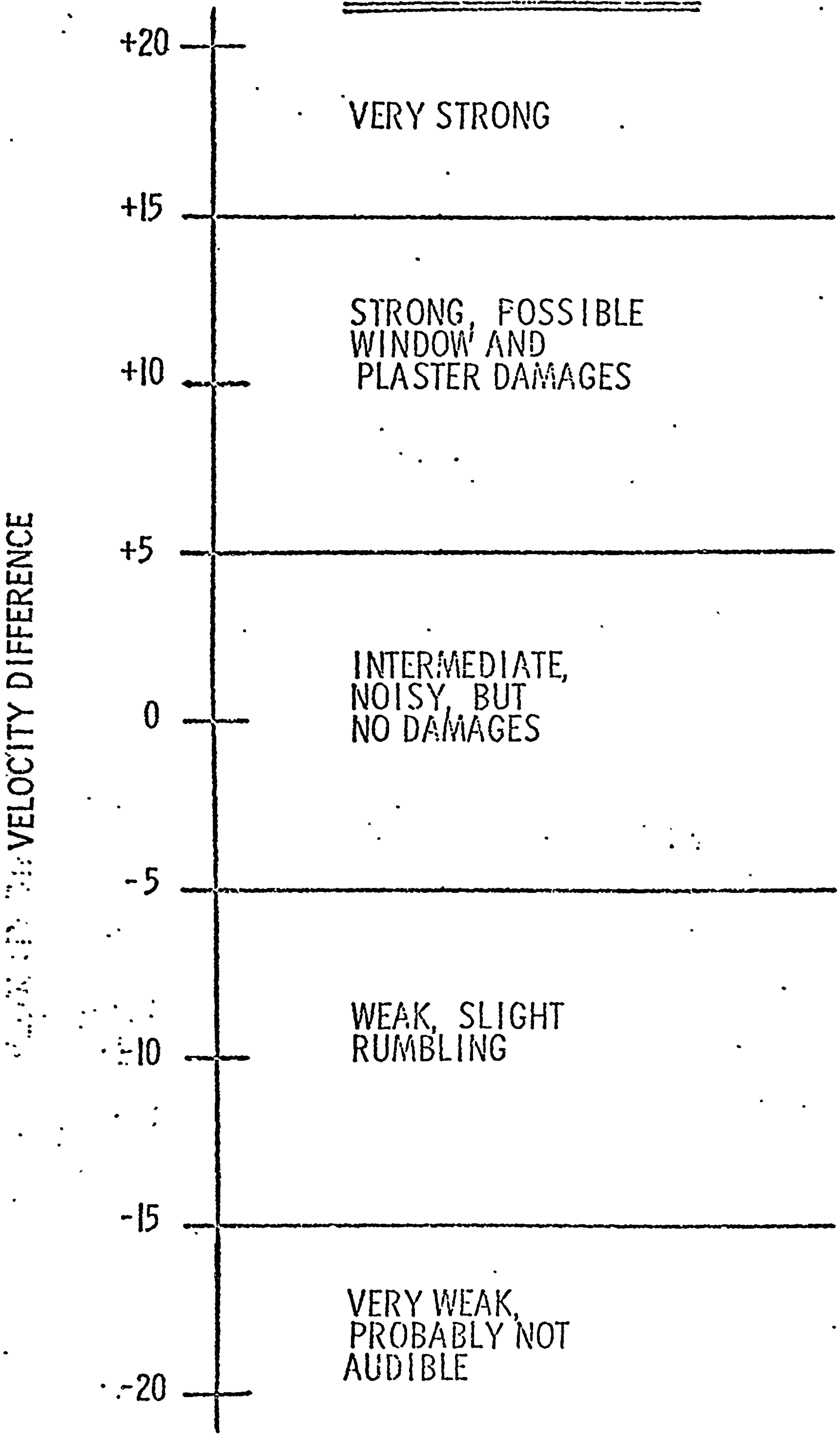

FIGURE 3. BLAST EFFECTS VERSUS SOUND VELOCITY DIFFERENCES

readings. Small perturbations or changes in temperature, or wind gusts should be ignored, because they are not representative of atmospheric conditions along the total propagation paths of 5 to 10 miles.

In general, for Tooele Army Depot activities, cold northerly winds would protect both Grantsville and Tooele from strong blast waves. Warm southerly winds of even 5 to 10 knots would increase the probability of nuisance noise and damage at either town. After some experience has been gathered there will be a better feeling for the effect of local lake and mountain-valley winds as they change during the daylight hours. Usually, near the mountains the surface wind flows downhill at night and blows uphill during the day. Firing conditions should be best during early afternoon because of high surface temperatures, as well as the local north wind blowing toward the mountains to the south, and away from communities to the north and east.

Generalizations

A similar procedure could be developed for other demolition sites. The most important parameters are the yield and the distance and population of nearby communities. Proper consideration of the local climatology of temperatures and winds, both at the surface and above the boundary layer, can possibly lead to an optimized site selection of certainly to a reasonable yield limitation.

Propagation of 1-mb recorded peak-to-peak wave amplitude correlates fairly well with the lower threshold of complaints. Ranges of this amplitude, for various yield and atmospheric conditions are shown in Table II. Although a 1-lb HE surface burst may, in strong propagation conditions under an early morning temperature inversion, give noise to nearly 2 miles, a 5000 lb HE burst may have its noise restricted to only 3 miles under optimized weather conditions.

Table II

Propagation Ranges for 1-mb Recorded Amplitude

Explosive Weight (lb)	Propagation Range (miles)		
	Downwind or Inversion	Standard	Gradient
1	1.8	0.7	0.2
50	7	2.7	0.7
2000	23	9	2.4
5000	31	12	3.2