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Field Behavior of NBC Agents

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FIELD BEHAVIOR OF NBC AGENTS

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Preface

Primary users of this manual are NBC staff officers, staff weather officers, fire support coordination personnel, artillery officers, and others involved in planning NBC operations. These soldiers must understand what effect weather and terrain have on nuclear, biological, and chemical (NBC) operations and smoke. This manual contains general information and the basic principles on how to get the best results. Commanders and staffs involved in planning for use of incendiaries or smoke operations will also benefit from the use of this manual along with other references such as FM 3-50, FM 3-100, FM 3-3, FM 3-4, and FM 3-5.

On the battlefield, the influences of weather and terrain on NBC operations provide opportunities to both sides. To retain the initiative, friendly forces leaders and staff officers must understand how weather and terrain can be used to their advantage.

FM 3-6 implements International Standardization Agreement (STANAG) 2103, Reporting Nuclear Detonations, Radioactive Fallout, and Biological and Chemical Attacks and Predicting Associated Hazards.

This manual explains how weather and terrain influence nuclear, biological, and chemical operations and discusses the following topics for use when planning operations:

- Basic principles of meteorology as they pertain to NBC operations.
- Influence of weather on the use and behavior of NBC agents.
- Local weather predictions and their use.
- Influence of terrain on the behavior of NBC agents.
- US Air Force Air Weather Service (AWS) forecasts and their use in planning for operations in an NBC environment. (The Navy gets meteorological forecasts from components of the Naval Oceanography Command. Meteorological report information is in the NAVOCEANCOMINST 3140.1 publications series. It also contains information on the behavior of smoke clouds and incendiaries. In addition, it discusses the influences of weather and terrain on the thermal, blast, and radiation effects of a nuclear detonation.)

Staffs planning the use of chemical weapons and commanders approving strikes must understand basic weather characteristics. Therefore, weather analyses significantly influence the selection of agents and munitions for employment. The target analyst must know his or her weather data needs and where to get this information in a combat environment. Chapter 1 covers meteorology and the impact of weather on chemical agent use. The remaining chapters address the impact of weather on smoke, incendiaries, biological agents, and nuclear detonations.

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DEPARTMENT OF THE ARMY
DEPARTMENT OF THE AIR FORCE
UNITED STATES MARINE CORPS
Washington, DC, 3 November 1986

FIELD BEHAVIOR OF NBC AGENTS (INCLUDING SMOKE AND INCENDIARIES)

Table of Contents

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CHAPTER 1

Chemical Agents

The field behavior of chemical agents is dependent on weather variables such as wind, temperature, air stability, humidity, and precipitation. The influence of each variable depends upon the synoptic situation and is locally influenced by topography, vegetation, and soil.

Chemical agents may appear in the field in different forms: vapors, aerosols, or liquids. To understand the impact of chemical agents on the battlefield, the soldier must also understand how these agents are affected by weather and terrain. The following paragraphs give an overview of the basic characteristics of chemical agents and how weather and terrain influence and have specific effects on them.

Basic Characteristics

Vapors and small particles are carried by the winds, while any large particles and liquid drops fall out in a ballistic-like trajectory and are quickly deposited on the ground. Many agents give off vapors that form vapor clouds. The speed at which an agent gives off vapors is called volatility. Agents may be removed naturally from the air by falling out (large particles fall out much more quickly), by sticking to the ground or vegetation, or by being removed by precipitation. Once deposited upon vegetation or other ground cover, volatile agents may be re-released to the atmosphere for further cycles of travel and present a hazard until sufficiently diluted or decontaminated.

During approximately the first 30 seconds, the size and travel of an agent are determined primarily by the functioning characteristic of the munition or delivery system. Thereafter, the travel and diffusion of the agent cloud are determined primarily by weather and terrain. For example, in high temperatures, volatile agents produce maximum agent vapor in 15 seconds. Light winds and low turbulence allow high local concentrations of agents. High winds and strong turbulence reduce the concentration and increase the area coverage by more quickly carrying away and diffusing the agent cloud.

Vapors

When a chemical agent is disseminated as a vapor from a bursting munition, initially the cloud expands, grows cooler and heavier, and tends to retain its form. The height to which the cloud rises, due to its buoyancy, is called the height of the thermally stabilized cloud. If the vapor density of the released agent is less than the vapor density of air, the cloud rises quite rapidly, mixes with the surrounding air, and dilutes rapidly. If the agent forms a dense gas (the vapor density of the released agent is greater than the vapor density of air), the cloud flattens, sinks, and flows over the earth's surface. Generally, cloud growth during the first 30 seconds is more dependent upon the munition or delivery system than upon surrounding meteorological conditions.

Nevertheless, the height to which the cloud eventually rises depends upon air temperature and turbulence. These determine how much cooler, ambient air is pulled into the hot cloud (and, hence, determines its rate of cooling). The agent concentration buildup is influenced by both the amount and speed of agent release and by existing meteorological conditions.

Shortly after release, the agent cloud assumes the temperature of the surrounding air and moves in the direction and at the speed of the surrounding air. The chemical cloud is subjected to turbulence forces of the air, which tend to stretch it, tear it apart, and dilute it. The heavier the agent, the longer the cloud retains its integrity. Under conditions of low turbulence, the chemical agent cloud travels great distances with little decrease in agent vapor concentration. As turbulence increases, the agent cloud dilutes or dissipates faster.

Aerosols

Aerosols are finely divided liquid and/or solid substances suspended in the atmosphere. Sometimes dissolved gases are also present in the liquids in the aerosols. Chemical agent aerosol clouds can be generated by thermal munitions and aerosol spray devices or as by-products of liquid spray devices and bursting munitions.

Airborne aerosols behave in much the same manner as vaporized agents. Initially, aerosol clouds formed from thermal generators have a higher temperature than clouds formed from other types of munitions. This may cause some initial rise of the cloud at the release point. Aerosol-generated clouds are heavier than vapor clouds, and they tend to retain their forms and settle back to earth. Being heavier than vapor clouds, they are influenced less by turbulence. However, as the clouds travel downwind, gravity settles out the larger, heavier particles. Many particles stick to leaves and other vegetative surfaces they contact.

Liquids

When a chemical agent is used for its liquid effect, evaporation causes the agent to form into vapor. Depending upon volatility, vapor clouds are usually of low concentration, have about the same temperature as the surrounding air, and tend to stay near the surface because of high vapor density. Additionally, vapor density governs the extent that the vapor will mix with the air. Liquid agents with high vapor density impact at ground level with very little evaporation of the agent. These agents are termed persistent agents. While drops are airborne, and after impacting, the liquid continues to evaporate. Agent vapor pressure will govern the rate at which the liquid will evaporate at a given temperature and pressure. Initial concentrations are lower, since the vapor source is not instantaneous as a vapor agent is but evolves over a long period (until the liquid source is gone). Liquid agents may be absorbed (soaked into a surface) and adsorbed (adhered to a surface), and they may also evaporate. Once the liquid is no longer present on the surface, desorption (going back into the air) begins. The vapor concentration over areas contaminated with a liquid agent tends to be less than with newly formed vapor clouds, and downwind agent concentrations are not nearly as great as with other types of agents.

Atmospheric Stability

One of the key factors in using chemical weapons is the determination of the atmospheric stability condition that will exist at the time of attack. This determination can be made from a meteorological report or by observing field conditions.

When a meteorological report is available, it should contain a description of the current or projected atmospheric stability condition. If the data given are based on an atmospheric description, Figure 1-1 may be used to convert the data into traditional atmospheric stability categories/conditions. When meteorological reports are not readily available, the stability condition can be derived by using the stability decision tree shown in Figure 1-2. Figure 1-2 is entered at the top with the current observed weather conditions (or estimated weather conditions). Follow the decision tree to determine the stability condition. The stability condition plus the wind speed indicates the dispersion category of an agent vapor cloud.

DISPERSION CATEGORY	ATMOSPHERIC DESCRIPTION	TRADITIONAL ATMOSPHERIC CONDITIONS
1	Very Unstable	Lapse
2	Unstable	Lapse
3	Slightly Unstable	Neutral
4	Neutral	Neutral
5	Slightly Stable	Neutral
6	Stable	Inversion
7	Extremely Stable	Inversion

Figure 1-1. Atmospheric stability categories and conditions.

Unstable conditions will cause lower concentrations and/or poorer target coverage. Stable conditions will cause greater agent stability and higher concentrations. Use Figure 1-2 as guidance for employing an agent by starting in the upper left corner at the word START. Follow the arrowed line to the first question. Answer the question "Is it nighttime?" by selecting, in

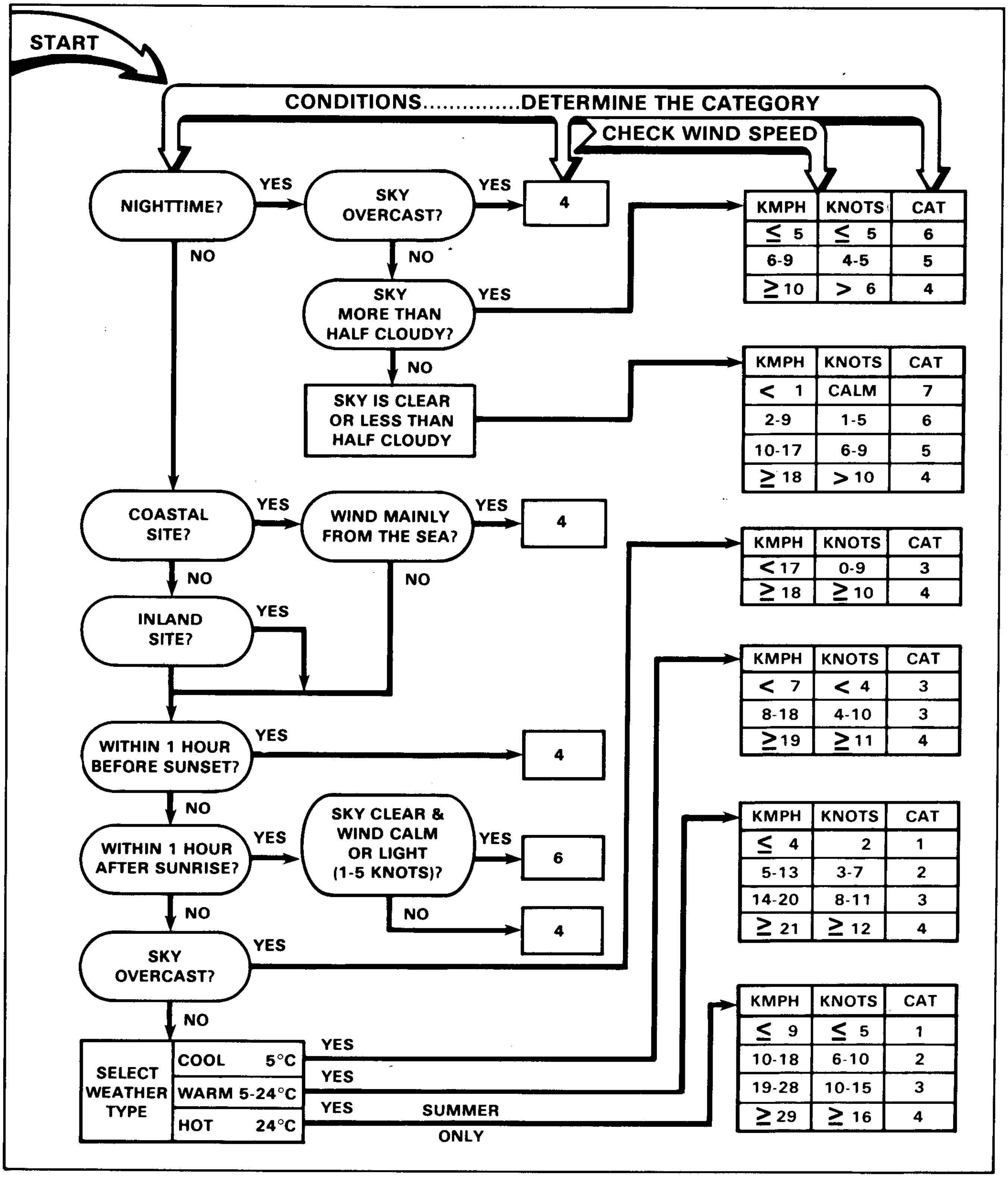

Figure 1-2. Stability decision tree.

accordance with the facts, the yes or no arrow indicating your decision. At each branch in the arrows, follow the arrow most nearly correct for the conditions under which the stability category is required. As questions are encountered along your path, answer each and proceed along the most nearly correct path until a dispersion category is identified. The result from Figure 1-2 is the stability category. An example of the use of Figure 1-2 is if you are inland one hour before sunset and the winds are calm, the stability category is neutral (N) (category 4).

The dispersion category, the wind speed in knots, and the wind direction are the most important meteorological data for deciding the influence of weather on vapor cloud dispersion. For any given dispersion category, a lower wind speed will produce higher dosages, smaller area coverage, and, consequently, higher toxic effects. This is because when the wind speed is lower, the cloud moves more slowly past the individual in the target area; and the individual is in the cloud longer, yielding a higher dose of the agent. See Table 1-1 for the dispersion categories and wind speeds during which atmospheric conditions are either generally favorable, marginal, or unfavorable for employment of chemical agents. Factors such as agent toxicity, target vulnerability, and the amount of the agent released will determine the actual doses, casualties, and other effects. Elevated agent releases will alter the table results somewhat, but the same trends occur. The main effect to be considered for elevated release effectiveness over a specific target is that the agent must be released further upwind to compensate for the drift as the agent comes down.

Table 1-1 is a general reference tool to provide an estimate, based on dispersion category and wind speed, when it would generally be most effective to employ a chemical agent vapor. Table 1-2 indicates the typical cloud widths at given downwind distances from a point source release for a chemical agent vapor cloud. Note that the cloud width depends upon dispersion category and not directly upon wind speed. The cloud width distances represented in Table 1-2 are the dosage contours for 0.01 milligram-minutes per cubic meter (mg-min\M^3). If the agent is released from a line source (spray system), the line length should be added to the cloud width (Table 1-2) to determine total cloud width for travel distances up to 1 kilometer. For longer travel distances, the length of the line source loses its importance (due to dissipation), and the total cloud width is represented by the values in Table 1-2. The chemical cloud widths listed in Table 1-2 are estimates. The widths will vary depending on the weather and terrain of a specific area.

The following examples are cited to explain further the use of Table 1-2. Based on a chemical agent vapor being released from a point source in dispersion category 4, the chemical cloud width at 7 kilometers downwind would be approximately 2.3 kilometers. Based on a chemical agent vapor being released from a line source that is 0.1 kilometer in length (dispersion category 2), the chemical cloud width at a 0.5 kilometer downwind distance would be .850 kilometer (0.75+0.1).

Table 1-3 presents the relative center line dosages (mg-min/M^3) at different distances downwind for different dispersion categories and wind speeds. Remember, low wind speeds at the same dispersion category give higher dosages. The dosages listed in Table 1-3 are estimates and will vary depending on the estimated category and wind speed in the target area. The dosage values in Table 1-3 are based on 100 kilograms of the nonpersistent nerve agent (GB) being released at ground level from a point source.

The information reflected in Table 1-3 is the dosage that would be incurred if the target were stationary. The dosage would decrease if the target were moving through the downwind cloud hazard area. Additionally, in general, if the source strength (100 kg) were doubled, the dosage would also double, and if the source strength were halved, the dosage would also decrease approximately one-half.

To aid in using Table 1-3, the following example is provided. With dispersion category 4, wind speed 8 knots, and a downwind distance of 2 kilometers, the center line dosage would be 18.91 mg-min/M^3. With dispersion category 2, wind speed 3 knots, and at a downwind distance of 4 kilometers, the center line dosage would be 1.030 mg-min\M^3.

Vapor Concentration and Diffusion

Agent concentration is governed by the volume of the agent cloud. Since clouds

Table 1-1. Relative effectiveness of vapor agent usage for different wind speeds and dispersion categories.

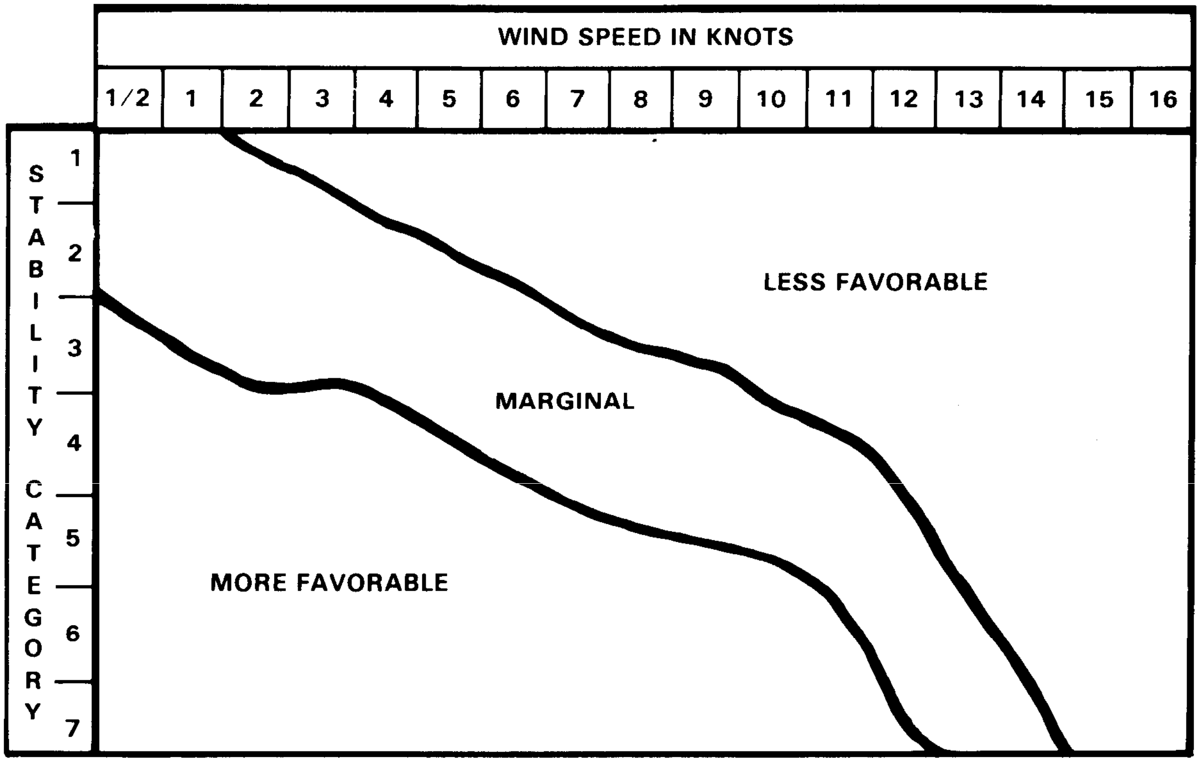

Table 1-2. Chemical cloud width.

STABILITY CATEGORY	DOWNWIND DISTANCE IN KM												
	.5	1	2	3	4	5	6	7	8	9	10	20	30
1	.9	1.6	2.8	3.9	5.0	6.0	6.9	7.8	8.6	9.4	10.2	15.4	19.0
2	.75	1.3	2.4	3.2	4.1	4.8	5.4	6.0	6.6	7.3	7.8	12.9	16.4
3	.5	.9	1.7	2.4	3.1	3.7	4.2	4.7	5.2	5.7	6.2	9.7	12.8
4	.3	.5	.9	1.2	1.5	1.8	2.1	2.3	2.6	2.8	3.1	4.9	6.4
5	.2	.3	.5	.7	1.0	1.0	1.1	1.3	1.4	1.5	1.6	2.6	3.3
6	.1	.2	.3	.3	.4	.5	.5	.6	.6	.7	.7	1.1	1.4
7	VERY LITTLE INCREASE IN CLOUD WIDTH WITH DOWNWIND DISTANCE												

Table 1-3. Center line dosages at different distances downwind for different dispersion categories and wind speeds for a unit source.

Stability Category	Wind Speed	Downwind Distance in km: .5	1	2	4	6	10	20	30
		Dosages (mg-min/M³)							
1	1	57.82	10.960	2.4820	1.2070	.8048	.48290	.24140	.16100
1	3	19.15	3.628	.8224	.3998	.2665	.15990	.07995	.05330
1	5	11.47	2.174	.4928	.2396	.1597	.09582	.04791	.03194
2	3	65.93	16.480	4.121	1.0300	.4671	.22840	.11360	.07575
2	6	32.86	8.215	2.054	.5135	.2328	.11380	.05663	.03775
2	10	19.75	4.938	1.235	.3087	.1400	.06843	.03404	.02269
3	3	172.60	46.26	12.400	3.321	1.5370	.5825	.18010	.11510
3	7	73.86	19.79	5.302	1.421	.6576	.2492	.07703	.04925
3	12	43.09	11.55	3.094	.829	.3837	.1454	.04494	.02874
4	3	572.4	170.20	50.590	15.040	7.398	3.0260	.8997	.44450
4	8	213.9	63.61	18.910	5.622	2.765	1.1310	.3363	.16620
4	16	107.1	31.84	9.467	2.814	1.384	.5662	.1683	.08318
5	2	1,837.0	606.0	199.90	65.94	34.470	15.220	5.021	2.6250
5	5	736.2	242.9	80.12	26.43	13.810	6.101	2.012	1.0520
5	9	408.7	134.8	44.47	14.67	7.668	3.387	1.117	.5839
6	1	10,080.0	3,691.0	1,351.0	494.50	274.70	131.00	47.930	26.630
6	3	3,339.0	1,222.0	447.4	163.80	90.96	43.37	15.870	8.818
6	5	2,001.0	732.4	268.1	98.12	54.51	25.99	9.5120	5.284
7	HIGHER DOSAGES THAN ABOVE								

continually expand, agent concentration levels decrease over time. Wind speed determines the downwind growth of the cloud. Vertical and horizontal turbulence determines the height and width of the cloud. The rate at which the downwind, vertical, and horizontal components expand governs the cloud volume and the agent concentration.

To be effective the agent cloud, at a specific concentration level, must remain in the target area for a definite period. Wind in the target area mixes the agent and distributes it over the target after release. For ground targets, high concentrations and good coverage can best be achieved with low turbulence and calm winds when the agent is delivered directly on target. A steady, predictable wind drift over the target is best when the agent is delivered on the upwind side of the target. Conditions other than these tend to produce lower concentrations and/or poorer target coverage. However, unless weather conditions are known within the target area, the effects of the agent on target will be approximations.

The concentration and diffusion of a chemical agent cloud are also influenced by the factors of hydrolysis, absorption, adsorption, lateral spread, drag effect, and vertical rise.

Hydrolysis is the process of the agent reacting with water vapor in the air. It does not influence most agent clouds in tactical use because the rate of hydrolysis is too slow. However, hydrolysis can be important for smoke screens. See the discussion of the effect of humidity on increasing smoke screen effectiveness in Chapter 2.

Absorption is the process of the agent being taken into the vegetation, skin, soil, or material. Adsorption is the adding of a thin layer of agent to vegetation or other surfaces. This is important in dense vegetation. Both absorption and adsorption of chemical agents may kill vegetation, thus defoliating the area of employment.

When a chemical cloud is released into the air, shifting air currents and horizontal turbulence blow it from side to side. The side-to-side motion of the air is called meandering. While the agent cloud meanders, it also spreads laterally. Lateral spreading is called lateral diffusion. Figure 1-3 shows a cloud with lateral spread and meandering. Table 1-2 indicates the amount of lateral spread that occurs under different dispersion categories and distances downwind. In more unstable conditions, the lateral spread tends to be greater than in stable conditions.

Wind currents carry chemical clouds along the ground with a rolling motion. This is caused by the differences in wind velocity. Wind speeds increase rapidly from near zero at the ground to higher speeds at higher elevations above the ground. The drag effect by the ground, together with the interference of vegetation and other ground objects, causes the base of an agent cloud to be retarded as the cloud stretches out in length. When clouds are released on the ground, the drag amounts to about 10 percent of the vertical growth over distance traveled over grass, plowed land, or water. It amounts to about 20 percent over gently rolling terrain covered with bushes, growing crops, or small patches of scattered timber. In heavy woods, the drag effect is greatly increased. The vertical spread of the cloud is illustrated in Figure 1-4.

Wind speeds can vary at different heights. The wind direction can also change with an increase in height. This is known as wind shear. Because of wind shear, a puff (or chemical cloud) may become stretched in the downwind direction and may travel in a direction different from that of the surface wind. Additionally, a chemical cloud released in the air may be carried along faster than it can diffuse downward. As a result, air near the

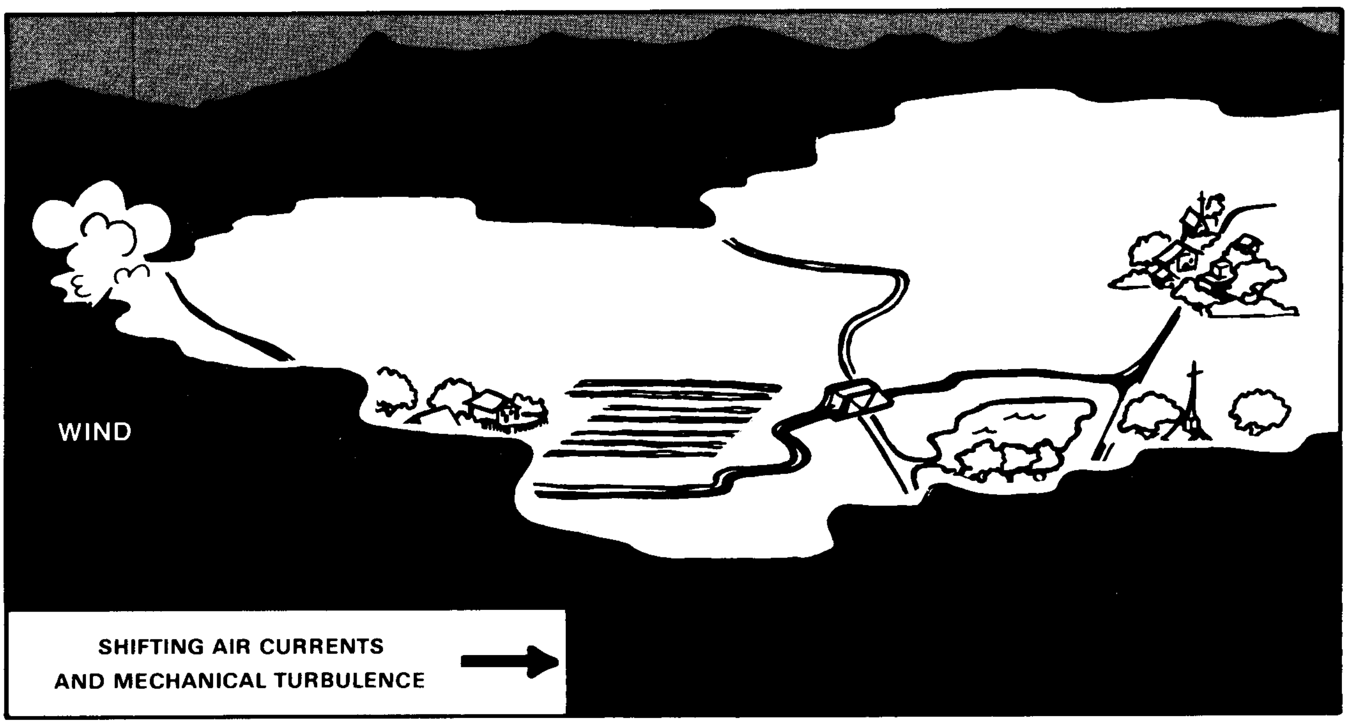

Figure 1-3. Lateral spread of a chemical cloud with some meandering.

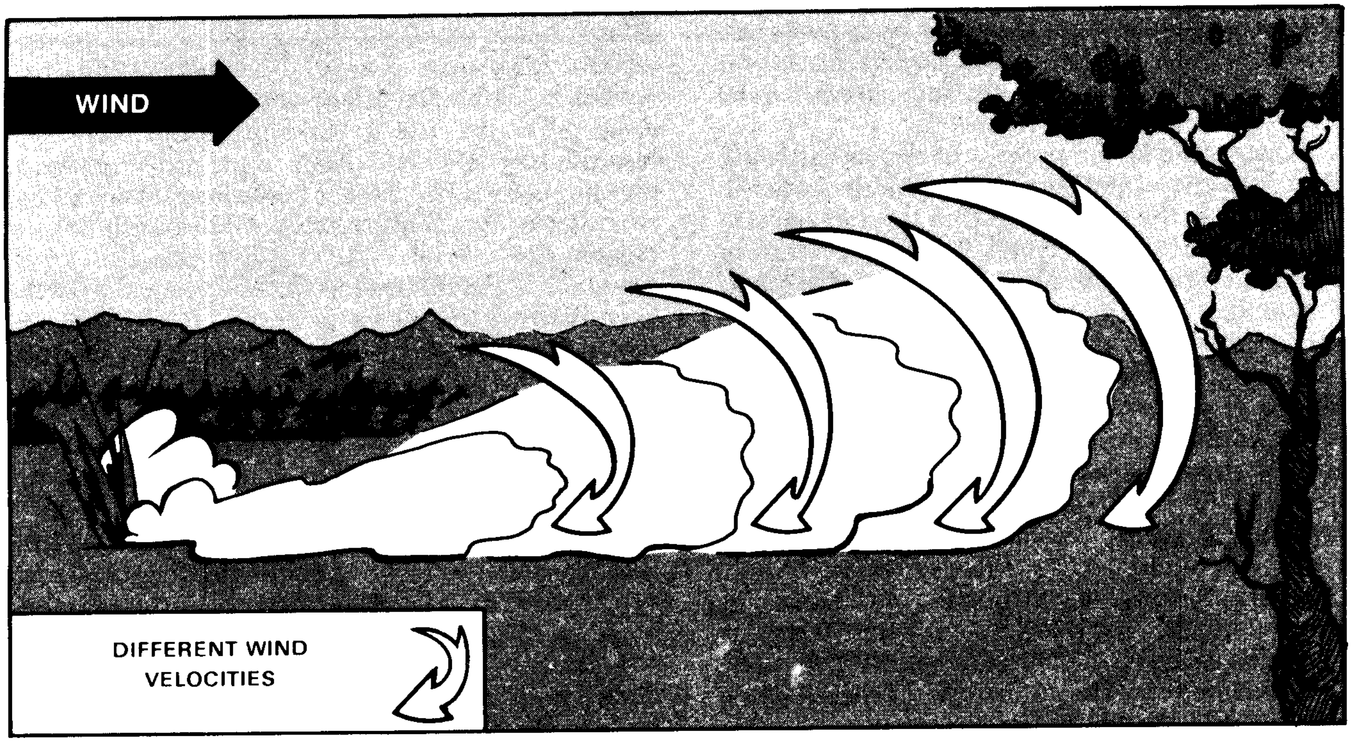

Figure 1-4. Vertical spread of a chemical cloud with drag effect.

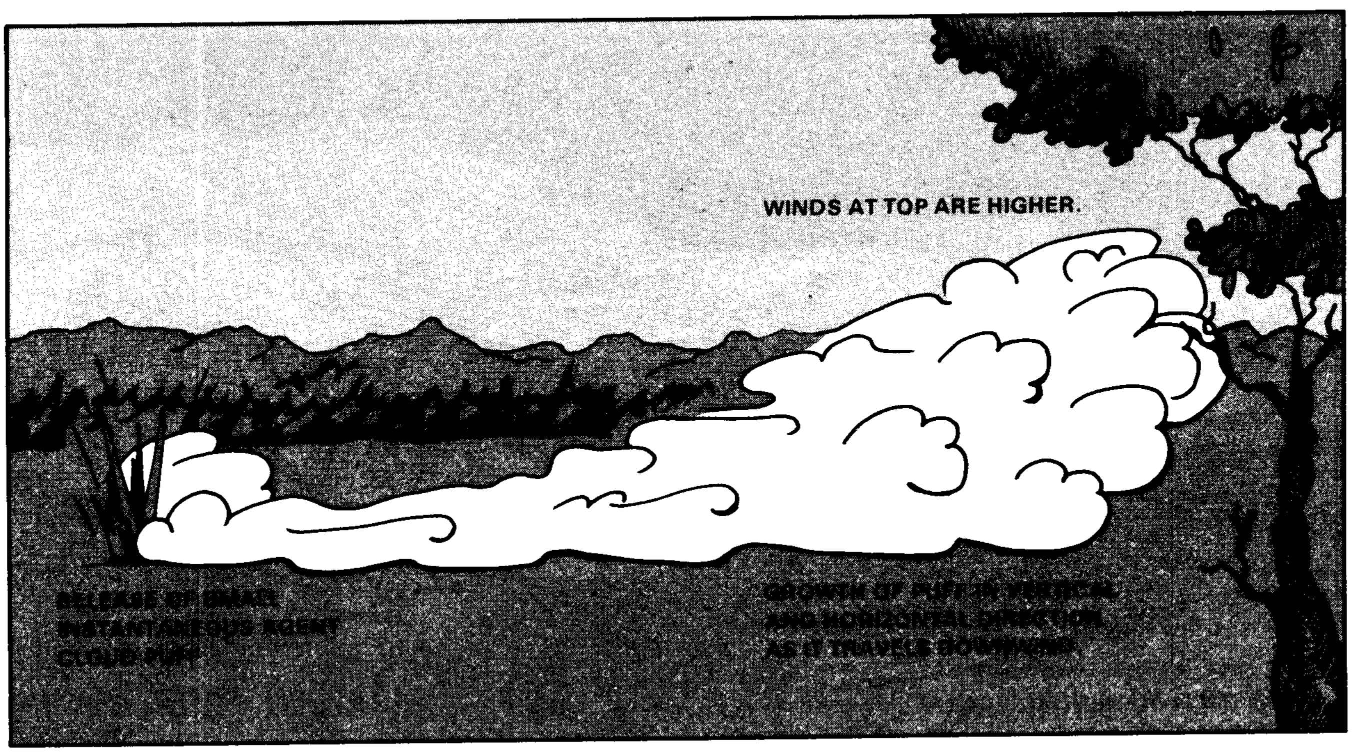

Figure 1-5. Horizontal and vertical spread of a cloud puff.

ground on the forward edge of the cloud may be uncontaminated, while the air a few feet up may be heavily contaminated. This layering effect becomes more pronounced and increases proportionately with the distance of the forward edge of the cloud from the source. Figure 1-5 illustrates this. A small puff of agent cloud released from its source some time earlier has tilted forward, while the bottom has been retarded due to slower winds caused by drag.

The vertical rise of a chemical cloud depends upon weather variables, such as temperature gradient, wind speed, and turbulence, and the difference between the densities of the clouds and the surrounding air. As mentioned earlier, the temperature of both the cloud and the air influences their relative densities. Hotter gases are less dense and, therefore, lighter than cooler gases and air. Therefore, they rise until they are mixed and somewhat diluted and attain the same temperature and approximately the same density as surrounding air.

The vapor cloud formed by an agent normally employed for persistent effect rises in a similar manner, but vapor concentrations build up more gradually.

Vapors and Aerosols

Wind, temperature, humidity, precipitation, terrain contours, and surface cover influence the field behavior of vapors and aerosols. For example, in a chemical attack on US forces (lst Division) 26 February 1918 in the Ansauville section, extremely stable conditions, calm winds, and heavy underbrush in the target area contributed to the overall effectiveness of a chemical attack. Several additional casualties resulted due to the increased chemical agent persistency caused by the favorable weather conditions. Favorable and unfavorable weather

Table 1-4. Summary of favorable and unfavorable weather and terrain conditions for tactical employment of chemical agent vapor or aerosol. (The stability condition listed for the south slope is for the northern hemisphere; due to solar loading on the slope, the situation would be reversed for the southern hemisphere.)

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Wind	Artillery employment if speed is more than 7 knots. Aerial bombs if speed is more than 10 knots.	Steady, 5 to 7 knots, or land breeze.	Steady, less than 5 knots, or sea breeze.
Dispersion Category	Unstable (lapse).	Neutral.	(Stable) inversion.
Temperature	Less than 4.4°C.	4.4° to 21.1°C.	More than 21.1°C.
Precipitation	Any.	Transitional.	None.
Cloud Cover	Broken, low clouds during daytime. Broken, middle clouds during daytime. Overcast or broken, high clouds during daytime. Scattered clouds of all types during daytime. Clouds of vertical development.	Thick, low overcast. Thick, middle overcast.	Broken, low clouds at night. Broken, middle clouds at night. Overcast or broken, high clouds at night. Scattered clouds of all types at night. Clear sky at night.
Terrain	Hilltops, mountain crests. South slopes* during daytime.	Gently rolling terrain. North slopes at night.	Even terrain or open water.
Vegetation*	Heavily wooded or jungle.	Medium dense.	Sparse or none.

*Cloud dissemination occurs above the canopy.

and terrain conditions for tactical employment of a chemical aerosol or vapor cloud are summarized in Table 1-4.

If a chemical cloud is to be placed directly on an occupied area, the best possible weather conditions are calm winds with a strong, stable temperature gradient. Under these conditions, the cloud diffuses over the target with minimum dilution and does not move away. Such conditions are most apt to occur on a calm, clear night. If a small amount of air movement is required to spread the cloud evenly over the target area, a low wind speed and stable or neutral conditions are most favorable. These conditions most often occur on a clear night, a cloudy night, or a cloudy day.

When the desired effect is for the chemical cloud to travel, the most favorable conditions are stable or neutral conditions with a low to medium wind speed of 3 to 7 knots. These conditions may be present on a clear night, a cloudy night, or a cloudy day. The presence of low to medium wind speeds keeps the cloud traveling over the area without too much diffusion, and the stable or neutral conditions keep the agent concentration high and the cloud close to the ground.

Favorable terrain conditions for a chemical cloud are smooth or gently rolling contours or wooded areas. Unfavorable conditions for chemical clouds (usually found on clear days) are extreme or marked turbulence, wind speeds above 10 knots, an unstable dispersion category, rain, and rough terrain.

Wind

High wind speeds cause rapid dispersion of vapors or aerosols, thereby decreasing effective coverage of the target area and time of exposure to the agent. In high winds, larger quantities of munitions are required to ensure effective concentrations. Agent clouds are most effective when wind speeds are less than 4 knots and steady in direction. The clouds move with the prevailing wind as altered by terrain and vegetation. Steady, low wind speeds of 3 to 7 knots enhance area coverage unless an unstable condition exists. With high winds, chemical agents cannot be economically employed to achieve casualties. The chart at Figure 1-2 indicates the effect of wind on stability categories. Tables 1-1, 1-2, and 1-3 indicate the effects of wind and dispersion categories upon dosage and area coverage.

Unstable conditions, as indicated in Figure 1-2 and Tables 1-1, 1-2, and 1-3, are the least favorable conditions. Unstable conditions (such as many rising and falling air currents and great turbulence) quickly disperse chemical agents. Unstable is the least favorable condition for chemical agent use because it results in a lower concentration, thereby reducing the area affected by the agent. Many more munitions are required to attain the commander’s objectives under unstable conditions than under stable or neutral conditions.

Stable conditions (such as low wind speeds and slight turbulence) produce the highest concentrations. Chemical agents remain near the ground and may travel for long distances before being dissipated. Stable conditions encourage the agent cloud to remain intact, thus allowing it to cover extremely large areas without diffusion. However, the direction and extent of cloud travel under stable conditions are not predictable if there are no dependable local wind data. A very stable condition is the most favorable condition for achieving a high concentration from a chemical cloud being dispersed.

Neutral conditions are moderately favorable. With low wind speed and smooth terrain, large areas may be effectively covered. The neutral condition occurs at dawn and sunset and generally is the most predictable. For this reason, a neutral dispersion category is often best from a military standpoint.

Temperature

There will be increased vaporization with higher temperatures. Also, the rate of evaporation of any remaining liquid agent from an exploding munition can vary with temperature. Generally, the rate of evaporation increases as the temperature increases. See FM 3-9/AFR 355-7 for specific information on chemical agents, such as their boiling and freezing points and vapor density.

Humidity

Humidity is the measure of the water vapor content of the air. Hydrolysis is a process in which compounds react with water resulting in a chemical change. Chemical agents with high hydrolysis rates are less effective under conditions of high humidity.

Humidity has little effect on most chemical agent clouds. Some agents (phosgene and lewisite) hydrolyze quite readily. Hydrolysis causes these chemical agents to break down and change their chemical characteristics. If the relative humidity exceeds 70 percent, phosgene and lewisite can not be employed effectively except for a surprise time-on-target (TOT) attack because of rapid hydrolysis. Lewisite hydrolysis by-products are not dangerous to the skin; however, they are toxic if taken internally because of the arsenic content. Riot control agent CS (see glossary) also hydrolyzes, although slowly, in high humidities. High humidity combined with high temperatures may increase the effectiveness of some agents because of body perspiration that will absorb the agents and allow for better transfer.

Precipitation

The overall effect of precipitation is unfavorable because it is extremely effective in washing chemical vapors and aerosols from the air, vegetation, and material. Weather forecasts or observations indicating the presence of or potential for precipitation present an unfavorable environment for employment of chemical agents.

Terrain Contours

Terrain contours influence the flow of chemical clouds the same as they influence airflow. Chemical clouds tend to flow over low rolling terrain and down valleys and settle in hollows and depressions and on low ground. Local winds coming down valleys at night or up valleys during the day may deflect the cloud or reverse its flow. On the other hand, they may produce conditions favorable for chemical cloud travel when general area forecasts predict a calm.

A chemical cloud released in a narrow valley subjected to a mountain breeze retains a high concentration of agent as it flows down the valley. This is because of minimal lateral spread. Hence, high dosages are obtained in narrow valleys or depressions. High dosages are difficult to obtain on crests or the sides of ridges or hills. After a heavy rain, the formation of local mountain or valley winds is sharply reduced. In areas of adjacent land and water, daytime breezes from the water and nighttime breezes from the land control chemical cloud travel.

Surface Cover

Ground covered with tall grass or brush retards flow. Obstacles, such as buildings or trees, set up eddies that tend to break up the cloud and cause it to dissipate more rapidly. However, street canyons or spaces between buildings may have pockets of high concentrations. Flat country (during a neutral or inversion condition) or open water promotes an even, steady cloud flow. Figure 1-5 illustrates the horizontal and vertical spread of a cloud over flat country.

The amount and type of vegetation in the area of the chemical operation also influence the travel of a chemical cloud. Vegetation, as it relates to meteorology or diffusion, is called vegetative canopy or just canopy. The effects of canopies are considered below.

Woods are considered to be trees in full leaf (coniferous or deciduous forests). The term "heavily wooded canopy" denotes jungles or forests with canopies of sufficient density to shade more than 90 percent of the ground surface beneath. For chemical operations, areas containing scattered trees or clumps of bushes are considered to be open terrain although drag is somewhat increased. In wooded areas where trees are not in full leaf or where foliage has been destroyed by previous attack so that sunlight strikes the ground, the diffusion (stability) category will be similar to those in the open.

When bombs are dropped into a wooded area, some may be expected to burst in the treetops. Although the released aerosol and vapor settle toward the ground, some of the agent is lost, depending upon the thickness and height of the foliage. The initial burst and pancake areas of chemical clouds released within woods or jungles are smaller than those released in the open. However, concentrations within the initial clouds are higher in wooded areas, sometimes three times that of bursts in the open. The magnitude of concentration from ground bursts depends upon the density of undergrowth and trees.

Generally, when conditions in the open are most favorable for the use of chemical agents, conditions also are favorable in heavily wooded areas if dispersion occurs below the canopy. Low wind speeds under the canopies spread agent clouds slowly in a downwind and downslope direction. Areas of dense vegetation also increase the potential surface area for the deposition of chemical agents. If there are gullies and stream beds within the woods, clouds tend to follow these features. This flow may be halted or diverted by upslope winds.

Vegetation absorbs some agents. However, for an attack against troops poorly trained in NBC defense (where lethal dosages may be obtained in 30 seconds or less), the amount of agent absorbed by foliage will have little or no effect on the success of the attack. High concentrations of chemical agents may destroy vegetation, since the leaves absorb some of the agent. In some instances, the absorbed agent may be released or desorbed when the vegetation is disturbed or crushed, creating a secondary toxic hazard.

Liquids

Weather, terrain contours, vegetation, soil, and some other surfaces affect the rate of evaporation. That, in turn, influences the persistence of a chemical agent liquid and the concentration of the vapor. Most weather conditions do not affect the quantity of munitions needed for an effective initial liquid contamination. Table 1-5 summarizes favorable and unfavorable weather and terrain conditions for the employment of a liquid chemical agent.

When a liquid agent is used to cause casualties through contact with the liquid in crossing or occupying the area, its duration of effectiveness is greatest when the soil temperature is just above the agent's freezing point. This limits the rate of evaporation of the liquid. Other favorable conditions are low wind speed, wooded areas, and no rain.

Conversely, unfavorable conditions are high soil temperature, high wind speed, bare terrain, and heavy rain.

Favorable and unfavorable conditions for liquid agents for vapor concentration effects are much the same as those for chemical clouds. In woods, however, a high temperature with only a very light wind gives the highest vapor concentrations.

Weather

Duration of the effectiveness of initial liquid contamination may be affected by wind speed; stability, mixing height, and temperature; and precipitation.

Wind Speed

Wind direction is important in determining the upwind side of a target for release purposes but has little impact on the duration of effectiveness, regardless of the method of release The vapor created by evaporation of the liquid agent, however, moves with the wind. Therefore, the vapor concentration is greatest on the downwind side of the contaminated area. Vapors are moved by the wind as discussed earlier in this chapter.

Evaporation due to wind speed depends on the amount of the liquid exposed to the wind (the surface of the liquid) and the rate at which air passes over the agent. Therefore, the duration of effectiveness is longer at the places of greater liquid agent contamination and in places where the liquid agent is sheltered from the wind.

The rate of evaporation of agents employed for persistent effect in a liquid state is proportional to the wind speed. If the speed increases, evaporation increases, thus shortening the duration of effectiveness of the contamination. Increased evaporation, in turn, creates a larger vapor cloud. The vapor cloud, in turn, is dispersed by higher winds. The creation and dispersion of vapor are a continuous process, increasing or decreasing in proportion to wind speed.

Releasing agents for persistent effect by point dispersal via bombs, shells, rockets, or land mines results in an unevenly distributed contaminant. Heavier concentrations of the liquid are found around the point of burst. Lighter concentrations result farther from the bursting position. There probably will be small areas between the points of burst that are not contaminated, depending upon the number of munitions used and the uniformity of dispersal.

Liquid agents released in the form of a spray are fairly evenly distributed, exposing the maximum surface area of the contaminant to the wind. This results in a more rapid evaporation than when the liquid agent is unevenly dispersed (as with bursting munitions). With spraying, the duration of effectiveness decreases, and there is a corresponding increase in the vapor concentration downwind from the sprayed area.

Some chemical agents have no significant vapor pressure, and, consequently, their rates of evaporation are not affected by wind speed. Also,

Table 1-5. Summary of favorable and unfavorable weather and terrain conditions for liquid agent employment.

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Liquid Agents Employed for Liquid Contamination			
Wind	High wind speeds, except liquid agents with little vapor pressure, which are only slightly affected. High turbulence.	Moderate wind speeds.	Low wind speeds for agents with a significant vapor pressure. Higher wind speeds for agents with little vapor pressure. Little or no turbulence.
Dispersion Category	Unstable.	Neutral.	Stable.
Temperature	High soil temperature.	Intermediate.	Surface temperature just above the freezing point of the agent when used for contamination effect.
Humidity	Low.	Intermediate.	High.
Precipitation	Heavy.	Light rain.	None.
Vegetation *	Heavily wooded; jungle canopy.	Intermediate.	Sparse or none.
Soil	Bare, hard ground.	Porous surface.	Intermediate.
Liquid Agents Employed as Aerial Spray for Casualty Effect			
Wind	High wind speeds and high turbulence.	Intermediate.	Low wind speeds with a small degree of turbulence.
Dispersion Category	Unstable.	Inversion if released below the inversion cap.	Neutral.
Temperature	Low.	Intermediate.	Intermediate to high.
Humidity	Low.	Intermediate.	High.
Precipitation	Heavy.	Transitional.	None.
Vegetation	Heavily wooded; jungle canopy.		
Liquid Agents Employed for Vapor Concentrations			
Favorable and unfavorable conditions are much the same as those for chemical agents, vapors, or aerosols (Table 1-4).			
*Cloud dispersal occurs above the canopy.			

some of these agents are extremely toxic, so even a very slight surface concentration represents a massive overkill dosage. When agents of this category are released from spray munitions under low wind speeds, they cover only a narrow zone. When released under higher wind speeds, they cover wider areas more effectively. Thus, when downwind safety is not a limiting consideration, high wind speeds may be more desirable than low wind speeds for these very persistent agents.

With agents that vaporize readily, high wind speeds may cause complete vaporization before the agent reaches the ground, creating only a vapor hazard. The resulting vapor cloud is nonpersistent and dissipates quite rapidly due to the high degree of mechanical turbulence associated with high wind speeds.

Turbulence has the same effect on agents employed for persistent effect, whether released from bombs, rockets, artillery shells, or land mines. Turbulence tends to reduce the duration of effectiveness in the liquid state by helping to increase the rate of evaporation. Temperature, rather than turbulence, has the greater effect on the duration of effectiveness of liquid agents. However, a contaminated area that has been subjected to pronounced turbulence does not remain contaminated as long as one that has been subjected to only slight turbulence with low wind speeds.

Turbulence also influences the spraying of agents employed for persistent effect. High winds and air movements divert the drops from the target or spread them over a larger area. Steep mountain regions sometimes produce large-scale eddies that prevent effective coverage of the target. Any vapor concentrations built up from sprayed areas are slight when the degree of turbulence is high.

Stability, Mixing Height, and Temperature

Unstable conditions are characterized by warmer surfaces. The solar heating then causes evaporation to be more rapid.

Temperature, velocity, and turbulence also affect the dispersion of spray. When stable (inversion) conditions prevail, there usually is little or no thermal turbulence, wind speeds are low, and the degree of mechanical turbulence is also low. Often stable conditions exist continually only near the ground. Above the top of the stable surface layer, wind speed and turbulence are increased. Wind direction here also may be substantially different from the surface wind direction. A chemical spray released below the top of the inversion falls fairly quickly. The height of the top of an inversion varies throughout the period of the surface inversion existence, and it may vary rapidly over large hills and mountains.

The mixing height is the capping inversion at the top of the mixing layer and serves as a lid. It prevents further upward vertical growth of a chemical vapor. A mixing height can also exist above unstable or neutral surface stability conditions. In radiation inversions, which commonly form at night, the top of the surface-based (mixing) stable layer is very close to the earth's surface shortly after the neutral condition changes to a stable condition (soon after sunset). As the surface stable layer intensifies, its top rises, reaching its maximum elevation between 0200 and 0400 hours local time. Maximum elevation may be 400 meters in a very intense stable layer. In the morning, solar radiation heats the surface and causes a good mixing condition close to the ground. The mixing height and turbulence condition increase until they destroy the stable layer. The mixing height can extend from the earth's surface up to 2 kilometers in elevation on a hot summer day. On a calm, clear night, the mixing height may extend only 50 to 100 meters above the earth's surface.

If a chemical agent is released above the surface stable layer, most of the agent remains aloft in the turbulence layer, and most of it will dissipate before settling low enough to be effective. For this reason, most spray missions are flown at either sunrise or sunset to take advantage of a neutral temperature gradient. With this gradient, there is some vertical exchange of air, and the chemical spray, being relatively heavy, has a natural tendency to settle to the ground. The Air Weather Service or an assigned meteorologist can provide information on the mixing height and the height of the top of the surface stable layer.

Under unstable conditions, convection currents often catch many very small droplets and carry them upward above the level of release. As a result, the spray takes longer to reach the ground, and much of it may dissipate before reaching the target area.

Temperature is one of the most important factors affecting the duration of effectiveness and vapor concentration of liquid agents. Agents employed for persistent effect acquire the temperature of the ground and the air they contact. Their evaporation rates are proportional to the vapor pressure at any given temperature. The temperature of the ground surface in winter in temperate zones closely follows the air temperature with a range of only 10 to 20 degrees between day and night. In the summer in temperate zones, the surface temperature may be much higher than that of the air in the daytime and much cooler at night. Turbulence usually accompanies a high ground temperature. The result is that although the vapor concentration in the immediate area may be very high, it falls off rapidly a short distance away. Temperature of vehicles, buildings, and other surfaces may be warmer. This is because of internal heat sources and/or higher solar heating.

From a defensive viewpoint, a dangerous situation is likely to occur on a summer evening when the ground temperature is still high and a stable condition has started to set in. Under these conditions, a heavy vapor cloud produced by evaporation could be dangerous downwind to a distance of 2,000 meters or more. With ordinary concentrations, however, danger from vapor is somewhat less.

Another important temperature factor to consider is that people perspire freely and wear lightweight clothing in a warm climate. Thus, they are more susceptible to the action of chemical agents.

For effective tactical employment of bombs, shells, rockets, and land mines in releasing liquid chemical agents, the actual temperature of the agent itself is vitally important. Generally, liquid agents are not effective when used at temperatures below their freezing points. However, liquid agents can produce casualties when the frozen particles thaw.

Humidity has little effect on how long liquid agents are effective. However, high relative humidity, accompanied by high temperatures, induces body perspiration and, therefore, increases the effectiveness of these agents. Also, permeable protective clothing is less resistant when sweat-soaked than when dry. Since sweaty skin is more susceptible to the action of vapor, lower vapor dosages produce casualties when the humidity is high.

Precipitation

Light rains distribute persistent agents more evenly over a large surface. Since more liquid is then exposed to the air, the rate of evaporation may increase and cause higher vapor concentrations. Precipitation also accelerates the hydrolysis effect. Rains that are heavy or of long duration tend to wash away liquid chemical agents. These agents may then collect in areas previously uncontaminated (such as stream beds and depressions) and present an unplanned contamination hazard.

The evaporation rate of a liquid agent reduces when the agent is covered with water but returns to normal when the water is gone. Precipitation may force back to the surface some persistent agents that have lost their contact effectiveness by soaking into the soil or other porous surfaces. These agents may again become contact hazards.

Snow acts as a blanket, covering the liquid contaminant. It lowers the surface temperature and slows evaporation so that only very low vapor concentrations form. When the snow melts, the danger of contamination reappears.

Terrain Contours

Terrain relief has little direct effect on a liquid agent. However, a slope affects temperatures and winds, and these influence the evaporation rates of liquid agents. However, the slope or contour may affect the delivery means capable of most efficiently delivering the agent on an area (for example, reverse slopes are normally not good for artillery employment, and mountainous terrain may restrict use of spray tanks).

Vegetation

When persistent agents are used in vegetated areas, some of the contaminant clings to grass and leaves. This increases the surface agent exposed to the air and, hence, the rate of evaporation. Personnel become most susceptible to liquid chemical agents in vegetated areas, because they are more apt to come in contact with the agent by brushing against the foliage. Within shaded woods, however, despite the greater surface covered by the liquid chemical agent (because of the vegetation), the reduction in surface temperature and wind speed increases the duration of effectiveness.

When bombs or shells burst in woods, usually most of the liquid falls near enough to the ground to be effective. An exception is bursts in virgin forests with dense canopies that may extend to 50 meters high.

A thick jungle or forest canopy usually prevents liquid agent spray from airplanes from reaching the ground in quantities sufficient to produce significant casualties. When stable conditions exist above the forest canopy, however, enough vapor penetrates the canopy to cause casualties.

Soil

The soil on which liquid agents are placed influences the evaporation rate and the duration of effectiveness. Bare, hard ground favors short-term effectiveness and high-vapor concentration. If the surface is porous, such as sand, the liquid agent quickly soaks in; and the area no longer appears to be contaminated.

The rate at which liquid agents evaporate from a sandy or porous surface is about 1/3 less than the evaporation rate from nonabsorbent surfaces. Extended contact with a contaminated porous material is dangerous if unprotected. However, if there is no free liquid on the surface, the danger from brief contact is relatively small if protected. If a porous surface on which liquid contamination falls has been wet by rain, the contaminant does not soak in as readily, and the surface is initially more dangerous to touch than it would be if the liquid agent had soaked in. When a mustard agent (HD) falls onto a wet surface, it stays in globules; and a thin, oily film spreads over the surface, making contamination easier to detect.

Other Surfaces

Persistence of liquids on painted surfaces of vehicles is much shorter than on most terrain. This is due to a number of factors, including increased surface temperature, turbulence of airflow over the vehicles or other equipment, and greater spread of drops to give more surface area for evaporation.

Persistence varies greatly with surface material. Absorption, adsorption, and resorption also vary with surface material. Rubber absorbs most agents rapidly and desorbs slowly. Chemical agent resistant coating (CARC) absorbs very little agent.

CHAPTER 2

Smoke and Incendiaries

Smoke and incendiaries are combat multipliers. Their effective use on a target can provide tactical advantages for offensive and defensive operations. For example, smoke has long been employed as a means of concealing battlefield targets. Additionally, incendiary fire damage causes casualties and materiel damage and can also impact psychologically.

Smoke

Chemical smokes and other aerosol obscurants can degrade the effectiveness of sophisticated antitank guided missiles (ATGMs). The precision guidance systems of ATGMs are typically electro-optical devices and generally operate in the near-, mid-, or far-infrared portions of the electromagnetic spectrum, rather than in the visible light band of the spectrum. The use of smoke in the target area can be a convincing combat multiplier offensively and a dynamic countermeasure defensively. Smoke should be of primary interest to all commanders and staff planners because the proper use of smoke can provide many operational advantages.

Smoke has four general uses on the battlefield—obscuring, screening, deceiving, and identify ing/signalling. Obscuring smoke is placed on an enemy to reduce vision both at, and out from, the position. Screening smoke is used in friendly operational areas or between friendly units and the enemy. Deceiving smoke is used to mislead the enemy. Identifying/signalling smoke is a form of communication that has multiple uses. Overall, the objective of smoke employment is to increase the effectiveness of Army operations while reducing the vulnerability of US forces. Specifically, smoke can be used to accomplish the following:

- Deny the enemy information.
- Reduce effectiveness of enemy target acquisition.
- Disrupt enemy movement, operations, command, and control.
- Create conditions to surprise the enemy.
- Deceive the enemy.

During offensive operations, smoke can screen the attacker while an attack is carried out. Some offensive applications include concealing movement of military forces and equipment; screening locations of passages through barriers; and helping to secure water crossings, beachheads, or other amphibious operations.

For defensive operations, smoke can be effectively used to blind enemy observation points to deprive the enemy of the opportunity to adjust fire, to isolate enemy elements to permit concentration of fire and counterattack, and to degrade the performance of threat ATGMs.

There are generally two categories of smoke operations on a battlefield-hasty and deliberate smoke. Hasty smoke operations are conducted with minimum prior planning, normally to counter some enemy action or anticipated action of immediate concern to a commander. Hasty smoke is usually used on small areas, is of short duration, and is most often used by battalion or smaller units. Deliberate smoke is planned in much greater detail. It is often employed over a large area for a relatively long period by brigades, divisions, or corps. For further information on hasty and deliberate smoke operations, refer to FM 3-50.

The following paragraphs on smoke operation contain information on smoke characteristics, diffusion of smoke, weather effects, hasty and deliberate smoke operations, and tactical considerations.

Characteristics

Smoke is an aerosol that owes its ability to conceal or obscure to its composition of many small particles suspended in the air. These particles scatter or absorb the light, thus reducing visibility. When the density or amount of smoke material between the observer and the object to be screened exceeds a certain minimum threshold value, the object cannot be seen.

The effectiveness of smoke used to obscure or conceal depends primarily on characteristics such as the number, size, and color of the smoke particles. Dark or black smoke absorbs a large proportion of the light rays striking individual smoke particles. In bright sunlight, a large quantity of black smoke is required for effective obscuration because of the nonscattering properties of the particles. At night or under low visibility conditions, considerably less smoke is needed.

Grayish or white smoke obscures by reflecting or scattering light rays, producing a glare. During bright daylight conditions, less white smoke than black smoke is required to obscure a target. Years of experience with smoke screen technology have shown that white smoke is superior to black smoke for most applications. Available white smoke includes white phosphorus (WP) and red phosphorus (RP) compounds, hexachloroethane (HC), and fog oil (SGF2). WP, RP, and HC are hydroscopic—they absorb water vapor from the atmosphere. This increases their diameters and makes them more efficient reflectors and scatterers of light rays. Fog oils are nonhygroscopic and depend upon vaporization techniques to produce extremely small diameter droplets to scatter light rays. The reflecting and absorbing qualities of smoke are illustrated in Figure 2-1.

Smoke, when placed between a target and a viewer, degrades the effectiveness of target-acquisition and aiming systems. The amount of smoke necessary to defeat aiming and acquisition systems is highly dependent upon the prevailing meteorological conditions, terrain relief, available natural light, visibility, and the attenuation effects of natural particles in the atmosphere. Other factors that must be considered include smoke from battlefield fires and dust raised by maneuvering vehicles and artillery fire.

The ability to detect and identify a target concealed by such a smoke screen is, in turn, a function of target-to-background contrast. Additionally, the amount of available natural light, the position of the sun with respect to the target, the reflectance of the smoke screen and the target, and the portion of the electromagnetic spectrum to be attenuated below the threshold contrast for detection will impact on detecting and identifying a target.

Diffusion

The diffusion of smoke particles into the surface and planetary boundary layers of the

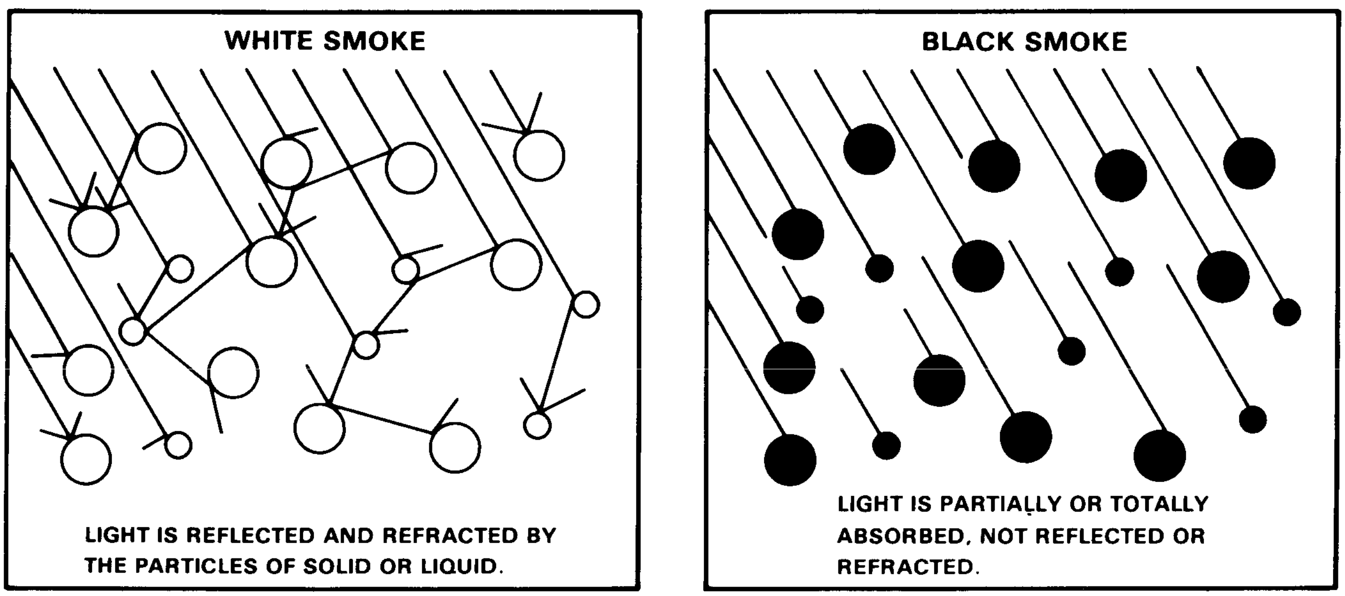

Figure 2-1. Action of smoke particles on light radiation.

atmosphere generally obeys physical laws. Diffusion is governed by wind speed, turbulence, stability of the atmosphere, and terrain. The diffusion of smoke, as used on the battlefield, originates from four basic source configurations. These may be defined as continuous point sources, instantaneous point sources, continuous line sources, and area sources. A continuous point source may bethought of as a smoke release from a single smoke generator or smoke pot. The bursting of a projectile containing WP is considered to be an instantaneous source. A series of generators, set up crosswind, represent a line source. Munitions which scatter smoke-generating submunitions in an area are considered an area source.

Weather Effects

Meteorological conditions that have the most effect on smoke screening and munitions expenditures (including the deployment of smoke generators) include wind direction, relative humidity, visibility, and atmospheric stability. To be effective, an obscuring screen must be placed in an advantageous position with respect to the prevailing wind direction. The target area to be screened must be defined in terms of whether the prevailing wind direction is considered to be a head or tail wind, a quartering wind, or a flank wind. Figure 2-2 illustrates these conditions. It must be remembered that flanking winds can be from either the right or left side of the screening area and that there are four quartering-wind directions. Wind direction is critical for determining the adjustment or aim point for screens deployed by artillery or mortars and also for the placement of generators if used to produce either hasty or deliberate smoke.

As smoke is released into the atmosphere, it is transported and diffused downwind. The plume is depleted quite rapidly by atmospheric turbulence. The obscuration power of the plume becomes marginal at relatively short downwind distances and must be replenished at each point where the attenuation of a line of sight approaches a minimum. The transport wind speed and direction for a diffusing plume in the surface boundary layer of the atmosphere occurs at a height of about half of the plume height. Usually, this would be a height of about 10 meters. For smoke operations, then, speeds and directions should be obtained for a height of about 10 meters above the surface.

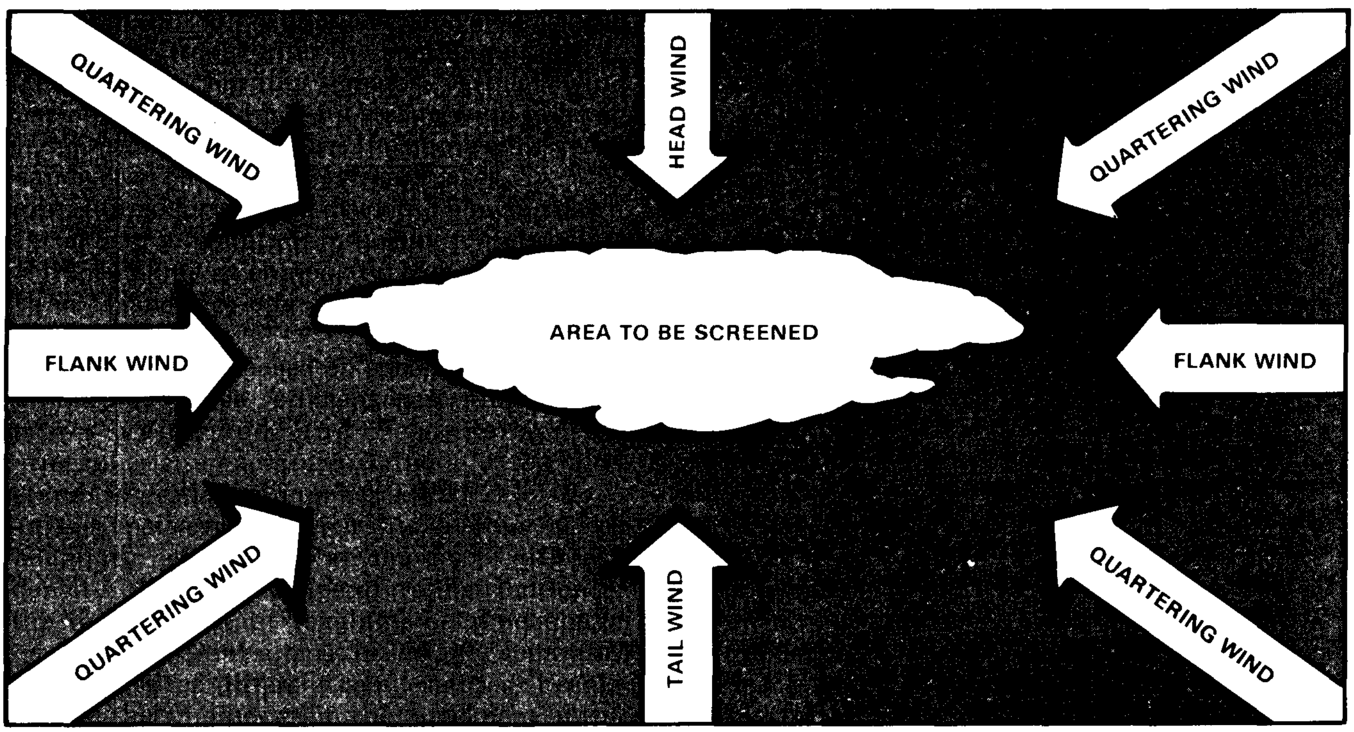

Figure 2-2. Prevailing wind directions.

The relative humidity of the atmosphere is important to the use of smoke on a battlefield. As previously stated, WP, RP, and HC smoke compounds are hydroscopic—they absorb moisture from the atmosphere. As relative humidity increases, the amount of screening material available for target obscuration increases. For example, the HC compound is considered to be only about 70-percent efficient; that is, for every 100 grams of HC in a munition, only 70 grams are available for screening. If the relative humidity yield factor is then added in, the screening power of HC increases. This is shown in Table 2-1. Applicable technical references indicate the amount of HC or WP contained in various munitions. For example, the 105-millimeter WP (M416) round contains 6 pounds of WP; the 155-millimeter HC (Ml16A1) round contains 5.45 pounds of HC; and the 76-millimeter WP (M361A1) round contains 1.38 pounds of WP (453.6 grams equals 1 pound).

Table 2-1. Smoke yields for HC and WP in various relative humidities.

RELATIVE HUMIDITY %	100 g HC (70% efficient)		100 g WP (100% efficient)	
	YIELD FACTOR	YIELD	YIELD FACTOR	YIELD
10	1.46	102 g	3.53	353 g
20	1.52	106	3.72	372
30	1.59	111	3.91	391
40	1.73	121	4.11	411
50	1.89	132	4.34	434
60	2.11	148	4.65	465
70	2.40	168	5.10	510
80	3.25	228	5.88	588
90	5.72	400	7.85	785

Phosphorous compounds are considered to be better screening agents than HC. This is because WP and RP have large yield factors for various relative humidities. Yields for WP are also shown in Table 2-1. Upon ignition, WP burns at a temperature of about 800°C to 850°C. As a consequence, the smoke from a WP munition pillars, creating an excellent vertical screen, especially with high relative humidities. However, only about 10 percent of the smoke generated from WP munitions is available for screening near the ground. This should be considered when planning smoke missions.

Battlefield visibility can be practically defined as the distance at which a potential target can be seen and identified against any background. Reduction of visibility on a battlefield by any cause reduces the amount of smoke needed to obscure a target.

Turbulence, atmospheric instability, and wind speed can have an adverse effect upon smoke expenditures. Unstable conditions are usually considered to be unfavorable for the use of smoke. Under calm or nearly calm conditions, the use of smoke is also sometimes unsatisfactory. In general, if the wind speed is less than 3 knots or greater than 20 knots, smoke can be an unsatisfactory countermeasure on the battlefield.

Operations

Smoke operations are of two types: hasty and deliberate.

Hasty Smoke

Hasty smoke generally is placed in the area to be screened by artillery, smoke pots, or mortar projectiles. Obscuring smoke usually is employed on enemy forces to degrade their vision both within and beyond their location. Screening smoke is used in areas between friendly and enemy forces to degrade enemy ground and aerial observation and to defeat or degrade enemy electro-optical systems. Screening smoke also may be employed to conceal friendly ground maneuver. Deception or decoy smoke is used in conjunction with other measures to deceive the enemy regarding friendly intentions. Decoy smoke can be used on several approaches to an objective to deceive the enemy as to the actual avenue of the main attack.

In the offense, hasty smoke may be used to establish screens, enabling units to maneuver behind or under screens and deny the enemy information about strength, position, activities, and movement. Ideally, a screen should be placed approximately 500 to 800 meters short of the enemy to allow for maximum visibility for mounted forces during the final assault. Hasty screens on the flanks also can be used. Flanking screens can be produced with mechanized generators. Hasty obscuring smoke also may be placed on enemy strongpoints.

On defense, hasty smoke may be used to impede and disrupt enemy formations. It also may be used beyond the forward line of own troops (FLOT) to silhouette Threat targets as they emerge through the smoke and are engaged. Smoke screens also may be used to conceal defensive positions and cover disengaging and moving forces. Mechanized smoke generator units are ideal for this type of hasty smoke.

Figure 2-3 shows the positioning of an obscuring hasty smoke cloud on enemy forces for tail wind and head wind conditions. Figure 2-4 illustrates screening smoke for flank and quartering winds ahead of an advancing force. Figure 2-5 is an example of mechanized units generating a smoke screen for a counterattacking force.

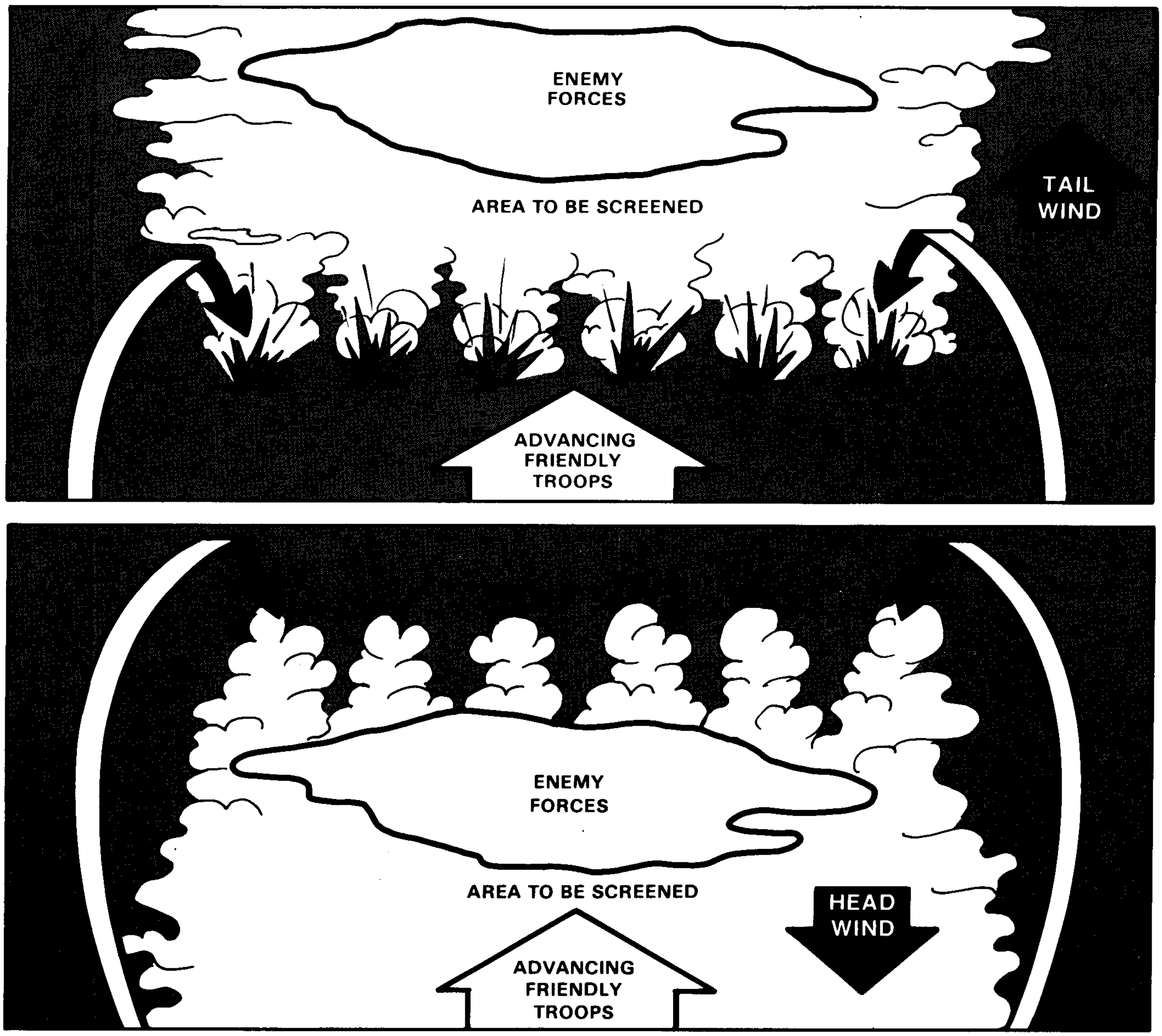

Figure 2-3. Obscuring smoke clouds for tail and head wind conditions.

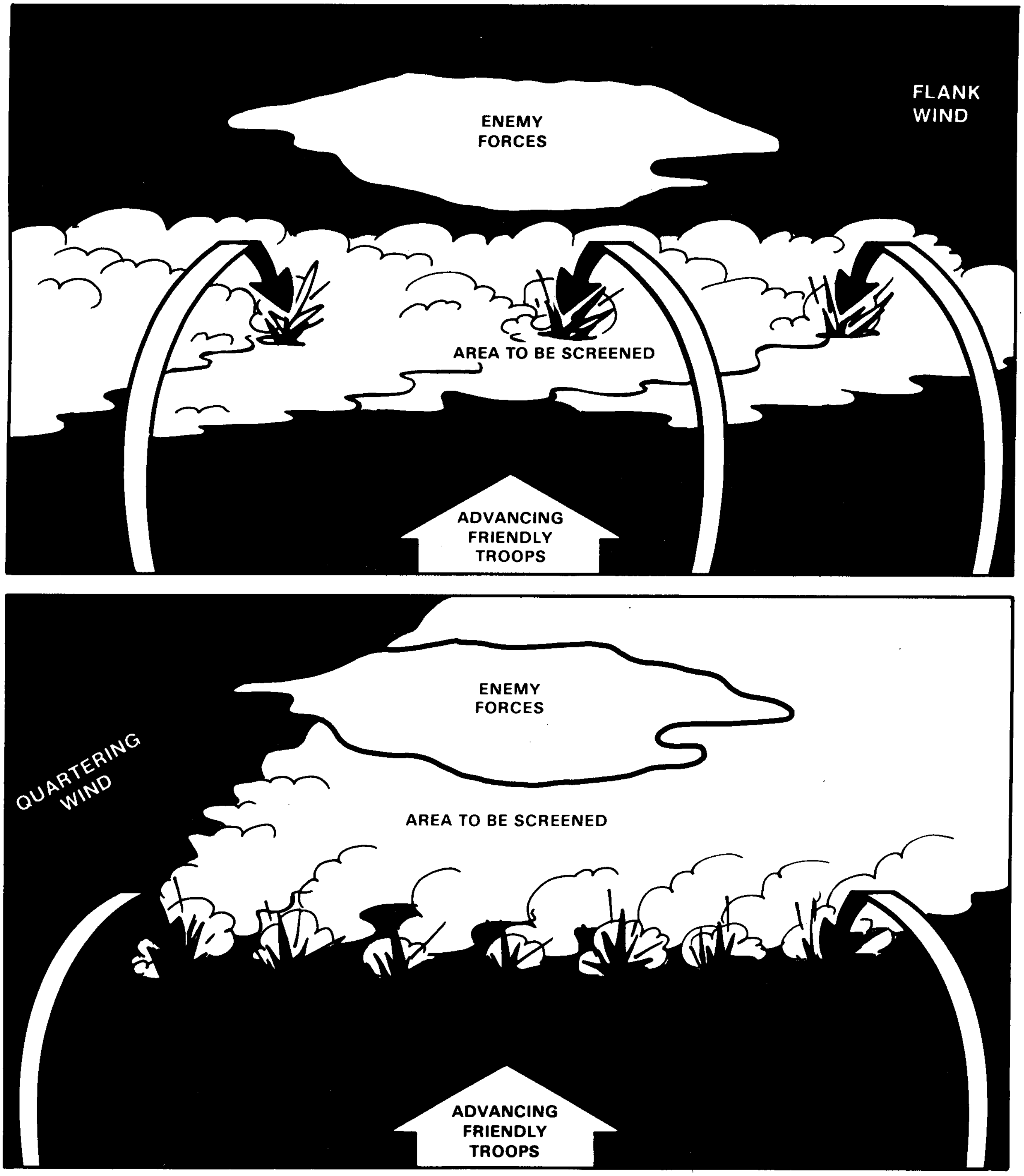

Figure 2-4. Screening smoke cloud for flank and quartering wind conditions.

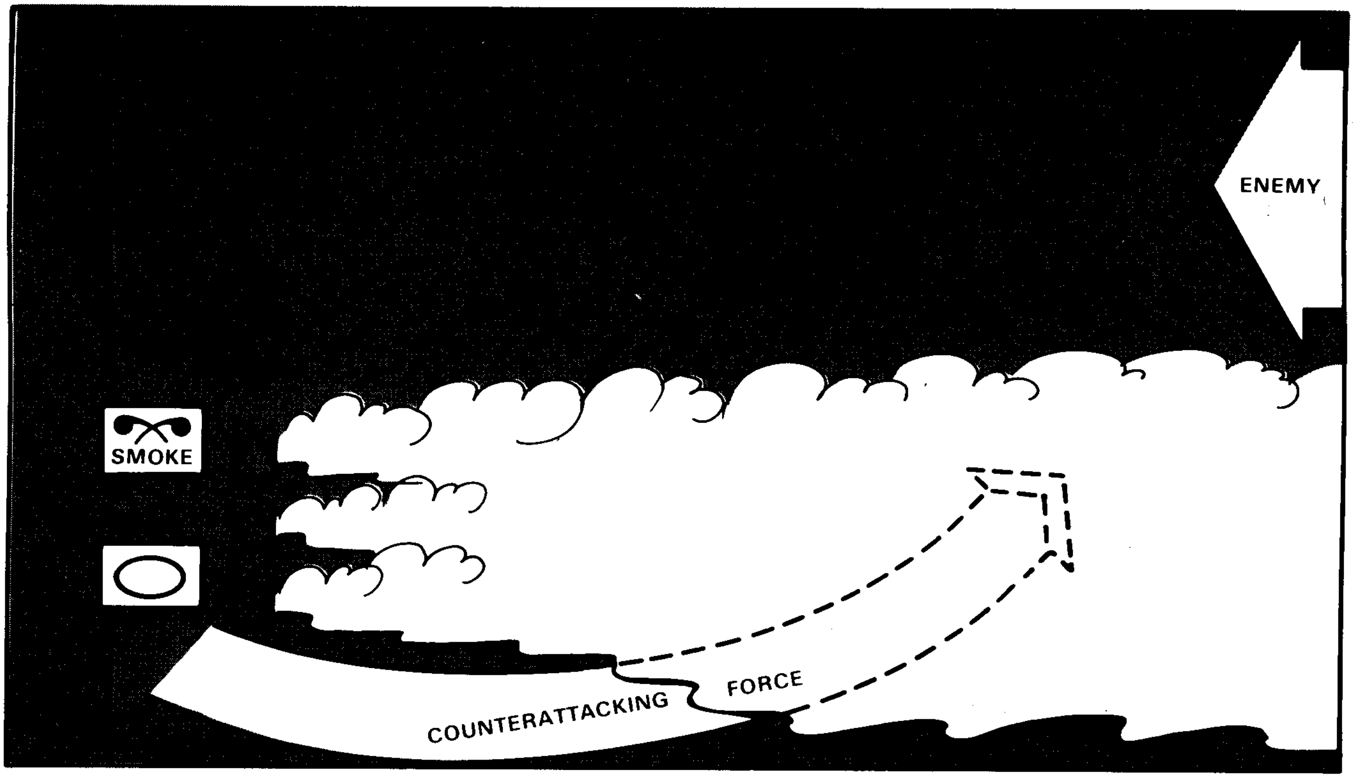

Figure 2-5. Mechanized smoke vehicles screening a counterattacking force.

Deliberate Smoke

Large area smoke screens generally fall within the realm of deliberate smoke in that they are usually planned well in advance of the operation. Large area screening or the establishment of a smoke blanket or haze is generally carried out by the use of smoke generators. Generators usually are positioned in a line source configuration at a right angle to the prevailing wind direction. Usually, if the terrain allows it, the generators are evenly spaced along the smoke line. Generators are ideal for screening river crossings if the prevailing wind direction is upstream, downstream, or a tail wind.

The employment of large smoke is probably most effective if the screen is generated before sunrise when stable conditions and light-to-moderate winds are most likely. Screens generated in these conditions will remain close to the ground with only moderate vertical diffusion. Screens also reduce incoming solar radiation reaching the ground so that convective turbulence is suppressed, similar to overcast weather conditions. Thus, smoke hazes and blankets can be maintained and remain useful for longer time periods.

The use of large area smoke screens in any area depends upon the prevailing wind direction. Operators must be prepared to shift their generators to preselected locations if the wind direction changes.

Tactical Considerations

In addition to the importance of wind direction, relative humidity, visibility, stability, and turbulence to the successful completion of a smoke mission, the effects of terrain and soil conditions should be considered. Terrain effects discussed in Appendix C apply to smoke as well as NBC agents. A diffusing smoke plume also tends to follow the terrain-influenced surface winds. Also, in forests and jungles smoke has a tendency to be more evenly dispersed and to persist longer than over more open terrain.

The condition of the soil influences the effectiveness of artillery-delivered and mortar-delivered smoke but has very little direct effect upon screening or obscuring smoke. An impacting smoke munition bursting in soft soil loses effectiveness since part of the filling compound is driven into the dirt. In some cases, totally ineffective screens result if smoke munitions are delivered to a boggy or swampy target area.

A last point to consider involves wind direction effects upon smoke screens. Munitions expenditures for a screen deployed in quartering wind conditions must be increased by a factor of about 1.5 over a flank wind direction condition. For head and tail winds, expenditures are three to four times those for flank winds. Thus, reduction in expenditures owing to visibility and relative humidity effects may be negated by wind directions.

Incendiaries

Weather conditions have little influence on incendiary munitions themselves. Wind and precipitation, however, may greatly influence the combustibility of the target and its susceptibility to fire spread. The purposes of incendiaries are to cause maximum fire damage on flammable materials and objects and to illuminate. Initial action of the incendiary munition may destroy these materials, or the spreading and continuing of fires started by the incendiary may destroy them. Incendiary materials used include gasoline gels, burning metals, incendiary mixes, and white phosphorus.

To be effective, incendiary munitions should be used against targets susceptible to fire or heat damage. A considerable part of the target must be flammable, so the fire can spread. Fire walls and cleared lanes offer some resistance to the spread of fires.

Winds assist in the effectiveness of incendiaries, increase the rate of combustion, and can spread fires downwind more rapidly. Actually, each large fire can create a wind system of its own. This wind system results from the tremendous heat generated and the resulting vertical wind currents. Incoming winds can feed more air to the fire. This increases the rate of combustion, which, in turn, can increase the wind. In extreme cases, this wind is called a fire storm and sometimes exceeds 60 knots.

Smoke, sparks, and flames fly in the direction of the wind. Incendiary strikes (at successive targets) should be planned to begin with the farthest downwind target and proceed upwind. This will prevent aiming points from becoming obscured by smoke traveling downwind of initial fires. Additionally, the position of friendly forces or facilities that must not be damaged must be considered (in relation to the wind direction) when planning incendiary strikes.

Temperature, temperature gradient, and clouds have little if any effect on incendiaries. Humidity also has little effect upon incendiary munitions but may affect combustible material. Wood, vegetation, and similar material absorb some moisture from the air over a period. If relative humidities have been high for some time, as in the tropics, it may be more difficult to achieve combustion from incendiary action.

Rain or snowfall, even when light, can render grass and brush quite incombustible and make a continuing fire unlikely. Heavy timbers are not affected unless they have been exposed to long periods of precipitation. Combustible materials exposed to rain may be susceptible to fire damage, such as in mass incendiary attacks. In these attacks, the heat of combustion may be sufficient to dry combustible materials in the target area.

In regions of high humidities, such as the tropics, mass incendiary attacks generate tremendous amounts of heat, causing vertical wind currents. This rising air can cause thunderstorms, counteracting the effects of the incendiaries.

It is difficult to extinguish burning metals with water; a spray actually speeds the burning. Water surrounding the area of burning metals prevents fire spread. Water extinguishes burning phosphorus, but unconsumed particles will burn again when dry.

Three elements of terrain affect the efficient use of incendiaries. These are soil, vegetation, and topography. The type of soil affects the impacting of the munition; combustibility of the vegetation affects the efficiency of the incendiary; and topography influences wind speed and direction.

CHAPTER 3

Biological Agents and Nuclear Detonations

In a general war, US forces may be faced by an enemy capable of employing nuclear or biological weapons. The effects of weather and terrain on biological agent aerosols and on nuclear weapons follow.

Biological Agents

In a general war, US forces may be faced by an enemy capable of producing and employing biological agents. These include disease-causing microorganisms (pathogens) and toxins. Toxins are biologically derived chemical substances that have desirable characteristics for use as biological warfare agents. Toxins may be natural or synthetic.

Biological agents will most likely be disseminated as an aerosol. Therefore, a basic knowledge of their field behavior is essential for estimating friendly vulnerability. These agents differ from chemical agents in some aspects of field behavior. Pathogens decay as a result of factors such as weathering. They also require time to invade a body and multiply enough to overcome the body's defenses. This is known as the incubation period. This period may vary from hours to months, depending on the type of pathogen.

The following paragraphs discuss biological agent dissemination, weather effects, and terrain influences, and they briefly summarize the influence of these on biological agent field behavior.

Dissemination

Pathogens are most likely to be disseminated as aerosols. Toxins, on the other hand, may be disseminated as either aerosols or large liquid drops. An aerosol is composed of particles containing pathogens or toxins. The force of the wind moves it along. At the same time, the aerosol spreads by turbulent diffusion.

Biological agents that die rapidly are said to have a high decay rate. High wind speeds (10 to 20 knots) carry these agents over more extensive areas during the agent survival period. Multiple wind shifts occur at low wind speeds. These shifts may cause more lateral spread and downwind diffusion than higher speeds. Optimum effect depends on the nature of the agent and atmospheric conditions. Highly virulent (malignant) agents with low decay rates can spread over large areas (by low or high wind speeds) and still present a casualty threat. Virulent agents with higher decay rates employed under the same atmospheric conditions are much less effective.

Weather Effects

Air stability, temperature, relative humidity, pollutants, cloud coverage, and precipitation have an effect on biological agents.

Air Stability

Atmospheric stability influences a biological cloud in much the same way it affects a chemical cloud. However, biological agents may be more effective in lower concentrations than chemical agents. This is because of their high potency. A stable atmosphere results in the greatest cloud concentration and area coverage of biological agents. Under unstable and neutral stability conditions, more atmospheric mixing occurs. This leads to a cloud of lower concentration, but the concentration is sufficient to inflict significant casualties. The coverage area under unstable stability conditions is also reduced.

Temperature

Air temperature in the surface boundary layer is related to the amount of sunlight the ground has received. Normal atmospheric temperatures have little direct effect on the microorganisms of a biological aerosol. Indirectly, however, an increase in the evaporation rate of the aerosol droplets normally follows a temperature increase. There is evidence that survival of most pathogens decreases most sharply in the range of -20°C to -40°C and above 49°C. High temperatures kill most bacteria and most viral and rickettsial agents. However, these temperatures will seldom if ever be encountered under natural conditions. Subfreezing temperatures tend to quick-freeze the aerosol after its release, thus decreasing the rate of decay. Exposure to ultraviolet light—one form of the sun's radiation—increases the decay rate of microorganisms. Ultraviolet light, therefore, has a destructive effect upon the biological aerosol. Most toxins are more stable than pathogens and are less susceptible to the influence of temperature.

Relative Humidity

The relative humidity level favoring employment of a biological agent aerosol depends upon whether the aerosol is distributed wet or dry. For a wet aerosol, a high relative humidity retards evaporation of the tiny droplets containing the microorganisms. This decreases the decay rate of wet agents, as drying results in the death of these microorganisms. On the other hand, a low relative humidity is favorable for the employment of dry agents. When the humidity is high, the additional moisture in the air may increase the decay rate of the microorganisms of the dry aerosol. This is because moisture speeds up the life cycle of the microorganisms. Most toxins are more stable than pathogens and are less susceptible to the influence of relative humidity.

Pollutants

Atmospheric pollutant gases can also affect the survival of pathogens. Pollutant gases have been found to decrease the survival of many pathogens. These gases include nitrogen dioxide, sulfur dioxide, ozone, and carbon monoxide. This could be a significant factor in the battlefield over which the air is often polluted.

Cloud Coverage

Cloud coverage in an area influences the amount of solar radiation received by the aerosol. Thus, clouds decrease the amount of destructive ultraviolet light the microorganisms receive. Cloud coverage also influences factors such as ground temperature and relative humidity, as discussed in Chapter 1.

Precipitation

Precipitation may wash suspended particles from the air. This washout may be significant in a heavy rainstorm but minimal at other times. High relative humidities associated with mists, drizzles, and very light rains are also an important factor, These may be either favorable or unfavorable, depending upon the type of agent. The low temperatures associated with ice, snow, and other winter precipitation prolong the life of most biological agents.

Terrain Influences

Soil, vegetation, and rough terrain influence a biological agent aerosol.

Soil and Vegetation

Soil influences a biological agent aerosol as related to temperature and atmospheric stability. Appendix C discusses the interrelationship between soil and these weather elements.

Vegetation reduces the number of aerosol particles. Impact of the suspended particles upon trees and grass causes some particles to settle, and this settling reduces agent concentration. However, vegetative cover reduces exposure to ultraviolet light, increases relative humidities, and may reduce temperatures (while fostering a neutral temperature gradient). All these factors favor the survival of wet aerosols.

Rough Terrain

Rough terrain creates wind turbulence, and turbulence influences the vertical diffusion of aerosol. This turbulence reduces agent effectiveness and area coverage. Terrain affects the path of the aerosol and the distribution of surface concentration.

Nuclear Detonations

When a nuclear explosion occurs, blast radiation and heat or thermal effects will occur. The influence of weather and terrain on these effects will be discussed in this section. When a nuclear weapon detonates at low altitudes, a fireball results from the sudden release of immense quantities of energy. The initial temperature of the fireball ranges into millions of degrees, and the initial pressure ranges to millions of atmospheres. Most of the energy from a nuclear weapon detonation appears in the target area in the form of three distinct effects. These are nuclear radiation, blast, and thermal radiation.

Nuclear Radiation. Neutron and gamma radiation from the weapon detonation produces casualties and, in many cases, material damage as well. Ionized regions, which may interfere 'with the propagation of electromagnetic waves associated with communication systems and radars, result when the atmosphere absorbs nuclear radiation.

Blast. A blast wave with accompanying drag effects travels outward from the burst.

Thermal Radiation. Intense thermal radiation emits from the fireball, causing heating and combustion of objects in the surrounding area.

In the detonation of a typical fission-type nuclear weapon, the percentage of the total energy appearing as nuclear radiation, blast, or thermal radiation depends on the altitude at which the burst takes place (subsurface, surface, or air) and on the physical design of the weapon. For bursts within a few kilometers above the earth's surface, slightly more than 50 percent of the energy may appear as blast, approximately 35 percent as thermal energy, and approximately 15 percent as nuclear radiation.

Certain weather conditions will influence the effects of nuclear weapons. Likewise, different types of terrain will also influence the effects of nuclear weapons. In addition to these considerations, the type of operation can have a direct bearing on weather and terrain effects on nuclear weapons use.

Nuclear Radiation

When a nuclear explosion occurs, one usual result is the well-known mushroom-shaped cloud. This cloud may extend tens of thousands of meters, and in the case of a surface burst or shallow subsurface burst, it is a tremendous vertically developed aerosol cloud bearing radioactive material. The effect of wind speed and direction at various altitudes is of particular interest. These factors are of great importance in predicting the location(s) of the fallout that may result from a nuclear explosion.

The effects of weather and terrain apply to both the initial and residual effects of nuclear explosions, although this section will primarily address the residual aspects. For more information on the effects of weather on both initial and residual effects, refer to FM 3-3.

Precipitation

Precipitation scavenging can cause the removal of radioactive particles from the atmosphere. This is known as rainout. Because of the uncertainties associated with weather predictions, the locations that could receive rainout cannot be accurately predicted. Rainout may occur in the vicinity of ground zero or the contamination could be carried aloft for tens of kilometers before deposition. The threat of rainout especially exists from a surface or subsurface burst. Vast quantities of radioactive debris will be carried aloft and be deposited downwind. However, rainout may cause the fallout area to increase or decrease and also cause hot spots within the fallout area.

For airbursts, rainout can increase the residual contamination hazard. Normally, the only residual hazard from an airburst is a small neutron induced contamination area around GZ. However, rainout will cause additional contaminated areas in unexpected locations.

Yields of 10 kilotons or less present the greatest potential for rainout, and yields of 60 kilotons or more offer the least. Additionally, yields between 10 kilotons and 60 kilotons may produce rainout if the nuclear clouds remain at or below rain cloud height.

Rain on an area contaminated by a surface burst changes the pattern of radioactive intensities by washing off higher elevations, buildings, equipment, and vegetation. This reduces intensities in some areas and possibly increases intensities in drainage systems; on low ground; and in flat, poorly drained areas.

Wind Speed and Direction

Wind speed and direction at various altitudes are two factors that determine the shape, size, location, and intensities of the fallout pattern on the ground because contaminated dirt and debris deposit downwind. The principles and techniques of fallout prediction from winds-aloft data are in FM 3-3. Surface winds also play an important role in the final location of fallout particles. Just as snow falls on pavements or frozen surfaces and surface winds pile it in drifts, so, too, can local winds cause localization of fallout material in crevices and ditches and against curbs and ledges. This effect is not locally predictable, but personnel must be aware of the probability of these highly intense accumulations of radioactive material occurring and their natural locations.

Clouds and Air Density

Clouds and air density have no significant effects on fallout patterns.

Terrain Contours

Ditches, gullies, small hills, and ridges offer some protection against the gamma radiation emanating from the contaminated area. Terrain contours also cause local wind systems to develop. These wind systems will affect the final disposition of fallout on the ground, creating both hot spots and areas of low-intensity within the pattern.

Heavy Foliage

Heavy foliage can stop some of the fallout from reaching the ground. This may reduce the intensity on the ground.

Soil

Soil surface materials (soil) at the burst site determine particle size (large or small). The particle size helps determine when and where most of the fallout will reach the ground, the larger particles settling first. Composition of the soil near ground zero will materially affect the size and decay rate of the pattern of residual radiation induced by neutrons from the weapon.

Type of Operation

Temperature and terrain can also influence the effects of nuclear radiation on tactical operations. The effects of cold weather, desert, jungle, mountain, and urban operations on nuclear defense planning follow.

Cold Weather Operations

Weather conditions limit the number of passable roadways. Radiological contamination on roadways may further restrict resupply and troop movement. Seasonal high winds in the arctic may present a problem in radiological contamination predictions. These winds may reduce dose rates at ground zero. At the same time, they extend the area coverage and create a problem for survey/monitoring teams. Hot spots or areas of concentrated accumulation of radiological contamination may also occur in areas of heavy snow and snow drifts.

Desert Operations

Desert operations present many varying problems. Desert daytime temperatures can vary between 90°F to 125°F (32°C to 52°C). These temperatures create an unstable temperature gradient. However, with nightfall, the desert cools rapidly and a stable temperature gradient results. A possibility of night attacks must be considered in all planning.

Nuclear defense planning in a desert is generally much the same as in other areas, with a few exceptions. Lack of vegetation and permanent fixtures, such as forests and buildings, makes it necessary to plan for and construct fortifications. Construction may be difficult because of inconsistencies of the sand. However, sand, in combination with sandbags, gives additional protection from radiation exposure. Blowing winds and sand make widespread radiological survey patterns likely. The varying terrain may make radiological survey monitoring very difficult.

Jungle Operations

Radiation hazards also may be reduced because some of the falling particles are retained by the jungle canopy. Subsequent rains, however, will wash these particles to the ground and concentrate them in water collection areas. Radiation hot spots will result.

Mountain Operations

In the mountains, the deposit of radiological contamination will be very erratic because of rapidly changing wind patterns. Hot spots may occur far from the point of detonation, and low-intensity areas may occur very near it. Limited mobility makes radiological surveys on the ground difficult, and the difficulty of maintaining a constant flight altitude makes air surveys highly inaccurate.

Urban Operations

Buildings provide a measure of protection against radiological contamination. Taking this into consideration, troops who must move in or through a suspected contaminated urban area should travel through buildings, sewers, and tunnels to reduce contamination risk. However, they should consider the dangers of collapse because of blast. They should also consider hazards of debris and fire storms resulting from ruptured and ignited gas or gasoline lines.

Blast

Most of the materiel damage and a considerable number of the casualties caused by an airburst result from the blast wave. For this reason, it is desirable to consider the phenomena associated with the passage of a blast wave through air.

The expansion of the intensely hot gases at extremely high pressures within the fireball causes a blast wave to form in the air, moving outward at high velocities. The main characteristic of the blast wave is the abrupt rise in pressure above ambient conditions. This difference in pressure with respect to the normal atmospheric pressure is called the overpressure.

Initially, the velocity of the shock front is many times the speed of sound. However, as the front progresses outward, it slows down and moves with the speed of sound.

The magnitude of the air blast parameters is dependent on the yield of the weapon, height of burst, and the distance from ground zero.

The blast wave may last from tenths of a second to seconds, depending on the yield and the distance from the burst. Weather, surface conditions, topography, and the type of operation being conducted all affect the blast wave.

Weather

Rain and fog may lessen the blast wave because energy dissipates in heating and evaporating the moisture in the atmosphere.

Surface Conditions

The reflecting nature of the surface over which a weapon is detonated can significantly influence the distance to which blast effects extend. Generally, reflecting surfaces, such as thin layers of ice, snow, and water, increase the distance to which overpressures extend.

Topography

Most data concerning blast effects are based on flat or gently rolling terrain. There is no quick and simple method for calculating changes hilly or mountainous terrain produce on blast pressures. In general, pressures are greater on the forward slopes of steep hills and are diminished on reverse slopes when compared with pressures at the same distance on flat terrain. Blast shielding is not highly dependent on line-of-sight considerations because the blast waves will bend or diffract around obstacles. The influence of small hills or folds in the ground is considered negligible for target analysis. Hills may decrease dynamic pressures and offer some local protection from flying debris.

Type of Operation

Temperature and terrain can also influence the effect of blast on tactical operations. The effects of cold weather and jungles or forests on operations follow.

Cold Weather Operations

At subzero temperatures, the radius of damage to material targets can increase as much as 20 percent. These targets include such items as tanks, APCs, artillery, and military vehicles. An increased dynamic pressure can result from a precursor wave over heat-absorbing surfaces. However, tundra, irregular terrain features, and broken ice caps break up the pressure wave.

Blast effects can drastically interfere with troop movement by breaking up ice covers and causing quick thaws. These effects can cause avalanches in mountainous areas. In flat lands, the blast may disturb the permafrost to such an extent as to restrict or disrupt movement.

Jungle or Forest Operations

Initial effects of nuclear detonations are not significantly influenced by the dense vegetation. However, the blast wave will probably cause extensive tree blowdown and missile effects. Forests, in general, do not significantly affect the overpressure but do degrade the dynamic pressure of an air blast wave.

Thermal Radiation

Thermal radiation results from the heat and light produced by the nuclear explosion. During a nuclear explosion, the immediate release of an enormous quantity of energy in a very small space results in an initial fireball temperature that ranges into millions of degrees. For a given type of weapon, the total amount of thermal energy available is directly proportional to the yield.

Within the atmosphere, the principal characteristics of thermal radiation are that it—

- Travels at the speed of light.
- Travels in straight lines.
- Can be scattered.
- Can be reflected.
- Can be easily absorbed.

The thermal effects will be influenced by weather, terrain, height of burst, and type of operation.

Weather

Any condition that significantly affects the visibility or the transparency of the air affects the transmission of thermal radiation. Clouds, smoke (including artificial), fog, snow, or rain absorb and scatter thermal energy. Depending on the concentration, they can stop as much as 90 percent of the thermal energy. On the other hand, clouds above the burst may reflect additional thermal radiation onto the target that would have otherwise traveled harmlessly into the sky.

Terrain

Large hill masses, forests, or jungles, or any opaque object between the fireball and the target may provide some protection to a target element. Trucks, buildings, or even another individual may protect an individual from thermal radiation. Foxholes provide good protection. However, personnel protected from direct line-of-sight radiation from the fireball may still receive thermal injury because of reflection from buildings or other objects. Good reflecting surfaces, such as water, snow, or desert sand, may reflect heat onto the target and intensify the thermal radiation effect. Even the backs and sides of open foxholes will reflect thermal energy. The reflective capability of foxhole materials varies from 8 percent for wet black soil to 93 percent for snow. Because of atmospheric scattering and reflections, thermal casualties may result at a greater range than casualties from other effects.

Height of Burst

The amount of thermal radiation that a surface target receives from a nuclear burst of a given yield will vary with the height of burst. The maximum thermal effect at the target will usually be produced by an airburst. A surface burst produces about half the amount of the thermal radiation that would be produced by an airburst because of the interaction of the fireball with the surface. Thermal radiation from a subsurface burst where the fireball is not visible is insignificant.

Type of Operation

Temperature and terrain can also influence the effect of thermal radiation on tactical operations. The effects of cold weather and mountains on thermal radiation follow.

Cold Weather Operations

The high reflectivity of ice and snow may increase the minimum safe distance as much as 50 percent for unwarned troops and even warned, exposed troops. Reflectivity may also increase the number of personnel whose vision is affected by the brilliant flash, or light dazzle, especially at night. The pale colors normally used to cover material in a cold weather environment give an advantage. Their low absorption properties may make personnel less vulnerable to thermal effects. Cold temperatures also reduce thermal effects on materials. Snow, ice, and even frost coverings on combustible materials greatly reduce the tendency of the materials to catch fire. However, thermal effects will dry out exposed tundra areas, and grass fires may result.

Mountain Operations

The clear mountain air extends the range of casualty-producing thermal effects. Within this range, however, the added clothing required by the cool temperatures at high altitudes reduces casualties from these effects.

APPENDIX A

Air Weather Service

The US Air Force Air Weather Service (AWS) provides operational weather service support, as described in AR 115-10 and AFR 105-3. A supporting Air Force weather unit will be assigned to all corps and divisions and to separate brigades, regiments, and groups on request. Assignment is subject to the following:

- When requested in peacetime in accordance with AR 115-12 and in wartime as stated in contingency, mobilization, and war plans.
- When it is jointly agreed that remote weather service will be inadequate.
- When consistent with jointly agreed tactical doctrine and operational support concepts.

Planning and executing a successful operation require timely and accurate weather information. To ensure prompt receipt of weather information and to ensure that both the meteorologist and the NBC officer understand what is required, close and continuous coordination is essential. The NBC officer should establish (through the intelligence officer) and maintain direct contact with the AWS detachment or staff weather officer (SWO) before, during, and after operations.

SWOs can provide the following services:

- Weather observations. Under field conditions, the SWO will not be able to establish a dense observational network. There will usually be areas of concern for which no observations are available. Therefore Army personnel should also be prepared to provide supplemental observations to the AWS weather unit. The SWO also should have access to observations and upper air soundings from artillery meteorological (arty met) units to further supplement weather collection efforts.
- Forecasting services. These services, which can vary considerably, are provided according to local arrangements with the SWO.
- Climatological data (weather history). This planning information can be obtained from the SWO. Those units without an SWO should obtain it from the USAF Environmental Technical Applications Center, Scott AFB, IL 62225 (see DA Pamphlet 115-1).

The dissemination of weather information within Army units is the responsibility of the intelligence officer. The AWS detachment or staff weather officer can supply information directly to the using agency, or the information can be routed through the intelligence officer for dissemination to staff and lower units. The intelligence officer determines the method to be used.

AWS operational support products are defined in terms of long-range planning (usually beyond 48 hours), mission planning (usually 24 to 48 hours), and execution support (usually 0 to 24 hours). For forecast periods in excess of five days, climatological analyses normally are provided. (NOTE: The forecast reliability decreases and the forecast provided becomes less specific as the forecast period increases. Significant changes or modifications may occur after the forecast is issued. The requestor must then inform the AWS facilities of the criteria for significant changes.

The following observation and forecast parameters and elements are normally available; however, additional products may be provided, depending on Army stated requirements and the AWS's ability to satisfy those requirements:

- Sky conditions, including amounts (tenths in CONUS and eighths overseas), type (according to standard classification), and cloud base height (in feet).
- Precipitation and / or obstructions to visibility, including intensity, type, and times of beginning and ending (in coordinated universal time and zone Z).
- Surface visibilities in statute miles and fractions.
- Surface wind direction and speed.
- Surface temperature.
- Temperatures and winds at desired standard levels above the surface.
- Humidity.

Prior to planning an operation, the target analyst should collect AWS climatic studies, other climatological data, and / or forecasts for the operational area valid for the time of the operation. To obtain maximum weather forecast assistance, the NBC officer must provide the AWS facility complete requirements as far in advance as possible. The request should include the following:

- Time period for the forecast and desired delivery time.
- Target or area to be covered by the forecast. Clearly identify an area by map coordinates, aerial photograph grid numbers, or established geographic boundaries.
- Special elements or conditions to be covered.
- Criteria for changes (amendments) in the forecast if desired.

If possible, supplementary forecast information should be obtained from the AWS facility prior to the release of agents when observations indicate the original forecast to be significantly in error; when the release time is appreciably delayed; or when, for any reason, the forecast requires updating.

The target analyst should also evaluate forecasts received. The analyst should use a detailed reconnaissance map, an aerial photograph, or a mosaic or study of the terrain and vegetation in and around these areas and those that might affect the behavior of the agents to be released.

After the operation, the NBC officer should pass to the intelligence officer, SWO, or AWS facility information on adequacy of support and any problems encountered. This information aids AWS forecasters in better tailoring future support.

Using agencies receive weather information in five general types of reports—weather forecasts, current weather observation reports, weather summaries, climatic summaries, and climatic studies.

A weather forecast is a prediction of weather conditions at a point, along a route, or within an area for a specified period. The accuracy and reliability of weather forecasts depend upon factors such as characteristics of the forecast area, age of the data available, reliability of weather communications facilities, length of the forecast period, state of meteorological science, and experience of the forecaster. The reliability and specificity of forecasts generally decreases as the forecast period increases. Also, the forecast becomes less specific as the forecast period increases.

Routine weather forecasts for use by troop units should be in plain language and should be as accurate as possible. Forecasts are Air Weather Service operational support products. These forecasts are defined in terms of long-range planning (usually beyond 48 hours), mission planning (usually 24 to 48 hours), and execution support (usually O to 24 hours). Figures A-1 and A-2 provide an example of a sample forecast containing information elements that could be provide by Air Weather Service or Fleet Weather Service and supporting artillery meteorological sources.

Current weather observation reports are oral, written, or graphic representations of existing weather conditions or specific weather elements. These reports are used in the operation of aircraft; in the employment of nuclear weapons, chemical agents, and smoke; and in other activities.

A weather summary describes the weather along a route or within an area during a specified recent period. Weather summaries are used in analyzing the effects of weather on recent operations. These summaries are also used in estimating the effects of weather on future operations.

Climatic summaries tabulate averages, extremes, and frequencies of weather elements or phenomena. These cover a specified period—a year, season, or month—and a given point, along a route, or within an area.

Climatic studies are analyses and interpretations of climatic summaries. Corps and higher headquarters usually prepare these studies. At the request of the intelligence officer, the supporting AWS unit prepares or obtains climatic studies on specific problems for given areas.

Care must be taken to understand the meanings of the technical terms used in this manual. Some of these terms have a strict technical definition that may be different from the definitions many laymen understand.

Field behavior of NBC agents and smoke depends upon weather variables, which are wind, temperature, vertical temperature gradients, cloud cover, humidity, and precipitation. Local topography, vegetation, and soil affects these variables. The cumulative effect of these variables

OPERATIONAL
NBC WEATHER FORECAST/OBSERVATION
(Available Data From Air Weather Service, Fleet Weather Service and Artillery Meteorological Sources)

1. Area forecasted Date *16 Jan 86* Time of forecast (T f) *1200Z*
Division *82 D*
(Other)________

	Time			
	T f	T f +3 hr	T f + 6 hr	T f + 24 hr
2. Wind (surface speed 5 knots)* Direction from (10° azimuth)*	05/360	10/360	15/290	10/270
3. Temperature gradient--stable, neutral, unstable (vertical between 1.0 and 4 meters)**	NEUTRAL	NEUTRAL	NEUTRAL	NEUTRAL
4. Height of inversion Bases and tops to 1,000 ft altitude**	6000	6000	6000	7000
5. Temperature (5°F at 1.0 meter level)*	70	65	65	60
6. Relative humidity (10%)	80	90	90	85
7. Precipitation (rain or snow) (light, moderate, heavy); depth of snow	LT RAIN	LT RAIN	LT RAIN	LT RAIN
8. Cloud cover (clear, scattered, broken, overcast) height: low (below 6,500 ft); middle (6,500 to 20,000 ft); high (over 20,000 ft)	LOW OVC	LOW OVC	LOW OVC	LOW OVC

9. Fallout winds (T f thru f + 6 hr) **
Direction and Speed
(10° and 5 knots)*
Altitude (1,000-ft units)

Feet		Meters	Feet		Meters
5	____	1.5	55	____	16.5
10	____	3.0	60	____	18.0
15	____	4.5	65	____	19.5
20	____	6.0	70	____	21.0
25	____	7.5	75	____	23.5
30	____	9.0	80	____	24.0
35	____	10.5	85	____	25.5
40	____	12.0	90	____	27.0
45	____	13.5	95	____	28.5
50	____	15.0	100	____	30.0

10. Height of tropopause *20,000* Feet/or________Meters

* Rounded to the nearest increment

** AWS/FWS does not routinely provide this information. Artillery meteorological sections normally provide the upper wind data. The chemical downwind message (CDM) can also provide other weather information such as the air stability category.

Figure A-1. Sample forecast format (front).

NBC WEATHER PLANNING FORECAST

Valid (T f + 3 hr through T f + 24 hr): 860606 / 1500Z to 860607 / 1500Z
(date/time)

1. Surface wind
   (same parameters as preceding format)

2. Vertical temperature gradient

   Stable ( )   Neutral (X)   Unstable ( )

   Time: ____/____/____/____/____

3. Temperature

   Maximum 70 °F at 860606 / 1500Z (Time); Minimum 60 / °F at 860607 / 1500Z (Time)

4. Relative humidity

   Maximum 90 % at 860606 / 1500Z (Time); Minimum 85 % at 860607 / 1500Z (Time)

5. Cloud cover

   Clear ( )   Scattered ( )   Broken ( )   Overcast (X)

6. Precipitation

   No ( )   Yes ( )   Rain (X)   Snow ( )

   Beginning 860606 1500Z (Time)   End 860607 1500Z (Time)

7. Fallout winds

   Significant changes?

   No (X)

   Yes ( ), as follows:

(Direction and speed as in preceding format)

Feet		Meters	Feet		Meters
10	____	3.0	40	____	12.0
20	____	6.0	50	____	15.0
30	____	9.0	60	____	12.0

8. Height of tropopause 20,000 Feet/or ____ Meters

Figure A-2. Sample forecast format (back).

governs the required quantity and optimum type of chemical agent and smoke best suited to achieve operational objectives. Since weather governs the transport of chemical agents and smoke clouds, it is a primary factor in determining the effectiveness of a specific agent and the extent of the hazard area.

You must understand the basic principles governing weather and have access to accurate forecasts to be able to use chemical agents effectively or to defend against their use by the enemy. You must be capable of using the data provided in weather forecasts and predictions in preparation of plans and estimates. Appendix C discusses weather elements and primary weather factors in further detail for you to work with your forecaster on how best to employ chemical agents, smoke, and other obscurants, or defend against NBC agent use.

APPENDIX B

Units of Measure

This appendix lists the units of measure and their abbreviations commonly used in meteorology. It also contains factors for converting from one unit of measure to another.

	Unit of Measure	Abbreviation	Conversion Formulas
Temperature	Degrees Fahrenheit	°F	9/5 (°C) + 32 = 1.8 (°C) + 32
	Degrees Celsius (Formerly referred to as degrees centigrade)	°C	5/9 (°F - 32) = .556 (°F - 32)

	Metric	Abbreviation	US Equivalent
Length	kilometer	km	1,000 m = .62 mi
	meter	m	1,000 mm = 100 cm = 39.37 in
	centimeter	cm	10 mm = .39 in
	millimeter	mm	.001 m = .04 in
	statute mile	mi	5,280 ft
	nautical mile	naut mi	1.15 mi = 1,852 m
	yard	yd	.9144 m
	foot	ft	30.48 cm
	inch	in	2.54 cm

	Unit of Measure	Abbreviation	Conversions
Velocity	kilometers per hour	kmph	1 knot = 1.84 kmph = 1.15 mph = .514 m/sec
	meters per second	m/sec	1 mph = .447 m/sec = .87 knot
	nautical miles per hour	knots	
	statute miles per hour, or miles per hour	mph	
	feet per second	ft/sec	

	Unit of Measure	Abbreviation
Pressure	atmosphere	atm
	pounds per square inch	psi
	millibars	mb
	inches of mercury	in Hg
	centimeters of mercury	cm Hg
	kilopascal	kP
	grams	gm
	kilograms	kg
	milligram-minutes per cubic meter	mg-min/m^3

Glossary

absolute humidity (also called vapor concentration and vapor density) - in a system of moist air, the ratio of the mass of water vapor present to the volume occupied by the mixture, that is, the density of the water vapor component. It is not commonly used by meteorologists. See relative humidity.

absorption - the process of an agent being taken into the vegetation, skin, materiel, or soil. Important for only a few agents.

active front - the boundary between two different air masses, or a portion thereof, which produces appreciable cloudiness and precipitation and is usually accompanied by significant shifts in wind direction.

adiabatic lapse rate - the rate of decrease of temperature with height of a parcel of dry air lifted upward through the atmosphere with no addition or deletion of heat.

adiabatic process - a thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system. In an adiabatic process, compression always results in warming, expansion in cooling. In meteorology the adiabatic process often is also taken to be a reversible process. For many purposes, changes of state in the free atmosphere over periods of two days or less are assumed to be adiabatic.

adsorption - adding a thin layer to vegetation (usually aerosol). Important in dense vegetation.

advection fog - a type of fog caused by the passage of moist air horizontally over a relatively colder surface and the consequent cooling of that air to below its dew point.

adverse weather - weather in which military operations are generally restricted or impeded.

aerology - the study of the air and of the atmosphere. Used in the US Navy until early 1957. The same as meteorology; however, this usage tended to be more administrative than scientific.

aerosol - a colloidal system in which the dispersed phase is composed of either solid or liquid particles and in which the dispersal medium is some gas, usually air. There is no clear-cut upper limit to the size of the particles comprising the dispersed phase in an aerosol, but as in all other colloidal systems, it is rather commonly set at 1 micron. Haze, most smokes, and some fogs may thus be considered aerosols.

air - the mixture of gases comprising the earth's atmosphere. Since the composition of the atmosphere is slightly variable with respect to certain components, the term "pure air" has no precise meaning, but is commonly used to imply freedom from nongaseous suspensoids (dust, hydrometeors) and also freedom from such gaseous contaminants as industrial effluents.

air drainage - general term for gravity-induced, downslope flow of relatively cold air. Winds thus produced are called gravity winds.

air mass - a widespread body of air, the properties of which can be identified as (a) having been established while that air was situated over a particular region of the earth's surface (air-mass source region) and (b) undergoing specific modifications while in transit away from the source region. An air mass is often defined as a widespread body of air that is approximately homogeneous in its horizontal extent, particularly with reference to temperature and moisture distribution; in addition, the vertical temperature and moisture variations are approximately the same over its horizontal extent.

air mass classification - a system used to identify and to characterize the different air masses according to a basic scheme. A number of systems have been proposed, but the Bergeron classification has been the most widely accepted. In this system, air masses are designated first according to the thermal properties of their source regions: tropical (T); polar (P); and less frequently, arctic or antarctic (A). For characterizing the moisture distribution, air masses are distinguished as to continental (c) and maritime (m) source regions. Further classification according to whether the air is cold (k) or warm (w) relative to the surface over which it is moving indicates the low-level stability conditions of the air, the type of modification from below, and is also related to the weather occurring within the air mass. This outline of classification yields the following identifiers for air masses:

cTk	**continental-tropical-cold**
cTw	**continental-tropical-warm**
mTk	**maritime-tropical-cold**
mTw	**maritime-tropical-warm**
cPk	**continental-polar-cold**
cPw	**continental-polar-warm**
cAk	**continental-arctic-cold**
cAw	**continental-arctic-warm**
mAw	**maritime-arctic-warm**
mPk	**maritime-polar-cold**
mPw	**maritime-polar-warm**
mAk	**maritime-arctic-cold**

air mass source region - an extensive area of the earth's surface over which bodies of air frequently remain for a sufficient time to acquire characteristic temperature and moisture properties imparted by that surface. Air so modified becomes identifiable as a distinct air mass. See air mass.

air parcel - an imaginary body of air to which may be assigned any or all of the basic dynamic and thermodynamic properties of atmospheric air. A parcel is large enough to contain a very great number of molecules, but small enough so that the properties assigned to it are approximately uniform within it and so that its motions with respect to the surrounding atmosphere do not induce marked compensatory movements. It cannot be given precise numerical definition, but a cubic foot of air might fit well into most contexts where air parcels are discussed, particularly those related to static stability.

albedo - the fraction of light or the amount of electromagnetic radiation reflected by a body to the amount incident upon it, commonly expressed as a percentage. The albedo is distinguished from the reflectivity, which refers to one specific wavelength (monochromatic radiation). (As the moon, a planet, a cloud, the ground, or a field of snow reflects light.)

altocumulus (abbreviated Ac) - a principal medium-level cloud type, white and/or gray in color, which occurs as a layer or patch with a waved aspect, the elements of which appear as laminae, rounded masses, or rolls. These elements usually are sharply outlined, but they may become partly fibrous or diffuse; they may or may not be merged; they generally have shadowed parts; and, by convection, when observed at an angle of more than 30° above the horizon, subtend an angle between 1° and 5°.

altostratus (abbreviated As) - a principal medium-level cloud type in the form of a gray or bluish (never white) sheet or layer of striated, fibrous, or uniform appearance. Altostratus very often totally covers the sky, and may, in fact, cover an area of several thousand square miles. The layer has parts thin enough to reveal the position of the sun; and if gaps and rifts appear, they are irregularly shaped and spaced.

anabatic wind - an upslope wind; usually applied only when the wind is blowing up a hill or mountain as a result of local surface heating and apart from the effects of the larger scale circulation; the opposite of katabatic wind. The most common type anabatic is the valley wind.

APC - armored personnel carrier.

arctic front - the semipermanent, semicontinuous front between the deep, cold arctic air and the shallower, basically less cold polar air of northern latitudes; generally comparable to the antarctic front of the southern hemisphere.

arty met - artillery meteorological.

ATGM - antitank guided missile.

AWS - Air Weather Service.

bora - a cold, often dry, northeasterly wind which blows, sometimes in violent gusts, down from mountains on the eastern shore of the Adriatic. It also applies to cold, squally, downslope winds in other parts of the world.

CARC - chemical agent resistant coating.

CDM - chemical downwind message.

Celsius (abbreviated C) - (formerly referred to as centigrade) thermometric scale with 100 degrees between freezing and boiling, OC for freezing and 100°C for boiling.

centigrade - see Celsius.

chinook - the name given to the descending, warm, dry wind on the eastern side of the Rocky Mountains. The chinook generally blows from the southwest, but its direction may be modified by topography. When it sets in after a spell of intense cold, the temperature may rise by 20°F to 40°F in 15 minutes due to replacement of a cold air mass with a much warmer air mass in minutes.

cirrocumulus (abbreviated Cc) - a principal high-level cloud type appearing as a thin, white patch of cloud without shadows, composed of very small droplets in the form of grains or ripples. The elements may be merged or separate, and more or less regularly arranged; they subtend an angle of less than 10 when observed at an angle of more than 30° above the horizon. Holes or rifts often occur in a sheet of cirrocumulus.

cirrostratus (abbreviated Cs) - a principal high-level cloud type appearing as a whitish veil, usually fibrous but sometimes smooth, which may totally cover the sky and which often produces halo phenomena, either partially or completely. Sometimes a banded aspect may appear, but the intervals between the bands are filled with thinner cloud veil. The edge of the veil of cirrostratus may be straight and clean-cut, but more often it is irregular and fringed with cirrus. Some of the ice crystals that comprise the cloud are large enough to fall and thereby produce a fibrous aspect. Cirrostratus occasionally may be so thin and transparent as to render it almost indiscernible, especially through haze or at night. At such times, the existence of a halo may be the only revealing feature, such as producing a halo around the moon.

cirrus (abbreviated Ci) - a principal high-level cloud type composed of detached cirriform elements in the form of white, delicate filaments, of white (or mostly white) patches, or of narrow bands. These clouds have a fibrous aspect and/or a silky sheen. Many of the ice crystal particles of cirrus are sufficiently large to acquire an appreciable speed of fall; therefore, the cloud elements have a considerable vertical extent. Wind shear and variations in particle size usually cause these fibrous trails to be slanted or irregularly curved. For this reason, cirrus does not usually tend, as do other clouds, to appear horizontal when near the horizon. Because cirrus elements are too narrow, they do not produce a complete circular halo.

climate - the long-term manifestations of weather. The climate of a specified area is represented by the statistical summary of its weather conditions during a period long enough to ensure that representative values are obtained (generally 30 years).

climatic study - analysis and interpretation of climatic summary data in light of probable impacts on operations, plans, construction, and the like.

climatic summary - tabular data for averages, extremes, and frequencies of weather elements or phenomena for a year, season, month, or other period at a specific location or area.

climatology - the science that deals with climates and investigates their phenomena and causes.

cloud - a collection of very small water droplets or ice crystals or both, with its base above the earth's surface.

colloidal system (also called colloidal dispersion, colloidal suspension) - an intimate mixture of two substances one of which, called the dispersed phase (or colloid), is uniformly distributed in a finely divided state throughout the second substance, called the dispersion medium (or dispersing medium). The dispersion medium may be a gas, a liquid, or a solid, and the dispersed phase may also be any of these, with the exception that one does not speak of a colloidal system of one gas in another. A system of liquid or solid particles colloidally dispersed in a gas is called an aerosol. A system of solid substances or water-insoluble liquids colloidally dispersed in liquid water is called a hydrosol.

coniferous forests - concentrations of evergreen trees normally found on slopes and mountains; for chemical behavior purposes, the same as medium-dense deciduous forests or woods (when in full foliage only).

CONUS – continental United States.

convection - in general, mass motions within a fluid resulting in transport and mixing of the properties of that fluid. Convection, along with conduction and radiation, is a principal means of energy transfer. Distinction is made between free convection (or gravitational convection)—motion caused only by density differences with the fluid-and forced convection—motion induced by mechanical forces such as deflection by a large-scale surface irregularity, turbulent flow caused by friction at the boundary of a fluid, or motion caused by any applied external force.

coriolis force - a force exerted on a parcel of air (or any moving body) due to the rotation of the earth. This force causes a deflection of the body to the right in the northern hemisphere and to the left in the southern hemisphere.

cumulonimbus (abbreviated Cb) - a principal cloud type, exceptionally dense and vertically developed, occurring either as isolated clouds or as a line or wall of clouds with separated upper portions. These clouds appear as mountains or huge towers, at least a part of the upper portions of which are usually smooth, fibrous, or striated, and almost flattened. This part often spreads out in an anvil shape (incus) or vast plume. Under the base of a cumulonimbus, which often is very dark, there frequently exists virga, precipitation, and low, ragged clouds, either merged with it or not. Its precipitation is often heavy and always of a showery nature. The usual occurrence of lightning and thunder within or from this cloud leads to its common names, thundercloud, thunderhead (usually refers only to the upper portion of the cloud), and thunderstorm.

cumulus (abbreviated Cu) - a principal cloud type in the form of individual, detached elements which are generally dense, low-level with vertical development and possess sharp nonfibrous outlines. These elements develop vertically, appearing as rising mounds, domes, or towers, the upper parts of which often resemble a cauliflower. The sunlit parts of these clouds are mostly brilliant white; their bases are relatively dark and nearly horizontal. Near the horizon, the vertical development of cumulus often causes the individual clouds to appear to be merged. If precipitation occurs, it is usually of a showery nature.

current weather report - information on existing weather conditions or specific weather element; may be oral, written, or graphic representations.

cyclone - a system of winds rotating around a center of low atmospheric pressure. A cyclone rotates counterclockwise in the northern hemisphere and clockwise in the southern hemisphere (opposite to that of an anticyclone). Modern meteorology restricts the use of the term cyclone to the cyclonic-scale circulations. But, it is still applied popularly to the more or less violent, small-scale circulations such as tornadoes, waterspouts, and dust devils (which may in fact exhibit anticyclonic rotation), and even, very loosely, to any strong wind. Because cyclonic circulation and relative low atmospheric pressure usually coexist (in the northern hemisphere), in common practice the terms cyclone and low are used interchangeably. Also, because cyclones nearly always are accompanied by inclement (sometimes destructive) weather, they are frequently referred to simply as storms.

deciduous forests - concentrations of seasonal, leafy trees; for chemical behavior calculations, the same as coniferous forests or woods when in full foliage only.

deliberate smoke - smoke operations which are planned with much detail for implementation over large areas or relatively long time periods.

dew - water condensed onto grass and other objects near the ground. Dew forms when temperatures fall below the dew point of the surface air due to radiational cooling during the night but are still above freezing. Hoarfrost (or white frost) forms if the dew point is below freezing. If the temperature falls below freezing after the dew has formed, the frozen dew is known as white dew or jackfrost.

dew point (or dew point temperature) - temperature to which a given parcel of air must be cooled at constant pressure and constant water vapor content for saturation to occur. When this temperature is reached, water is condensed onto grass and other objects contacting the cooled air. When the dew point is below 32°F (0°C), it is sometimes called the frost point. The dew point may be defined as the temperature at which the saturation vapor pressure of the parcel is equal to the actual vapor pressure of the contained water vapor.

diffusion - exchange of airborne media between regions in space in an apparently random motion of a small scale.

diurnal - repeated or recurring daily. Having a daily cycle of completed actions in 24 hours and recurring every 24 hours. Thus, most reference is made to diurnal tasks, cycles, tides, or sunrise to sunset.

dose - amount of agent taken into or absorbed by the body.

dose rate - how fast a dose is absorbed or taken into the body.

drizzle - very small, numerous, and uniformly dispersed water drops, mist, or sprinkle. Unlike fog droplets, drizzle falls to the ground. It is sometimes accompanied by low visibility and fog.

dry-bulb humidity - dryness of the free air as measured by use of two thermometers. One is dry-bulb and the other is wet-bulb. The difference between the two readings is the humidity for surrounding air. (See hygrometer, psychrometer.)

dry-bulb temperature - temperature of the free air as measured with a dry thermometer on a sling psychrometer over a grassy surface at a height of approximately 6 feet (1.8 meters).

easterlies - any persistent wind from the east (usually applied to broad currents or belts of easterly winds). The easterly belts are referred to as the equatorial easterlies, the tropical easterlies, and the polar easterlies.

electromagnetic spectrum - the entire range of wavelengths of all known electromagnetic radiations extending from gamma rays through visible light, infrared, and radio waves. It is divided into 26 alphabetically designated bands.

fire storm - an atmospheric wind system caused by a large fire (as after the bombing of a city). The intense burning creates vertical wind currents, which induces a strong wind to bring in more air to feed the fire. Incoming wind speed can exceed 60 knots in extreme cases.

foehn - name for a warm dry wind blowing down the side of a mountain in northern and central Europe; (same as chinook-type warm dry wind that descends eastern slopes of Rocky Mountains).

fog oil - petroleum based oil specially blended to produce a dense, efficient screening smoke when vaporized and recondensed at atmospheric temperatures. Officially, fog oil is standard grade fuel number 2 (SGF2).

front - in meteorology, generally, the interface or boundary between two air masses of different density. Since the temperature distribution is the most important regulator of atmospheric density, this front almost invariably separates air masses of different temperatures. Fronts receive their names from the movement of the air masses involved. A cold front is the leading edge of an advancing mass of cold air. A warm front is the trailing edge of a retreating mass of cold air. When an air mass boundary is neither advancing nor retreating along the surface, the front is called a stationary front. An occluded front occurs when a cold front overtakes a warm front at the surface and a temperature contrast exists between the advancing and retreating cold air masses.

frost - a cover of minute ice crystals on objects that are exposed to the air. Some of these are tree branches, plant stems, leaves, wires, poles, vehicles, rooftops, or aircraft skin. Frost is the same process by which dew is formed except that the temperature of the frosted object is below freezing. Frost can be light or heavy.

FWS - Fleet Weather Service.

geostrophic - relates to or arises from the deflective force exerted on the atmosphere due to the rotation of the earth.

geostrophic wind - a wind whose direction and speed are determined by a balance of the horizontal pressure gradient force and the force due to the earth's rotation to the left in the northern hemisphere and to the right in the southern hemisphere.

geostrophic wind level (also called gradient wind level) - the lowest level at which the wind becomes geostrophic. In practice, the geostrophic wind level is between 1.2 kilometers (3,928 feet) and 1.6 kilometers (5,238 feet). This wind level probably marks the upper limit of frictional influence of the earth's surface. The geostrophic wind level may be considered to be the top of the planetary boundary layer, that is, the base of the free atmosphere.

glaze - a smooth coating of ice formed on objects due to the freezing of rain.

gradient wind - any horizontal wind velocity tangent to the contour line of a constant pressure surface (or to the isobar of a geopotential surface) at or above 2,500 feet (762 meters).

gravity wind - see air drainage and katabatic wind.

greenhouse effect - the heating effect exerted by the atmosphere upon the earth because the atmosphere (mainly, its water vapor) absorbs and reemits infrared radiation. In detail, the shorter wavelengths of solar radiation are transmitted rather freely through the atmosphere to be absorbed at the earth's surface. The earth then reemits this as long-wave (infrared) terrestrial radiation, a portion of which is absorbed by the atmosphere and again emitted. Some of this is emitted downward back to the earth's surface (counterradiation). It is essential, in understanding the concept of the greenhouse effect, to note that the important additional warming is due to the counterradiation from the atmosphere. The glass panes of a greenhouse function the same way as the atmosphere does to maintain high greenhouse temperatures and hence the name.

hasty smoke - smoke operations conducted with a minimum of prior planning usually to counter enemy action or anticipated action of immediate concern to a commander.

HC - hexachloroethane.

head wind - in this manual, wind blowing away from the objective and directly toward your site.

heavily wooded - for chemical behavior purposes, jungles or forests with canopies that shade more than 90 percent of the ground surface beneath.

hoarfrost (commonly called frost, white frost, crystalline frost, or hoar) - a deposit of interlocking ice crystals formed by direct sublimation on objects, usually those of small diameter freely exposed to the air, such as tree branches, plant stems and leaf edges, wires, and poles. Also, frost may form on the skin of an aircraft when a cold aircraft flies into warm and moist air or when it passes through air that is supersaturated with water vapor. Hoarfrost is formed similarly to the way dew is formed except that the temperature of the frosted object must be below freezing. Frost forms when air with a dew point below freezing is brought to saturation by cooling. In addition to its formation on freely exposed objects (air hoar), hoarfrost also forms inside unheated buildings and vehicles, in caves, in crevasses (crevasse hoar), on snow surfaces (surface hoar), and in air spaces within snow, especially below a snow crust (depth hoar). Hoarfrost is more fluffy and feathery than rime, which in turn is lighter than glaze. Hoarfrost is designated light or heavy (frost) depending upon the amount and uniformity of deposition. See also dew and dew point.

humidity - a moderate degree of wetness, especially of the atmosphere; dampness.

hurricane - a severe tropical cyclone in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, or in the eastern North Pacific off the west coast of Mexico with winds of 75 miles per hour or greater accompanied by rain, lightning, and thunder that sometimes moves into temperate latitudes. Variant names given to the same type of storm in other areas of the world include typhoon (eastern Asia), cyclone (India), winy winy (Australia), and baguio (China Sea).

hydrolysis - process of an agent reacting with water. It does not materially affect the agent cloud in tactical use, because the rate of hydrolysis is too slow.

hygrometer - consists of two similar thermometers with the bulb of one being kept wet. This is so that the cooling that results from the evaporation makes the wet bulb register a lower temperature than the dry one. The difference between the readings constitutes a measure of the dryness (humidity) of the atmosphere.

hygroscopic - readily takes up and retains water, such as water in clay.

infrared radiation - thermal electromagnetic radiation lying outside the visible spectrum at the red end with wavelengths longer than those of visible light.

inversion - an increase of air temperature with increase in altitude (the ground being colder than the surrounding air). When an inversion exists, there are no convection currents and wind speeds are below 5 knots. The atmosphere is stable and normally is considered the most favorable state for ground release of chemical agents.

ionosphere - the part of the earth's atmosphere beginning at an altitude of about 50 kilometers (30 miles) and extending outward 500 kilometers (300 miles) or more.

isobar - a line drawn on a map or chart connecting places of equal or constant pressure. In meteorology, it most often refers to a line drawn through all points of equal atmospheric pressure along a given reference surface, such as a constant height surface (notably mean-sea-level on surface charts); the vertical plane of a synoptic cross section, or a map of the air unaffected by surface heating or cooling. The pattern of isobars has always been a main feature of surface chart analysis. Until recently it was standard procedure to draw isobars at 3-millibar intervals. However, the advent of constant pressure charts for upper-air analysis has brought about the use of 4-millibar intervals to simplify the conversion from surface isobars to 1,000-millibar contour lines.

isothermal - of equal or constant temperature with respect to space, volume, or pressure.

joules (abbreviated J) - international system unit of energy, equal to the work done when the point of application of a force of 1 newton is displaced 1 meter in the direction of the force.

katabatic wind - any wind blowing down an incline; the opposite of anabatic wind. If the wind is warm, it is called a foehn; if cold, it may be a fall wind (such as the bora) or a gravity wind (such as a mountain wind).

kg - kilogram(s).

kmph - kilometer(s) per hour.

lapse - a marked decrease in air temperature with increasing altitude because the ground is warmer than the surrounding air. This condition usually occurs when skies are clear and between 1100 and 1600 hours, local time. Strong convection currents exist during lapse conditions. For chemical operations, the state is defined as unstable. This condition is normally considered the most unfavorable for the release of chemical agents.

lapse rate - the rate of change in atmospheric temperature with increase of height. The variable normally is temperature unless specified otherwise. This is a vertical direction of travel (up or down) and the temperature may rise or fall suddenly.

leeward - the side the wind is blowing away from. Used most often in this manual in reference to a slope facing away from the wind.

M - meter(s).

mechanical turbulence - irregular motion of air resulting from surface roughness and wind speed.

met message - gives wind direction in different increments. May be artillery, ballistic, fallout, computer, or NATO in origin.

meteorology - the science that deals with the study of the atmosphere (or weather) and its phenomena, especially with weather and weather forecasting.

mg - milligram.

micrometeorology - the portion of meteorology dealing with the observation and explanation of small-scale weather and weather forecasting for a local area up to several kilometers in diameter.

min - minute(s).

mistral - a northwesterly or northerly wind which blows offshore along- the north coast of the Mediterranean from Ebra to Genoa. It is characterized by its frequency, strength, and dry coldness.

mixing height - the height to which atmospheric pollutants can be distributed by convective mixing in unstable conditions.

mph - miles per hour.

NBC - nuclear, biological, and chemical.

neutral - when the temperature of the ground is approximately the same as the temperature of the lower air up to 4 meters above it. This condition has light to moderate winds and slight turbulence, and is considered average for the release of chemical agents.

nimbostratus (abbreviated Ns) - a low-level, principal cloud type, gray colored and often dark, rendered diffuse by more or less continuously falling rain, snow, or sleet of the ordinary varieties and not accompanied by lightning, thunder, or hail. In most cases the precipitation reaches the ground, but not necessarily. Nimbostratus is composed of suspended water droplets, sometimes supercooled, and of falling raindrops and/or snow and ice crystals or flakes. It occupies a layer of large horizontal and vertical extent. The great density and thickness (usually many thousands of feet) of this cloud prevent observation of the sun. This, plus the absence of small droplets in its lower portion, gives nimbostratus the appearance of dim and uniform lighting from within. It also follows that nimbostratus has no well-defined base, but rather a deep zone of visibility weakness. A false base may frequently appear at the level where snow melts into rain.

pibal - see pilot-balloon observation.

pillaring - rapid rising of smoke clouds due to heat generated by burning munitions and/or existing convection currents.

pilot balloon - a small unmanned balloon whose ascent is followed by a theodolite (instrument) to obtain data for the computation of the speed and direction of winds in the upper air.

pilot-balloon observation (abbreviated

pibal) - a method of winds-aloft observation, that is, the determination of wind speeds and directions in the atmosphere above a station. This is done by reading the elevation and azimuth angles of a theodolite (instrument) while visually tracking a pilot balloon. The ascension rate of the balloon is approximately determined by careful inflation to a given total lift. After release from the ground, periodic readings (usually at one-minute intervals) of elevation and azimuth angles of the balloon are recorded. These data are transferred to a winds-aloft plotting board, and wind speed and direction at selected levels are calculated by trigonometric methods.

planetary boundary layer (also called the friction layer or atmospheric boundary layer) - that layer of the atmosphere from the earth's surface to the geostrophic wind level.

precipitation - any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground. It is a major class of hydrometeor, but it is distinguished from cloud, fog, dew, rime, and frost in that it must fall. It is distinguished from cloud and virga in that it must reach the ground.

pressure gradient (also, in meteorology, called barometric gradient) - the rate of decrease (gradient) of pressure in space at a fixed time. The term is sometimes used to denote simply the magnitude of the gradient of the pressure field.

psychrometer - a hygrometer (which consists of two similar bulb thermometers with one bulb kept wet and the other one dry). The psychrometer has a sling attached to the mounted bulb thermometers. A handle is on the free end of the sling. The operator can whirl the bulb thermometers in a circular pattern and speed up the evaporation of water from the wet bulb thermometer. The difference between the two readings constitutes the measure of the dryness of the air—or humidity of the atmosphere—at your location.

QSTAG - quadripartite standardization agreement.

radiation inversion - a stable condition caused by heat released from the earth. See also inversion.

radiosonde - a miniature radio carried aloft by an unmanned balloon to broadcast the pressure, temperature, and relative humidity of the upper air and to automatically transmit that information to the ground.

raob - an abbreviation for radiosonde observation.

rate of dosage - see dose rate.

rawin - a winds-aloft observation made by balloon and radio methods (rawinsonde observation).

relative humidity (popularly called humidity) - the ratio of the actual amount of water vapor present in the air to the saturation point at the same temperature. The corresponding ratios of specific humidity or of mixing ratio give approximations of sufficient accuracy for many purposes in meteorology. The relative humidity is usually expressed in percent and can be computed from psychometric (wet bulb-dry bulb temperature) data.

rime - a rough, white icy covering deposited on trees, or other exposed objects, somewhat resembling white frost, but formed only from fog- or vapor-bearing air.

RP - red phosphorus.

screening length - distance from the source of a smoke screen to the point downwind where the background begins to become recognizable.

sferics - a phonetic contraction of the word "atmospherics."

SGF2 - standard grade fuel number 2.

smoke - a particulate of solid or liquid particles dispersed into the air on the battlefield to degrade enemy ground and aerial observation. Smoke has many uses—screening smoke, signaling smoke, smoke curtain, smoke haze, and smoke deception. Thus it is an artificial aerosol.

solstice - one of the two points on the sun's apparent annual path where it is displaced farthest north or south from the earth's equator. In the northern hemisphere, the summer solstice is reached about 22 June. In the southern hemisphere, the winter solstice is reached about 22 December.

STANAG - standardization agreement.

storm - any disturbed state of the atmosphere, especially as affecting the earth's surface, and strongly implying destructive or unpleasant weather.

stratocumulus (abbreviated Sc) - a principal low-level cloud type, predominantly stratiform, in the form of a gray and/or whitish layer or patch, which nearly always has dark parts and is nonfibrous.

stratosphere - the region of the upper atmosphere characterized by little or no temperature change with altitude. The stratosphere extends from the tropopause (13 kilometers) to approximately 80 kilometers.

stratus (abbreviated St) - a principal low-level cloud type in the form of a gray layer with a rather uniform base. Stratus does not usually produce precipitation, but when it does occur, it is in the form of minute particles, such as drizzle, ice crystals, or snow grains. Stratus often occurs in the form of ragged patches or cloud fragments in which case rapid transformation is a common characteristic. When the sun is seen through the cloud, its outline is clearly discernible, and it may be accompanied by corona phenomena. In the immediate area of the solar disk, stratus may appear very white. Away from the sun, and at times when the cloud is sufficiently thick to obscure it, stratus gives off a weak, uniform luminance.

sublimation - the transition of a substance from the solid phase directly to the vapor state, or vice versa, without passing through the intermediate liquid phase.

superadiabatic lapse rate - an environmental lapse rate greater than the adiabatic lapse rate such that potential temperature decreases with height.

surface boundary layer - the portion of the atmosphere lying next to the surface of the earth and extending up to between 50 and 100 meters.

SWO - staff weather officer.

synoptic - in general, pertaining to or affording an overall view. In meteorology, this term has become somewhat specialized in referring to the use of meteorological data obtained simultaneously over a wide area for presenting a comprehensive and nearly instantaneous picture of the state of the atmosphere. Thus, to a meteorologist, synoptic takes the additional connotation of simultaneity.

thermal turbulence - irregular motion of air caused by convection currents rising from heated surfaces. See also mechanical turbulence.

tornado (sometimes called cyclone or twister) - a violently rotating column of air, pendant from a cumulonimbus cloud, and nearly always observable as a funnel cloud or tuba. On a local scale, it is the most destructive of all atmospheric phenomena. Its vortex, commonly several hundred yards in diameter, whirls usually counterclockwise with wind speeds of 100 to more than 300 miles per hour (161 to 483 kmph). Its general direction of travel is governed by the motion of its parent cloud.

TOT - time on target.

toxicity - relating to a poison or toxin; poisonous.

toxin - a colloidal poisonous substance that is a specific product of the metabolic activities of a living organism and is notably toxic when introduced into living tissue.

tropopause - the zone of transition between the troposphere and the stratosphere (approximately 13 kilometers). The tropopause normally occurs at an altitude of between 25,000 and 45,000 feet in polar and temperate zones. It occurs at 55,000 feet in the tropics.

troposphere - the lower levels of the atmosphere extending from the earth's surface up to the tropopause. It is characterized by convective air movements and a large vertical temperature change.

turbulence - irregular motion of air. See also mechanical turbulence and thermal turbulence.

unstable condition - see lapse.

venturi effect - constricting a passageway, so that the air (or fluid) moving through the constriction is greatly accelerated.

virga - rain or snow that is dissipated in falling and does not reach the ground, commonly appearing in trails descending from a cloud layer.

virulent agents - agents that produce rapid, severe, and malignant results in victims.

volatile - pertaining to a readily vaporizable liquid that evaporates at a relatively low ambient temperature.

weather - the state of the atmosphere, mainly with respect to its effects upon life and human activities. As distinguished from climate, weather consists of the short-term (minutes to months) variations of the atmosphere. Popularly, weather is thought of in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, and wind.

weather forecast - a prediction of weather conditions expected at a place, within an area, or along a route for a specified time or during a specified period.

weather summary - a description of weather along a route or within an area during a specific period; used in analyzing the effects of weather on recent operations and estimating effects on future operations.

wind - air in motion, usually parallel to the earth's surface.

wind direction - the compass point, degree, or roils (see Figure C-4) from which the wind blows.

wind shear - a change of wind speed, direction, and magnitude.

wind velocity - the horizontal direction and speed of air motion.

windward - the side receiving the wind's force. Used most often in this manual in reference to a slope facing into the wind.

woods - for chemical behavior purposes, trees in full leaf (coniferous or medium-dense deciduous forests). See, also, heavily wooded, coniferous, and deciduous.

WP - white phosphorus.

References

All references with information on the subjects listed in this publication may not be listed here. New material is constantly being published and present references may become obsolete. Consult the applicable directory of publications and instructional material catalogues to keep updated.

Required Publications

Required publications are sources that users must read in order to understand or to comply with this publication.

Field Manual (FM)

100-5 Operations

Joint Chiefs of Staff (JCS) Publication

1 Dictionary of Military and Associated Terms

Related Publications

Related publications are sources of additional information. Users do not have to read them to understand this publication.

Air Force Regulation (AFR)

105-3 Meteorological Support for US Army

Army Regulations (ARs)

115-10 Meteorological Support for US Army
115-12 US Army Requirements for Weather Service Support
316-25 Dictionary of US Army terms
310-50 Authorized Abbreviations and Brevity Codes

Department of Army Pamphlet (DA Pam)

115-1 Requests for Climatology to Army Activities

Field Manuals (FMs)

3-3 NBC Contamination Avoidance
3-4 NBC Protection
3-5 NBC Decontamination
3-9 Military Chemistry and Chemical Compounds
3-10-1 Chemical Weapons Employment
3-10-2 Chemical Target Analysis
3-50 Deliberate Smoke Operations

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6-15 Field Artillery Meteorology
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34-81 Weather Support for Army Tactical Operations

Technical Manual (TM)

3-216 Technical Aspects of Biological Defense

Naval Warfare Publications (NWPs)

12-1 Tactical Threat to Naval Air Forces
12-2 Tactical Threat to Naval Surface Forces
22 Doctrine for Amphibious Operations
22-1 The Amphibious Task Force Plan
22-2 Supporting Arms in Amphibious Operations
28 Nuclear Warfare Operations
28-2 The Nuclear Explosion Environment
28-3 Vulnerability and Survivability of Navy Systems
36 Armed Forces Doctrine for Chemical Warfare and Biological Defense (to be renumbered NWP 18)
36-2 Employment of Chemical Agents (to be renumbered NWP 18-1)
36-4 Employment of Chemical Agents (to be renumbered NWP 18-2)

Allied Tactical Publications (ATP)

ATP-1 Vol 1 Allied Maritime Tactical Instructions and Procedures
ATP-25 Nuclear Fall-Out Forecasting and Warning Organization
ATP-31 NATO Above Water Warfare Manual
ATP-45 Reporting Nuclear Detonations, Biological and Chemical Attacks

Instructions

OPNAVINST S3400.10C Offensive Chemical Warfare and Chemical, Biological, and Radiological Defense
NAVOCEANCOMINST 3140.1 DON Meteorological and Oceanographic Support Manual
SECNAVINST 3403.1 Riot Control Agents and Chemical Herbicides in War (rules governing use)

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