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Smokes and Obscurants: A Guidebook of Environmental Assessment Volume I. Method of Assessment and Appended Data

Joseph H. Shinn
Laurel Sharmer
Michael Novo
Lori F. Katz

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<p>Environmental assessments (EAs) are one type of document that can be required prior to the authorization of field tests of smokes and obscurants; EAs are documents that are written to comply with the National Environmental Policy Act (NEPA). This guidebook was prepared to facilitate the preparation of EAs for field tests of smokes and obscurants. The guidebook is divided into two volumes: Volume I--Method of Assessment and Appended Data, and Volume II--A Sample Environmental Assessment. This volume (Volume I) is further divided into two major parts. Part 1 contains introductory material about the legal basis for EAs and general information about smokes and obscurants. Part 2 provides information about writing an EA. The major subjects that should be discussed in an EA, which are described in Part 2, include (1) an introduction, (2) a statement of the proposed action, (3) a description of the environmental setting, (4) a discussion of the physical, chemical, and biological properties of the smokes and obscurants being tested, (5) a discussion of impact criteria, (6) an identification of environmental effects, (7) a consideration of environmental consequences, (8) a discussion of the cumulative, long-term effects of repeated tests, (9) a discussion of short-term effects versus effects on long-term productivity, (10) a statement of recommended alternatives, (11) a consideration of mitigation, (12) recommendations for the next step in the NEPA process, and (13) references. Specific meteorological data for potential sites and distance to interim threshold values are also provided in Volume I.</p>					
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Smokes and Obscurants: A Guidebook of Environmental Assessment

Volume I. Method of Assessment and Appended Data

Joseph H. Shinn
Laurel Sharmer
Michael Novo
Lori F. Katz

Environmental Sciences Division
Lawrence Livermore National Laboratory
University of California
P.O. Box 5507
Livermore, CA 94550

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The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

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SMOKES AND OBSCURANTS:
A GUIDEBOOK FOR ENVIRONMENTAL ASSESSMENT
VOLUME I. METHOD OF ASSESSMENT AND APPENDED DATA

PART 1. INTRODUCTION

I. PURPOSE OF GUIDEBOOK

Smokes and obscurants must be tested in the field to properly evaluate their effectiveness during their development, to evaluate their continued effectiveness after they are in the stockpile, and to train personnel in their use. Such field tests have environmental impacts at the locations where they are conducted. To comply with current laws and regulations governing the environment, documents that analyze the environmental effects of these field tests must be prepared. This guidebook was prepared to facilitate the preparation of one type of environment document, the Environmental Assessment (EA).

II. ORGANIZATION

This guidebook is presented in two volumes: Volume I gives general information about the contents of EAs and Volume II is a sample EA for a hypothetical test site. Volume I is subdivided into two major parts. Part 1 contains introductory material about the legal basis for the EA and general information about smokes and obscurants. Part 2 provides the information about writing the EA.

III. LEGAL BACKGROUND AND REQUIREMENTS

For hundreds of years, man's environment has been abused at the expense of agricultural and industrial development. This technological progress had always been considered more important than the preservation of the environment.

By 1969, however, it had become clear to many people that the abuse of the environment was detrimental not only to the environment itself but to mankind as well. On January 1, 1970, the National Environmental Policy Act

(NEPA) went into effect. This historic legislation established a national environmental policy and the Council on Environmental Quality (CEQ). The CEQ was set up to assist and advise the President on environmental and ecological matters.

As a trustee of the environment, the Department of the Army has established its own policy to conform with the goals of NEPA. Department of the Army Regulation 200-2 states Army policy, assigns responsibility, and establishes procedures for the integration of environmental considerations into Army planning and decision making. In addition, Army Materiel Command policy requires environmental analysis and documentation for all smoke testing that is being developed under its program, project, and production managers and research and development commands.

The Department of Defense (DOD) issued its implementing procedures for environmental policy in DOD Directive 6050.1, "Environmental Effects in the United States of DOD Actions" in July 1979. The Department of the Army is committed to carrying out its mission of national security in a manner that is consistent with the goals and policies of NEPA.

Within the Army, the responsible official for NEPA matters is the Assistant Secretary of the Army for Installations, Logistics, and Financial Management. Specific responsibilities with respect to NEPA of the Chief of Engineers, Headquarters, the Judge Advocate General, the Comptroller of the Army, the Surgeon General, the Chief of Public Affairs, major field commanders, and all Army commands and agencies are presented in Appendix A, a summary of Army Regulation 200-2.

A. Environmental Assessments

An Environmental Assessment (EA) is a written analysis of the environmental consequences of a proposed action; EAs are prepared for activities that do not normally require an Environmental Impact Statement (EIS), are not categorically excluded from environmental examination, or are not excluded from environmental review by law. The EIS is a report that identifies and analyzes in detail the environmental impact of a proposed agency action and feasible alternatives to that action when significant environmental effects have been identified. Generally, an EIS is preceded by an EA.

Department of the Army criteria for writing an EA (Army Regulation 200-2) are

- Potential for measurable degradation of environmental quality.
- Potential for cumulative impact on environmental quality when effects are combined with those of other actions or when the action is of lengthy duration.
- Presence of hazardous/toxic chemicals that could be released into the environment.
- Potential for violation of pollution abatement standards.
- Potential for some harm to culturally or ecologically sensitive areas.

Actions which normally require an EA are

- Test activities on DOD land of a level, nature, or magnitude not within the installation training cycle.
- Changes to established installation land use that may be expected to have some impact on the environment.
- Actions that could potentially affect prime or unique farmland, wetlands, floodplains, coastal zones, wilderness areas, wild and scenic rivers, or similar areas of critical environmental concern.
- Significant changes to installation master plans and land and natural resource management plans.
- Activities that affect any species that is on or proposed for the US Fish and Wildlife Service list of Threatened and Endangered Plant and Animal Species in accordance with the Endangered Species Act of 1973, as amended, or that is on an applicable state or territorial list of threatened or endangered species.
- Production of hazardous or toxic materials.

Components of an EA should include

- A brief discussion of the purpose and need for the proposed action.
- A description of the proposed action.
- Consideration of appropriate and reasonable alternatives when the proposed action concerns an unresolved conflict concerning alternative uses of available resources.

- A discussion of the environmental impact of the proposed action and any alternatives.
- Recommendations to prepare a finding of no significant impact (FNSI) or an EIS.
- A list of references and agencies and persons consulted.

The EA is required to be signed by the appropriate decision maker to indicate that the document and other appropriate planning documents have been reviewed.

The EA considers and examines the long-term, short-term, primary, and secondary effects of a proposed action. For example, a proposed action may have little immediate impact on the environment, but may result in dramatic increases in energy requirements or changes in air or water quality over a number of years. In addition, an action by a particular agency may have an insignificant impact, but the involvement of several other agencies may result in a major action. For example, the field testing of smokes and obscurants by itself may have little environmental impact, but the construction of the materials and buildings as well as troop movements for the testing procedures may have a significant impact. (This manual, however will be dealing only with the environmental impact of the testing procedures.)

The site location may determine whether an EA should be prepared. Historic regions, archaeological sites, parklands, and wild or scenic rivers are examples of sites that could be highly controversial as the site of a proposed federal action.

B. Finding of No Significant Impact (FNSI)

Every EA must lead to either a FNSI document or the preparation of an EIS. The FNSI document briefly presents reasons why an action will not have a significant effect on the human environment and, thus, will not be the subject of an EIS. The FNSI will either summarize the EA or have the EA attached, and will refer to any other environmental documents that are being or have been prepared on closely related topics. The FNSI should be about two typewritten pages and must contain

- The name of the action.
- A brief description of the action including any alternatives.
- A short discussion of anticipated environmental effects.

- The conclusions that have led to the FNSI.
- A deadline and point of contact for further information or receipt of public comments.

The FNSI or the notice of availability of the FNSI will be made available to the affected, potentially affected, or interested public prior to initiation of the proposed action unless excluded on a security basis in accordance with Army regulations. The FNSIs that are proposed to be published in the Federal Register will be submitted through command channels to the Department of the Army Headquarters staff proponent. FNSIs that have national interest or impact will be coordinated with the Chief of Public Affairs. Local publication will not precede the Federal Register publication. The text of the publication should be identical to the Federal Register publication.

If the action is of regional or local interest only, the FNSI will be published in accordance with Title 40 of the Code of Federal Regulations Section 1506.6(b) (App. C). Copies of the FNSI should be distributed to any agencies, organizations, or individuals that the proponent feels are appropriate.

When involving the public, some factors to be considered are

- The magnitude of the proposed tests.
- The extent of anticipated public interest.
- The urgency of the proposal.
- Any relevant questions of national security classifications.

If substantial changes in the test procedure occur, new environmental documentation must be prepared. The existing EA will be periodically reviewed as the testing continues to insure that the setting, actions, and effects remain substantially accurate.

IV. SMOKES AND OBSCURANTS

A. Historical Background

Smoke has been used for signaling on the battlefield since ancient times. The use of smoke to promote success in battle in the distant past was often accidental, however. When gunpowder was developed, smoke became less

effective for military use because the field of combat was continually covered with the black haze from firing weapons. The use of smoke for screens first occurred in naval operations. During the Civil War, black smoke screens found wide application. This smoke was produced by burning wood with a high resin content in the ships' furnaces. When smokeless gunpowder was invented, the use of smoke for land-war purposes again became an important part of combat operations.

The systematic use of smokes for camouflaging the combat actions of troops began with World War I. Along with this use began research into the development of more effective smokes and obscurants. During the period 1915 to 1916, the first use of deceptive smokes were used by the Imperial German Army. The opposing forces mistook a harmless smoke screen for a gas attack and donned gas masks. This, together with the lowered visibility, greatly reduced the effectiveness of the opposing forces. The first smokes of World War I were black smokes, which were insufficient for camouflaging and also unstable. Research was begun to change the composition of the smoke mixture to produce a brighter smoke cloud.

US forces were the first to use white smoke from phosphorus during World War I (WWI). At the same time, the French Army developed another type of white smoke that was produced from carbon tetrachloride, powdered zinc, and zinc oxide. The carbon tetrachloride-based smoke had a tendency to evaporate during storage, however, and by the beginning of World War II (WWII), a solid smoke-producing mixture, hexachloroethane, was developed. This smoke was released from smoke pots, which were quite useful in setting up a preliminary screen during the brief time that it took to set up the large mechanical generators that produced oil and diesel fogs. Smoke pots were instrumental in shielding harbors and installations in North Africa and harbors on Sicily during WWII. Because they were so small and lightweight, it was possible to carry smoke pots onto shore to use until the heavy mechanical generators could be landed. Smoke pots were also used in Italy to screen supply routes, bridge construction, river assault crossings, tanks, ammunition dumps, troop concentrations, and ground operations and to hide the flash of mortars. Floating smoke pots were developed to aid with amphibious operations. They were also used in harbors to maintain smoke rings against enemy planes. They were employed by the Third Army in its drive across France into Germany and by

the Ninth Army in crossing the Ruhr and Rhine Rivers. Because floating smoke pots could be used on both land and water, they became the primary device for hexachloroethane smoke.

The mechanical smoke generator was used during WWII and the Korean War to produce smoke for large-area screening of rear-area targets, beach landings, paratroop assaults, and other tactical operations. This device burned fog oil but was so large that it had to be transported by barge, trailer, or truck. The first generator, the M1, was a domestic oil burner that also required water to operate. A later model, the M3, a pulse-jet generator, did not require water, and could easily be carried by two people.

During the 1973 Yom Kippur War, the use of smoke for tactical operations was given much attention. In this conflict, smokes and obscurants played a large role in reducing the effectiveness of antitank guided missiles against armored assaults. Because of this, it became clear that smoke was to play an important role in any modern combat operation, and research efforts to produce safe, effective smokes and obscurants for military use were reconfirmed.

B. The Role of Smokes and Obscurants in Present US Army Operations

In the modern military, smokes have a variety of applications. Man-made smoke, when properly employed as a passive defense, can significantly influence the tactical operations of both friendly and enemy forces. The US Army Training and Doctrine Command (TRADOC) has developed an operational concept for the employment of smoke and smoke countermeasures (Berkowitz et al., 1981). Troops are being trained in the tactical use of smoke and how to operate in areas of low visibility.

There are four general applications for battlefield smoke: obscuration, screening, deception, and identification/signaling.

1. Obscuration. Obscuration smoke can be either offensive or defensive. In offensive applications, smoke can be used to blind the enemy system of observation and separate firing points, especially those firing from the flanks. It can also be used in camouflaging the following:

- The movement of friendly troops to an initial offensive position.
- The creation of passages in barriers.
- The buildup in the initial position for an attack by subunits of infantry that are operating on open terrain.

- An infiltration through intervals in the enemy's defense position for a strike on the flank or rear.
- The crossing and securing of water barriers.

Obscuration smoke can be used for many defensive applications.

- To blind one group of the enemy that has broken into the defense, so that all their forces and fire are concentrated on another group.
- To blind enemy tanks that have broken into the depths of defense so they can be approached secretly and destroyed by grenades and other weapons.
- To blind enemy observation posts to lessen the possibility of fire adjustment.

In addition, obscuration smoke is used on or directly in front of enemy forces to lessen the effectiveness of modern electro-optical acquisition and guidance systems, such as antitank guided missiles. It is also used to slow the movement of advancing troops by causing confusion and forcing the enemy to deviate from its original plan. Obscuration smoke also prevents the enemy from observing friendly maneuvers. Of critical importance today is the use of obscuration smoke to conceal installations from aerial surveillance because the accurate delivery of many modern weapons depends on the attacker having direct sight of the target.

2. Screening. Screening smokes are used in areas of friendly troop operations or between the enemy and friendly troops. Friendly troops, under an effective smoke screen, may assemble, deploy, and perform ground maneuvers in relative safety. Smoke screens can also be used to degrade enemy observation posts and target-acquisition systems. Combat-support units, supply routes, and maintenance facilities can also be protected by screening smokes. Number, location, and sequence of operation of smoke machines for the creation of camouflaging screens are established in each separate case, depending on the mission at hand, nature of the terrain, and meteorological conditions.

Smoke screens may be frontal, flanking, or rear. Frontal smoke screens are placed in front of friendly troops and cover them from the front. The screens can be placed in the enemy position, between the enemy and friendly forces, and directly in front of the friendly forces. Smoke screens are placed in a line that is longer than the front of combat actions of the covered troops.

Flanking smoke screens are produced on the flanks of a combat formation to cover friendly troops from observation and hostile flanking fire. They are set up in both the enemy position and between enemy and friendly forces.

Rear smoke screens are produced in the rear of the combat formation of friendly troops for the purpose of camouflaging rear units and the movement of troops.

Smoke screens can be either fixed or mobile. A fixed smoke screen is one produced on a line that remains fixed during the entire time of release of smoke. A mobile smoke screen is one that is shifted as a result of the movement of the smoke-generating devices or the shifting of fire of the artillery smoke devices.

3. Deception. Deceptive smoke is used to deceive and confuse the enemy and to create false impressions of troop movements. Generally, deception smokes are used in conjunction with obscuring and screening smoke to deceive the enemy of the intentions of the friendly forces.

4. Identification and Signaling. Identification and signaling smoke is used to mark specific battlefield and supply areas. It is also used for battlefield communications, as it has since ancient times.

Modern combat operations have created some new problems associated with the production of smoke for military use. Radar reconnaissance, devices for night vision, and means for artificial illumination require new smoke applications.

C. Major Types of Smokes and Obscurants (S&O)

The smoke types that are in inventory for smoke tests are phosphorus smokes, hexachloroethane smokes, fog oil (SGF-2), diesel fuel, and infrared smokes.

1. Phosphorus Smokes (P). Both white and red phosphorus have military value and are major modifications of elemental phosphorus. White phosphorus (WP) is a highly reactive compound that reacts spontaneously with air when released from munitions. Consequently, white phosphorus is often combined with other materials that slow down smoke propagation. A white phosphorus/felt wedge (WP/FW) munition consists of a felt wedge that is impregnated with white phosphorus. The wedges are separated by a central burster charge in the munition. Plasticized white phosphorus (PWP) is in

inventory but is no longer being produced; the butadiene-styrene rubber with which the phosphorus was coated produces hazardous reaction products.

Red phosphorus (RP) is a less reactive form of elemental phosphorus. It is used almost exclusively in the plasticized form. Red phosphorus/butyl rubber (RP/BR) is the plasticized form of red phosphorus; the red phosphorus is coated with butyl rubber. Red phosphorus wedges (RPW) are munitions that consist of a felt wedges that are impregnated with red phosphorus. The wedges are separated by a central burster charge in the munition.

2. Hexachloroethane Smoke (HC). Hexachloroethane is used to produce smoke in a pyrotechnic composition consisting of grained aluminum and zinc oxide as well as hexachloroethane.

3. Fog Oil (SGF-2). Fog oil (standard grade fuel-2) is a light-duty lubricating oil and is equivalent to a SAE 20-grade motor oil.

4. Diesel Fuel (DF). Diesel fuel is the same fuel that is used to power the high-speed engines of the tanks and trucks that produce the oil smoke.

5. Infrared (IR) Smokes EA-5763 and EA-5769. Infrared smoke consists of powdered brass, which is an alloy of copper and zinc.

D. Delivery Systems and Munitions

The S&O are delivered by one or more of nine basic systems. The systems employ basic mechanisms of diffusion (usually burning) or bursting (usually by an explosive munition).

1. Bursting Munitions. Bursting munitions can be delivered by the following methods.

a. Field Artillery Cannons. Artillery smoke munitions are available for 105-mm and 155-mm howitzers. These weapons systems provide screening in hard-to-reach areas and can deliver smoke on distant targets in both offensive and defensive maneuvers.

b. Mortars. Mortars deliver white-phosphorus-filled munitions for high-volume smoke operations at midranges. They are available for 60-mm, 81-mm, and 4.2-inch mortars.

c. Smoke Grenades. Smoke grenades are used by the individual soldier and can be thrown 30 to 35 meters. They can also be launched by rifles and grenade launchers on tanks. Smoke grenades are used for signaling and screening in small areas. The M8 smoke grenade is placed or thrown by

hand and is used to cover or screen individual vehicles. The XM-76 IR grenade is used to deflect electro-optical warfare systems.

d. Tank Guns. White-phosphorus-filled munitions are available for 75-mm, 90-mm, and 105-mm tank guns. These munitions produce smoke for spotting and marking targets, signaling, or dispensing obscuring smoke on small areas.

e. Aerial Smoke Munitions. These munitions consist of rockets, bombs, and bomblets. Rockets can be used in helicopter air-delivery systems to produce smoke screens and to mark targets.

2. Burning Munitions. Dissemination modes of oil smoke/obscurants are presented in Table 1. The major types of burning munitions are discussed below.

a. Smoke Pots. These munitions include the M1 or M5 land-based smoke pots or M4A2 floating smoke pots. Floating pots can be used on either land or water, but the land pots can be used only on land. This system can produce large volumes of smoke for an extended period of time. They can be put in place by hand or dropped from vehicles or helicopters. Ignition can be done by hand or by remote electronic signal.

b. Vehicle Engine Exhaust Smoke System (VEESS) for Diesel Fuel. This system is an integral part of the engine of the M60 series Main Battle Tank. It uses the same fuel, the same supply system, and the same electrical system as the tank. The VEESS injects diesel fuel onto the hot exhaust manifold in front of the turbochargers. When it comes in contact with the hot engine, the fuel is flash vaporized and is carried with the exhaust vapors into the atmosphere. When it comes in contact with the air, it condenses and produces a dense, white smoke cloud.

The engine and hull of the M60A1/A3 Main Battle Tank with AVDS-1790-2C and 2D engines can be modified to accommodate the VEESS. The VEESS, which uses approximately one gallon of fuel per minute, is activated by the driver of the tank. This fuel is equally divided between the right and left tube assemblers into the hot engine exhaust system.

c. The M3A3 Generator. Smoke from fog oil is produced by a M3A3 US Army fog generator, a small gasoline-powered ram-jet engine that weighs 163 lb. It burns 4 gallons of gasoline per hour while vaporizing 40 gallons of fog oil per hour. A manually operated valve meters the oil onto the exhaust manifold of the engine at a predetermined rate. (Because this operating rate cannot be adjusted, the generator operates only in "on" and

TABLE 1. DISSEMINATION MODES OF OIL SMOKE/OBSCURANTS.*

Dissemination Method	Type of Smoke/ Obscurant	Particle Size Range	Total Rate of Vaporization
1. XM16, Truck Mounted, Jet Exhaust, Decontaminating/ Smoke System (JEDSS)	Fog Oil, Diesel Fuel	0.5-1.0 μm	16 gal/min
2. M3A3, Smoke Generator, Mechanical, Pulse Jet	Fog Oil, Diesel Fuel	0.5-1.0 μm	25-40 gal/hr for fog oil; 35-40 gal/hr for diesel fuel
3. XM52, Smoke Generator, Mechanical, Gas Turbine Engine	Fog Oil, Diesel Fuel	0.5-2.0 μm	60 gal/hr
4. M52, Smoke Generating Subsystem, Helicopter (UH-1)	Fog Oil (SGF-2)	0.5-1.0 μm	15 gal/min
5. Vehicle Engine Exhaust Smoke System (VESS) for M1 and M60A1/A3 Tanks, M88A1 MRV, and M551 OPFOR Vehicles	Diesel Fuels	0.5-1.0 μm	0.4 gal/min to 1.0 gal/min depending on the vehicle
6. AN-M7, SGF-2, and AN-M7A1, SGF-2 Floating Smoke Pots	Fog Oil (SGF-1 and SGF-2)	0.5-1.0 μm	8-13 min to vaporize the entire load (1-1.6 lbs/min)

* Muhly, 1983.

"off" states.) The generator requires manual starting using a coupled air pressure pump to prime the pulse jet and a magneto for ignition spark. The pulse-jet burner provides the heat and airflow to vaporize the fog oil injected into the smoke-generation chamber. The smoke is then ejected into the atmosphere through three nozzles. When the oil reaches the atmosphere, it condenses and becomes a dense fog.

d. Jet-Turbine Helicopter. Smoke from fog oil can be produced by spraying it into the exhaust of a jet-turbine helicopter. This smoke will trail out behind the helicopter as it flies, and a large cloud can be spread

in a short period of time, even under conditions of low wind speed. The duration of time in which the smoke is produced is limited, however, because of the rapid flow rate and the limited capacity of the helicopter.

e. Smoke Grenades. Burning smoke grenades are used for the same purposes as bursting smoke grenades, which were discussed above.

E. Physical Characteristics of S&O Essential for Military Use

Aerosols are systems that consist of a dispersion medium (a gas, usually air) and a dispersed phase (solid or liquid colloidal bodies with a high degree of dispersion). When the dispersed phase is a liquid, the aerosol is called a fog; when the dispersed phase is a solid, it is called a smoke. Some aerosols can constitute smoke and fog together. Generally speaking, fogs consist of aerosol particles that are larger than the particles of smokes. In military use, however, there is usually no differentiation made between fogs and smokes and, because of this, military obscurants are referred to as smokes.

All military smokes consist of a collection of aerosol particles, which are generally the same size as the wavelength of light they scatter. To be effective as an obscurant, however, the particle size of the smokes used must be generally of minimum size. The camouflaging ability of a smoke also depends on its stability. Stability is the capacity to be held in the air for a prolonged period of time without settling and without being broken up. All smokes can be measured by the following properties.

1. Optical Properties - Absorption and Extinction. Absorption is the ability of the smoke to absorb light at certain wavelengths. A ray of light passing through a smoke cloud will emerge from it less intense than at its entrance. In smokes, light is partially reflected, scattered, and absorbed by particles of smoke and only partially passes through the smoke without a change. A dense cloud will completely scatter light that is transmitted through it, so that the outline of an object behind the cloud will be obscured. A cloud will also absorb electromagnetic energy that passes through it.

Extinction is the normal unit of absorption intensity and is a function of light wavelength. The mass concentration of a smoke needed to achieve a desired level of obscuration decreases with an increased extinction coefficient.

2. Particle-Size Distribution and Mass Concentration. Particle-size distribution is the distribution of the size range of particles in the smoke. It is the most important aspect in determining the usefulness of a smoke as an obscurant. It is also an important factor in the environmental fate of smokes and in the analysis of exposure. The optimum particle-size distribution is from 0.1 to 1 μm in diameter. This range is about the same as the wavelength of light, and the light is strongly scattered. Particles in this range will also remain airborne for a long period. When the particles are smaller than this range, they will be rapidly diffused. When they are larger, they will settle out too rapidly.

Mass concentration is the weight of the smoke per cubic meter. The lower the mass concentration for particles of the optimum size, the longer acting and better the camouflaging properties of the smoke will be. Of course this is true only to a certain threshold level, below which the obscuration capability is diminished.

F. Meteorological Effects on S&O

Wind direction and speed are the most important factors affecting the behavior of a smoke cloud. In setting up smoke screens, the wind direction and the position of the troops determine the placement of the smoke. Head and tail winds blow perpendicular to the front line of troops or at an angle of less than 90 degrees to it. A head wind will blow smoke back onto the troops if it is placed in front of them. A tail wind will blow smoke away from the troops if it is placed in front of them. Source and quartering winds blow at an angle to the front line of troops. Flanking (lateral) winds blow parallel to the front line or with a deflection from it up to 30 degrees.

Relative humidity is the amount of moisture in the air compared to the total amount the air can hold at that temperature. This moisture may be absorbed by the smoke particles, causing them to increase in size and, therefore, making the smoke more dense.

Age is the amount of time it takes for a smoke cloud to dissipate. As the aerosol ages, the mass concentration is reduced, and it becomes necessary to produce more smoke to maintain an effective obscurant.

Atmospheric stability is the tendency of the air to resist overturning. The rise of the smoke plume is based on the buoyancy and stability of the atmosphere. This stability can be described in three states.

1. Stable Conditions. Under stable conditions, a parcel of air, if displaced, will return to its original level due to thermal stratification. Under these conditions, smoke will linger for a relatively long period. Smoke streamers will travel parallel downwind for long distances before they spread and merge into a continuous blanket of smoke. This blanket of smoke will lie low to the ground and will prevent visibility at ground level.

2. Neutral Conditions. Under neutral conditions, a parcel of air, if displaced vertically, will remain displaced. Neutral conditions are best for smoke operations because the smoke streamers will tend to rise and spread more rapidly than under stable conditions. They have a steadier direction, and there is less tendency for them to rise than when conditions are unstable.

3. Unstable Conditions. Under unstable conditions, vertical displacements of air are accelerated due to thermal buoyancy. The air temperature decreases with an increase in altitude, and this will cause the smoke to break up because the air is moving. If wind speed is slow, the smoke streamer will rise abruptly from the source. With faster winds, the streamer will pass only a short distance downwind before rising and becoming diffused. Unstable conditions are the least favorable for the production and testing of smokes and obscurants.

PART 2. WRITING AN ENVIRONMENTAL ASSESSMENT FOR SMOKES AND OBSCURANTS (S&O)

Environmental assessments for S&O testing are written to meet the requirements of NEPA and should identify and analyze all relevant impacts and alternatives of the proposed tests. Data should be presented in a manner that can be evaluated and appraised objectively and can be easily understood.

After the introduction, the EA should state the purpose of the tests and the reasons for implementation. The methods and procedures for S&O testing should be described. Following this will be the location, size, and surrounding region of the test. Maps, diagrams, and a summary of technical data are helpful in facilitating a comprehensive assessment of the area's environment. This will help provide an inventory of environment of the test and the scope of the test before the actual testing begins.

Each installation at which the S&O testing could take place operates under an existing environmental assessment. The EA that is written specifically for the S&O project should be carefully compared with the existing EA for the installation to prevent inadvertent inconsistencies.

It will be necessary to summarize the procedures for carrying out the tests. The handling, transportation, preparation, and operation of the smoke products should be defined as well as a timetable for operation. Included in the timetable will be personnel training periods, test dates, and a brief description of future tests.

Alternate plans and actions that will accomplish similar goals of the S&O tests must be identified and evaluated. The alternatives can include modifications to the tests and moving to another site. The EA must address the alternative of no project.

Alternatives will be based on the significance (quality) and the magnitude (quantity) of each impact of the test on the environment. Alternatives and their impacts must be identified and evaluated in some detail, and this assessment of the alternatives must be done early in the planning process. The environmental, social, and economic factors must be considered for each alternative.

The descriptions of the alternatives do not need to be as detailed as the description of the proposed action. When an alternative is discussed, it will be necessary, especially if it poses less environmental risk, to state why it was rejected in favor of the proposed action.

The criteria for selecting each alternative and the alternatives themselves should be presented in both tabular and narrative form.

Reference material, including agencies and individuals contacted, should be correctly cited in a "References" section.

I. INTRODUCTION

The EA will begin with a concise introduction. Although an introduction is not formally required, it provides the opportunity to give background information about the site and about S&O and to acquaint the reader to the issues that will be addressed. The introduction should briefly describe the area of the test, the type of smoke being tested, and the type of data to be used. It should state the reasons for conducting the tests. Any special legal or environmental considerations may also be stated in the introduction.

II. PURPOSE OF THE PROPOSED ACTION

The EA should state the purpose of the tests and the reasons for implementation, for example, the purpose of the tests could be development of a new S&O material, assurance of the continued effectiveness of S&O in the stockpile, or instruction of personnel in the use of S&O. The method of testing should be described as well as the munition used. The handling, transportation, preparation, and operation of the smoke products should be stated. Operations hazards, special security precautions, or other potentially significant considerations should be presented.

The description of the test should state the geographic area that will be affected. The volume and concentration of contaminants released from S&O testing can be directly controlled by the judicious deployment of the material. As a consequence, the geographic area that is affected by the release can be limited. The boundaries are established by using meteorological data, standard air quality criteria, occupational exposure limits to hazardous materials, and Army operations procedures. Then, using an appropriate atmospheric dispersion model, the atmospheric consequences of the test under a variety of meteorological conditions can be predicted. HAZRD2, a computer model, was developed for the purpose of predicting the atmospheric dispersion and downwind hazards of smokes and obscurants and can be used as a screening tool upon which to base test criteria (Pennsyle and Winkler, 1984).

The model provides data for graphic displays of contours for concentration, dosage, ground deposition, and multiple sources. It also includes an internal data base for US Army inventory munitions and a provision for user override. Calculations have been made of the maximum (centerline) downwind range to environmentally significant concentrations for specific munitions at a selected number of Army sites. These calculations in combination with limits on exposure can be used to define areas of concentrations that are potentially hazardous to personnel. Use of these calculations to determine the boundaries is described in Section VI, Identification of Environmental Effects.

It is appropriate to state the geographic boundaries at the beginning of the EA so the limits of the discussion are understood from the outset.

III. THE ENVIRONMENTAL SETTING

The EA is written so that it will be possible to understand all of the interrelationships of the ecological communities at the installation before the implementation of the tests. The communities, then, act as a control and establish a norm by which it is possible to evaluate the impacts of the tests on the area. The control environment is depicted as it presently exists. Historical trends should be taken into account and efforts should be made to identify any environmentally significant items, such as marginal air or water quality or rare or endangered plant or animal species.

The description of the environmental setting in the EA also provides sufficient information so that decision makers and reviewers, who may be unfamiliar with the general location, can develop an understanding of and the environmental characteristics of the test area. It should be comprehensible to the general public as well. One should not have to be a scientist to understand the report.

It is very helpful to use visual representations such as maps and transparent overlays in the description of the environmental setting. These types of representations identify such items as access roads, infrastructure, surface-water bodies, important biological communities, land features, test locations, and smoke dispersion areas.

The environmental setting part of an EA is divided into sections to make the large amount of information clear and easier to understand. These sections are the following:

- Physical Factors. This will include an analysis of the air, water, topography, geology, meteorology, and soil.
- Biological and Ecological Factors. This will include the plants (flora) and animals (fauna) in the environment. The habitat, population, growth rate, and ecological interactions of each species are considered.
- Aesthetic, Cultural, and Socioeconomic Factors. This will describe the sensory aspects (primarily visual) of the area and the quality of human life, including health and welfare.

A. Physical Factors

1. Air Quality. An air contaminant is anything emitted into the atmosphere that would not ordinarily be there. It may be a single constituent gas or particle or a combination of gases and particles. Basic determinants in analyzing air pollution are the concentration of contaminants, the persistence of a given concentration level of a contaminant, and the effects the contaminants can have on living things, inanimate objects, and physical and aesthetic features of the test area.

Air pollution can result in human safety hazards from lack of visibility, and health hazards such as eye and lung irritation. Effects that pollution can have on the aesthetics of an area include loss of clarity of the atmosphere and objectionable odors. Metals can be corroded by some contaminants, and vegetation and crops can be damaged.

One of the major impacts of the S&O testing procedures will be the impact on air quality. There are a number of steps that need to be followed to evaluate the ambient air quality of a given area and to evaluate the impact the testing of smokes and obscurants will have on that air quality.

a. Determine the Existing Ambient Air Quality in the Area. This information may be obtained from local, state, and federal air pollution control agencies or from the existing site EIS or EA. The federal data and some state and local data are stored in EPA's SAROAD (Storage and Retrieval of Aerometric Data) data base. Sampling stations in the area will have the complete history of air quality for the locale, and this information should be used. Any unique factors about the site should be described. If there have been any upward or downward trends in air quality, it is helpful to present such trends in graphical form.

b. Analyze and Summarize the Basic Meteorological Data for the Area. This section should include precipitation, temperature, wind speed and direction, solar radiation and relative humidity, and the effect of local terrain on these values as well as other factors. This weather information can be obtained from state climatology offices, the National Oceanographic and Atmospheric Administration (NOAA), the National Climatic Data Center (NCDC), and the Federal Aviation Administration.

c. Determine the Air Pollution Dispersion Potential for the Area. Air pollution must be able to disperse into the atmosphere if it is not to become a severe health and safety hazard. Several factors will determine how well this dispersion will take place. They are mixing depth, inversion height, and average and minimum wind speeds. High-air-pollution-potential advisories and episode days can provide information about past dispersion in the area.

Mixing depth is the distance above the surface of the earth in which pollutants can easily mix at a given time period. The depth varies daily, seasonally, and with the sky cover and topography of an area. In the daytime, it is usually the top of the thermal convection layer, while at night, it is very low, often capped by an inversion. (A convection layer is the height to which most thermal eddies [bubbles of warm air] rise during the day, usually about 1 km in winter and closer to 2 km in summer.) Tables of typical mixing depths for a selected number of Army installations likely to test S&O are provided in the Appendix B.

An inversion is a state in which the air temperature increases with increasing altitude, holding cooler surface air down along with its contaminants. The heating and cooling patterns of the earth's surface result in inversions being more frequent during night and early morning hours. They are also more common during fall and winter and are generally accompanied by wind speeds of less than 7 mph.

A history of high-air-pollution-potential advisories and one or more episode days are other important factors in determining air pollution dispersion. A record of these occurrences may be obtained from local and state air pollution agencies and the NCDC.

d. Obtain Air Quality and Emissions Standards for the Area. Ambient air pollutants should be chemically identified. In addition to the chemical analysis of the air, there should also be a comparison of the concentration of

constituents to those of state and federal air quality standards. This will also help the evaluation of potential impacts that testing will have on air quality. If a standard is exceeded more than once a year, the area is considered nonattainment with respect to that pollutant. Emission offsets are then required from other emitters.

National Ambient Air Quality Standards (NAAQS) were set by the Clean Air Act of 1970 (amended 1977) and include five different pollutants:

- Total Suspended Particulates (TSP). These are solid and liquid particles in the atmosphere that include smoke, dust, mists, and spray from many sources. Most of the smokes produced by the S&O testing procedures would fall into this category.

- Sulfur Dioxide (SO₂). A heavy, pungent, colorless gas formed from the combustion of coal, oil, and other products.

- Carbon Monoxide (CO). An invisible, odorless, toxic gas formed from the incomplete combustion of gasoline, coal, and other products. The largest man-made portion comes from automobiles.

- Photochemical Oxidant (O₃). A pungent, colorless, toxic gas; a component of photochemical smog.

- Nitrogen Dioxide (NO₂). A brown, toxic gas formed from the chemical combination of N₂ and O₂ in air under high temperatures during fuel combustion. This gas is consumed during the formation of oxidants (O₃).

Seven additional hazardous substances are regulated under the provisions of the Clean Air Act. They are asbestos, mercury, beryllium, vinyl chloride, benzene, radionuclides, and arsenic. In July 1979, states were required to bring their own air quality up to national standards. Many states now have air quality standards that are more stringent than the federal standards. In this case, it will be necessary to adhere to the state standards.

e. Compile an Emission Inventory. An emission inventory is a collection of the quantities of air pollutants emitted from all sources in the test area for a given time period (usually one year). The inventory is a detailed list of pollutants. It does not measure atmospheric chemical changes or any of the damage resulting from the pollution.

2. Water Quality. The Environmental Assessment should include an evaluation of the water quality in the area of the proposed action.

Data about water resources in a given area are often already available from local, state, or federal agencies in the area or from the existing site

EIS or EA. The EPA's STORET (storage and retrieval of water quality data) system is another source of information about an area's water resources. However, if these data are insufficient to adequately describe a region's water resources, a sampling and monitoring program may have to be implemented.

Meteorological data will also be necessary to assess the water environment of a given area. Data on climatological factors such as precipitation, evaporation, and air temperature will be necessary to adequately assess the water quality impact. Local and state agencies as well as the National Oceanographic and Atmospheric Administration (NOAA) are sources of data about meteorological conditions. Tables of typical winds, stability, and mixing depth for selected Army sites are provided in the Appendix B.

The water resources in a given area can vary greatly. They depend on the season, the amount of annual precipitation, land characteristics, groundwater and reservoir storage capacities, and meteorological conditions. Most water pollutants are in the form of sediment particles and dissolved minerals. Some of the reaction products of the smokes and obscurants would pollute the water as dissolved minerals. There are a number of steps in the evaluation of the water in a given area.

a. Describe the Existing Water Resources. Above the water table in the zone of aeration is the surface water, which includes lentic (running) sources, such as streams, rivers, and creeks, and lotic (impounded) sources, such as ponds, lakes, and reservoirs. The amount of this surface water should be determined as well as the direction and flow rate of streams. Present and projected uses for the water should also be evaluated.

Groundwater includes all sources of water located in the zone of saturation under the water table. In this zone, all openings such as crevices and pores are filled with water. Groundwater includes wells, artesian aquifers (groundwater that is held under pressure between layers of impermeable rock), and water-table aquifers (groundwater that is not held under pressure). The depth of the groundwater table and direction of the groundwater flow should be determined. The water will flow more rapidly through a substrate such as sand or gravel, which has a high level of porosity. Conversely, substrates such as clay and silt will slow the movement of groundwater. Present and projected uses of the water as well as historical trends in the depletion or quality deterioration of the source should be enumerated.

b. Analyze the Physical Characteristics of the Water. Physical characteristics include color, odor, temperature, solids, and pH. Solids can be further divided into organic (volatile) or inorganic (fixed) components. The turbidity of the water, or how clear it is, is also determined by the amount of suspended solids in the water. Inorganic dissolved solids present in ionic form are measured by specific conductance.

c. Analyze the Chemical Characteristics of the Water. Chemical characteristics are divided into organic and inorganic constituents. Several tests can be used to determine the organic characteristics of water. The most widely used test is for biochemical oxygen demand (BOD). The BOD is the amount of oxygen that is needed by bacteria in the process of decomposing organic material in a sample of the water held at 20 C over a 5-day period. Other tests for organic characteristics include the chemical oxygen demand (COD) and total organic carbon (TOC).

The inorganic characteristics of water include salinity (amount of salt), hardness, and mineral content. Of special concern for the S&O project is the amount of iron, manganese, chlorides, sulfates, sulfides, heavy metals, such as mercury and lead, nitrogen products (organic, ammonia, nitrate, and nitrite), and phosphorus. Both nitrogen and phosphorus have nutrient characteristics.

d. Analyze the Bacteriological Characteristics of the Water. Bacteriological characteristics include coliform bacteria and other pathogens.

3. Geology, Topography, and Soils. Much information about geology, topography, and soils may be obtained from local, state, and federal agencies in the area and the US Geological Survey. These agencies should be consulted first to avoid duplicating efforts. They will also be a useful source for maps and charts. The US Geological Survey (USGS) has systematically mapped and analyzed the geology of the United States and provides a base of geological information for detailed studies, such as an Environmental Assessment. Regional analyses are also available. The central offices of the USGS are located in Washington, DC and large regional offices are located in Rolla, Missouri; Denver, Colorado; and Menlo Park, California. Additional information may be obtained from published studies in technical journals and the results of conference proceedings. In addition, local residents with special expertise and experience with respect to the local physical environment can serve as data sources.

a. Geological Factors. Geological factors to be evaluated include

- Seismic activity. A history of earthquakes including the range of magnitudes and frequency of previous earthquakes should be noted.
- Faulting. Any major faults in the area should be identified and described.
- Rock structure. The rock form for the area should be identified according to its major geological period. Rocks will be either igneous, metamorphic, or sedimentary. They should be identified according to composition, size, and arrangement.
- Regional erosion. Landforms created by erosion should be noted.
- Permeability. Depending on geological conditions, the materials left behind after the testing process may permeate the rock, enter the groundwater system, and pollute water supplies.

b. Topography. The following topographic features should be identified and discussed.

- Precise location. The longitude and latitude of the test area or some other method of pinpointing the site should be stated.
- Relative location. This should include the distances from major urban areas, highways, and populated areas.
- Landscape. Features such as drainage, vegetation, buildings, and communication or power lines should be presented.
- Boundaries. These should include local, state, and federal areas.
- Relief. This should include the shape of the ground surface, elevation, and shape and gradient of the land. Because smoke is carried by the wind, it will generally follow the contours of the earth. When the land is flat and unbroken, it will take the smoke longer to spread out and mix than in a complex terrain. When there are large hills and rugged terrain in the test area, the smoke will be dispersed by wind crosscurrents and this will create holes and unevenness in the cloud.
- Surveyed points. These are accurately surveyed points (benchmarks) that are shown as elevations above mean sea level and give the map reader an indication of the map's relief.
- Geology. A geologic map will show the distribution of rocks and other deposits that occur at the surface of the earth as if the soil had been stripped away. This will include the age of rocks and fault

lines. The Topographic Division of the USGS is responsible for preparing topographic maps of the entire United States. Maps are available for the whole country at a variety of scales. Special purpose maps, such as geologic maps and land use maps, are also available at various scales from the USGS.

c. Soil. There are many hundreds of thousands of kinds of soil, but they may be classified basically as either a clay, loam, or a sand type. Soil is composed of organic materials and their by-products and minerals. Most of the minerals are plant nutrients, and some of the reaction products of the smoke testing may be available as plant nutrients as well. The soil in the test area should be analyzed for its content of phosphorus, nitrogen, sulfur, manganese, boron, zinc, copper, molybdenum, and vanadium. The pH (the degree of acidity or alkalinity) of the soil should be measured. In addition, the soil should be tested for its accumulation of salts.

4. Meteorology. Depending on both short-term meteorological conditions and long-term climatology, it may be necessary to alter the proposed action to assure that the smoke plume will be effectively dispersed. Short-term meteorological data should be obtained on site within 15 minutes prior to a given test (before the action takes place). These data will provide a general knowledge of the behavior of the smoke cloud.

The US Army, Navy, Air Force, and Coast Guard as well as the US National Weather Service all take their own weather observations. The US Forest Service, the Federal Aviation Administration, and state and local air-pollution, agriculture, forestry, and water-resources agencies also take observations. All these agencies may have knowledge of private data sources.

Data from all federal and some state and local agencies are archived at the National Climatic Data Center (NCDC) in Asheville, NC. Monthly and annual "normals" are available. A 30-year period is generally considered to be the minimum period required to establish climatological normals. Data for shorter periods are helpful but, due to variations in weather regimes from year to year, they should, if possible, be used in combination with long-term offsite data. Any deviations in the mean for the short-term data base can then be corrected with information from the long-term data.

An adequate meteorological assessment will include the following.

a. Preparation of a Climatological Narrative. This will be a description of the local and regional climate. Such accounts are available

from the NCDC for each state as well as for portions of some states. The narrative should include a description of the climate type, precipitation types and regimes, and synoptic patterns, including storm tracks, airflow trajectories, moisture and temperature patterns, and major weather features affecting the area at all times of the year.

b. Presentation of Temperature, Humidity, and Precipitation Data.

These data are critical because most smoke munitions will produce a denser smoke when humidity is high; therefore, conditions of high humidity are always favorable to the production of smoke. Precipitation will reduce visibility and, if it is heavy enough, no smoke at all would be required. This information should be presented in narrative and tabular form. Monthly tables are suggested, and these can be obtained for nearby locations from the NCDC. The tables should show temperature means and extremes and average relative humidity by time of day. The amount of detail necessary will depend on the size and nature of the operation.

c. Presentation of Wind and Dispersion Potential Information. Wind roses for the area should be presented. A wind rose is a diagram that shows the distribution of wind direction (the direction from which the wind is blowing) for a given site over a period of time. From this pictorial graph, one can obtain an idea of prevailing wind direction and speed during the proposed action. This information will be critical because winds have the greatest influence on smoke operations.

Wind speed will determine the optimal distance between the smoke-producing source and the objective. The best wind speeds for producing effective military smoke are between 2.5 and 8 m/s; i.e., 5 to 16 mph (Yon et al., 1983). When the wind is blowing faster than this, the smoke source will have to be closer to the objective, or more equipment and material will be required to produce effective smoke. White phosphorus smoke will form a pillar, however, if wind speeds are less than 5 m/s.

These types of wind data are available on a monthly basis for the larger airports and military bases. In addition to tabular wind data, wind roses can be of great visual aid. Joint-frequency data of wind speed and direction, with or without atmospheric stability, are available on computer tape for some locations. Computer software is available to construct such tables and wind roses from hourly observations of wind speed and direction. See the tables provided in Appendix B.

d. Description of Local Air-Flow Patterns. If site-specific data are available, a more detailed description of local wind patterns as related to terrain and other nearby features can be constructed. If these data are not available, a few general statements about the nature of mountain and valley winds or sea breezes can be made. These should be written (or at least reviewed) by a trained meteorologist familiar with the terrain and local meteorology in the area of the test.

A history of unusual meteorological occurrences, such as tornadoes, severe thunderstorms, or fog persistence should be noted. This information may also be obtained from publications at the National Technical Information Service (NTIS) or from the local, state, or federal agencies discussed above.

B. Ecological Factors

Ecology is the study of the interrelationships between organisms and their surroundings. It includes studies of populations, the collections of organisms of the same species or type, and communities, the collections of different and interacting populations. It also includes studies of ecosystems, the whole complex of physical factors that includes communities and their environments.

All ecosystems include four components--the abiotic environment and the three basic niches: the primary producers, the consumers, and the decomposers. A niche can be described as the occupation of a particular species. Primary producers transform the radiant energy of sunlight and inorganic nutrients into living materials. This is accomplished through photosynthesis. Chlorophyll is required for this process and, therefore, all green plants are primary producers. Consumers are the organisms that consume organic materials and convert them into living substance. Herbivores transform the organic material from primary producers into animal tissue and carnivores transform other animal tissue into tissue of their own. Omnivores (such as people) consume both. Decomposers are the organisms that transform organic materials back into inorganic, thereby making nutrients available again to the primary producers. Decomposers can be fungi, bacteria or other animals.

Habitats determine which kinds of populations will be able to carry out the function of the niches. Habitat has been described as the address of a

particular species. While niches are the three basic types of work carried out by the organisms in a community, it is the particular habitat that provides the difference between communities. Habitats will be determined by competitions between populations, natural selection, and characteristic stresses on individual organisms.

In general, the environment can be divided into three different types of ecosystems--aquatic, terrestrial, and wetland.

The aquatic ecosystem is generally further divided into two separate categories: saltwater systems in tidal and nontidal areas and freshwater systems that include surface waters and groundwater. This manual will assume that there will be no deposition of smoke or smoke reaction products on or near saltwater systems.

The dynamics of the aquatic ecosystem involves the interrelations of the three basic niches. The primary producers may be aquatic macrophytes (such as water lilies), phytoplankton (microscopic, free-floating algae), periphyton (microscopic algae that grow attached to rocks or other material), or pigmented bacteria that can carry on photosynthesis. The consumers are the second niche and subdivide into primary consumers such as zooplankton, which consume plants; secondary consumers, typically benthic organisms (bottom-dwellers, such as mud worms and clams), which consume the primary consumers; and tertiary consumers, typically nekton (those organisms that can swim against the current of the water, such as fish), which consume the secondary consumers. (This sequential consumption of one organism by another is a food chain. It is through understanding this chain that it is possible to assess the effects of an action on all the organisms in an ecosystem.) The last niche comprises the aquatic decomposers, those organisms such as fungi and bacteria that convert organic material back into inorganic material.

The terrestrial ecosystem also involves the interrelationships of the three basic ecological niches. In the terrestrial ecosystem, the primary producers are the plants--the trees, shrubs, grasses, and flowers. The primary consumers are a large number of herbivorous mammals, insects, birds, reptiles, and amphibians. The secondary and tertiary consumers are the predatory animals. The work of decomposition is carried out by a variety of fungi, bacteria, and other organisms.

Two additional concepts have been defined for the terrestrial ecosystem: plant association and biome. Plant association is a term that describes the

fact that plants occur in certain relationships with other plants; that is, one type of vegetation in an area will be the predominant species and there will be several other types of subdominant vegetation that, in any locale, will generally occur with it. Associations may include only a few species or it may contain many dozens of species. Occasionally, there will not be a single dominant species, but rather a group of two or more prevalent species. A biome is a large community of plants and animals that will usually exist together under certain climatic conditions. A biome will be named after the predominant vegetation in the area such as a grassland biome or a deciduous forest biome.

According to US Fish and Wildlife Service, wetlands are lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes:

- (1) at least periodically, the land supports predominantly hydrophytes;
- (2) the substrate is predominantly undrained hydric soil;
- (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Until fairly recent times, most of the wetland area in the United States had been considered economically unimportant. Large efforts were made to fill in these areas to make them into productive farmland and, as a result, there has been an enormous loss of wetland environments in this country. Today, however, that outlook is changing. The remaining wetland environments are being viewed as important both ecologically and economically.

The three basic niches in wetlands can be occupied by populations similar to those of both the aquatic ecosystems and the terrestrial ecosystems.

A large percentage of the wetland environments are located in coastal or tidal areas, rather than inland, nontidal areas. This manual assumes that no testing will occur in coastal or tidal wetlands areas.

For each of these ecosystems, there are a number of steps that need to be followed to effectively evaluate the existing ecological community and to predict the impact of testing of smokes and obscurants. This information for a particular Army site may be readily available in an existing EIS or EA. If such information is not readily available, the steps for evaluating the ecosystem setting include the following.

1. Describe the Ecosystem. The general community types (such as desert reptiles, migratory birds, or deciduous forest) must be defined and described according to their geographical distribution. Then, species descriptions (such as desert tortoise, mallard duck, or hickory tree) for each community type must be developed and quantitative data for population density should be given. Population densities are described as either common, occasional, or rare. A species is common if it occurs in large numbers in many localities in the community, occasional if it occurs in small numbers in several localities, and rare if it is scarce and is located in only a few areas. Both the common and biological names of each species should be given.

Information for preparing the description of the ecosystem may be obtained from published papers in technical journals, conference proceedings, and state and local agencies such as wildlife commissions, fish and game commissions, and departments of natural resources. Information may be obtained from the federal government through the Bureau of Land Management, Fish and Wildlife Service, National Forest Service and the National Park Service. Universities in the area can also provide information and data that have not been published.

The information necessary for a complete description of the ecosystem depends on the type of ecosystem being evaluated. The following subsections set out these differences.

a. Aquatic Environment. Each aquatic habitat will be determined by the water, the land around the water, and the area between the two. In addition to descriptions of general community types, population densities, and specific species, the description of an aquatic ecosystem should include the following: (1) whether the aquatic plants in the project area are adapted for floating, for growing completely under water, or growing partly submerged; (2) which plants and animals are adapted to live at the bed of the water body and which ones are adapted to live near the surface; and (3) which aquatic organisms are particularly adapted to survive under conditions of fluctuations in available oxygen, chemical composition, and nutrients.

b. Terrestrial Environment. Terrestrial habitats are characterized by abiotic factors (such as geography, temperature and humidity) that influence the biotic factors (the plants and animals). Consequently, it is necessary to describe the physical environment to identify the factors that make the area unique. The relationship of seasonal and geographic constraints

of the habitat to plant structure or animal behavior should also be described. In addition, a Reconnaissance Evaluation or a Vegetation Analysis should be conducted.

A Reconnaissance Evaluation covers a large area and is used to determine the suitability of the area for particular species. It should include the following:

- A map of the entire project area showing types of vegetation, including trees, shrubs, and ground cover.
- An evaluation of the density of the vegetation.
- An evaluation of the soil, including physical and chemical characteristics.
- An evaluation of the material used as food by the animals in the area, including its availability, consumption, and yearly production. Also included should be the ratio of the amount of food produced to the amount that is consumed.
- An identification of the kinds of natural vegetation that will give an indication of the climate, soil, and moisture conditions of the habitat, as well as range-fire potential.

A Vegetation Analysis provides a detailed look at the vegetation in the area in relation to the wildlife that lives there. It should include the following:

- A simple presence-absence statement that tells whether or not a particular type of vegetation is present or absent.
- The basal area, which is the amount of ground that is covered by a particular plant species.
- The height of the vegetation.
- How frequently a species occurs. This will be the percentage of sample plots in which the plant occurs.
- The density of vegetation, which is the number of individual plants per unit of area.
- An analysis of the dominant plants in the area.
- The importance (value) of a particular plant for a given purpose.

Most of the information for reconnaissance evaluation and vegetative analysis can usually be obtained from existing literature or from the existing Army site EIS or EA. Agencies that have this type of information include federal and state fish and wildlife agencies, geological survey agencies,

environmental quality and natural resource agencies, local and regional universities, and wildlife and conservation organizations.

To organize the information obtained from these agencies, the assessor should use the concepts of plant associations and biomes. Plant association information can indicate the type of wildlife that will live in that particular type of habitat, and the physical structure of the environment. In addition, plant associations provide food, shelter, sites for breeding and rearing of offspring for all the animals of the community, and nesting materials for birds. Because of this, information obtained from the analysis of the plant associations will supply much of the information needed about the existing biome.

If such information cannot be obtained, it will be necessary to perform the evaluation of the habitat. This evaluation should include (1) as much information as possible about soils, climate, water, and vegetation, (2) information about plant associations and animal populations solicited from local botanists, zoologists, and ecologists, and (3) the results of aerial and field reconnaissance of the plant and animal species in the area. Detailed, long-term studies of the test area will only be required if a possibility exists that rare or endangered species will be affected.

c. Wetland Environment. The inland, nontidal wetland environments should be classified according to the amount of water in the region. These are known as classification regimes, and are listed below:

- Saturated. No surface water with only slight fluctuations in the water table.
- Temporarily flooded. Flooding will not occur for more than 10 consecutive days.
- Seasonally flooded. Surface area is covered with water for less than half the year.
- Semipermanently flooded. Surface area is flooded for more than half the year, but not permanently.
- Permanently flooded. Entire surface is covered with water for the entire year).
- Intermittently flooded. Entire area is occasionally flooded, but not on a regular basis.

In addition to the type of regime, wetlands are also classified according to water chemistry. This will include the salinity (the amount of salt in the water) and the pH (the acidity or alkalinity of the water).

In addition to the classification of the wetland, the description of the wetland environment should identify the energy and materials that go into and come out of the region. Wetlands in surrounding regions should be classified and their energy and materials described. Important biotic and abiotic factors in the area and their interrelationships should be presented. Finally, the interrelationship of the wetland with regional aquatic and terrestrial ecosystems should be discussed.

Information about wetland environments may be obtained from the US Department of Fish and Wildlife, local, state, and other federal agencies, published reports in technical journals and conference proceedings, and local and regional universities.

2. Identify Rare and Endangered Species. A description of the characteristics of rare and endangered species should be prepared even if there is only a potential for their existence in the test area. These characteristics will include breeding and nesting requirements, life-cycle features, and any other unique requirements. This is one of the most critical aspects of the environmental assessment.

3. Identify Any Management Practices for the Area. Local, state, or federal agencies in the area may already have management practices for the environment of the test area. If any components of the environment are already being managed, this will indicate an area of concern when conducting the assessment.

4. Describe Natural Succession. The assessment should describe the expected biological community in the future without the implementation of the tests. This can be facilitated by describing the predictable changes within the community that lead to the alteration of community types and species.

Ecological succession is a natural process that will occur with or without the presence of human activity. It results in the sequential replacement of one biological community with another until the climax community is established. It will be necessary to distinguish between changes that will occur as a result of the tests, and changes that would occur naturally. For example, the reaction products of some of the smokes are plant nutrients and their introduction into the environment may slow down what would ordinarily be a natural loss of plants and animals in the area.

Local, state, and federal agencies in the area are the best sources of information on the stage of succession in the test area. Local colleges and

universities and botanical and wildlife organizations are also sources of information. These agencies can help determine the present stage of succession in the area, possible future stages if the tests are not undertaken, and possible stages if the tests are undertaken.

C. Aesthetic, Cultural, and Socioeconomic Factors

The cultural environment is not limited to artifacts and old buildings. It is the nonrenewable history of the civilization of the area. It will include the archaeological, historical, and architectural sites of the immediate region and those of surrounding regions. In addition, many archaeological sites contain valuable information about the environment of the region because past ecological conditions may be reflected in its cultural resources.

Laws and regulations governing the preservation of cultural resources have been evolving in recent years. Most states have laws that regulate the disturbance of cultural resources on state land. Some of these state laws are quite aggressive, but there is considerable variation between states. Federal, state, and local ordinances should be reviewed.

1. Culture. A number of steps need to be followed to evaluate the cultural environment of the test area and to predict the impact that testing of smokes and obscurants will have on that environment.

a. Identify the Cultural Resources. This information may be obtained from local professional societies, regional universities, state historic preservation societies, and the National Register of Historic Places. Cultural resources will include all archaeological artifacts or areas made or modified by humans such as caves, hunting stations, habitation sites, arrowheads, stone axes, and pottery. Local government officials will also be able to identify ethnic cemeteries, burial grounds, and other sacred or religious sites. This information should be contained in existing EAs or EISs for the site.

b. Identify Potential Cultural Resources. All of the cultural and archaeological sites in this country have not yet been identified. To identify potential cultural resources, it may be necessary to conduct a preliminary archaeological reconnaissance. In conducting an adequate assessment of the cultural environment, this survey should not require more

than one-fourth of the total research time. Local, state, and regional historical preservation societies as well as the National Park Service can provide assistance in conducting an archaeological reconnaissance.

c. Identify the Significance of Cultural Resources. It may be necessary to consult with a specialist to determine the value or importance of any archaeological sites in the area of the tests. More than 5,000 sites are lost to development projects each year in the United States. Experts should help decide whether or not a particular site will warrant preservation.

Some of the criteria for determining the value of an archaeological site will include the following: the age of the site, the concern of the local population for the site, the cost of conducting the archaeological reconnaissance, the eligibility of the site for inclusion in the National Historical Register, the nature of the site, the feasibility of preserving the site, and the importance of archaeological data that may be obtained from the site.

2. Land Use. Land use should be described. This will include a narrative history of the use of the land including both military and civilian use. The use of airspace should be identified as well including any use for training by the Air Force, any NASA tracking stations, and any commercial or military air corridors. A description of both the routes and methods of transportation for supplies should be given.

3. Economy. A brief analysis of the economy of the area should include the following.

a. Regional Economics. This will include a narrative describing the economic resources in the area including manufacturing, mining, agriculture, or military assets.

b. Population. This will be the population for the area from the last national census, projected rates of growth or decline, and reasons for any changes in population.

c. Employment. This will include both the numbers of persons in the area who are employed and the rate of unemployment. Any rates of growth or decline should be explained.

d. Transportation and Public Utilities. This will include modes of transportation such as highways and rail service, methods of producing energy for the area, and communication networks.

4. Government, Institutional, and Social Conditions. An analysis of the government, institutional and social conditions of the area will include a description of the following community services.

a. Health Facilities. This will include hospitals, clinics, and numbers of practitioners, both public and private.

b. Education. This will be the schools from elementary through college and the numbers of students and staff at each institution.

c. Parks and Recreation.

d. Cultural Facilities.

e. Public Safety. This will include the number of police, both civilian and military, in the area.

f. Fire Protection. This will include a description of the methods and personnel in the area, both military and civilian, that are available to fight fires.

g. Transportation. This will be a description of roads, highways, public transportation, and airports.

h. Public Finance.

i. Public Utilities. This should include a description of the infrastructure of the area including water and sewage facilities covering pipelines, wastewater collection and disposal systems, and the number of acres served by the sewage system. Also included should be a description of the methods of sewage treatment, both civilian and military.

5. Aesthetics. The Bureau of Land Management has the ability to designate an area as either prime or scenic. The existence of such a designation should be investigated. If the area has been designated prime or scenic, this designation should be described.

6. Electromagnetic Interference. The use of radios, radar, and electromagnetic warfare systems can interfere with non-cable and FM radio transmission. This use can also interfere with existing military or NASA operations. The Department of Defense Electromagnetic Compatibility Analysis Center in Annapolis, Maryland, can conduct an electromagnetic analysis for the area and recommend specific frequency assignments, operating locations, and times of operation.

IV. PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES OF SMOKES AND OBSCURANTS

To assess the impact of particular smokes on a particular environment, each smoke and the reaction products produced by its ignition should be analyzed. In this section, each individual smoke will be described according to its physical and chemical properties, its environmental chemistry, and its biological effects and toxicology.

A. Physical and Chemical Properties by Major Type of Smoke

1. Phosphorus Smokes. White (WP) and red (RP) phosphorus smokes are aerosols that block a visual portion of the light spectrum. They are important on the battlefield in screening and obscuring friendly operations from the enemy.

White phosphorus is a crystalline network of elemental phosphorus. It is prepared commercially by roasting phosphate ores with silica and coke in an electric furnace. Phosphorus pentoxide is formed when the silica reacts with the phosphate ore. The coke then reduces the phosphorus pentoxide to white phosphorus in vapor form. This vapor is cooled and condensed under water to produce solid white phosphorus. In this state, it is a yellowish, waxy solid that looks like paraffin and melts to a straw-colored liquid. If the ore is not pure, the final product may contain small amounts of arsenic and hydrocarbons as contaminants.

When white phosphorus is exposed to air, it reacts spontaneously to produce phosphorus oxides. The most important oxide is phosphoric pentoxide, which is responsible for the dense white cloud that is produced when WP munitions are ignited. Because white phosphorus uses up so much oxygen, it is quite dangerous to use within a confined space. The oxides produced are poisonous as well. When phosphoric pentoxide comes into contact with atmospheric moisture, it becomes phosphoric acid and phosphorus acid. These are both powerful dehydrating agents. The other major oxide of phosphorus, phosphorus trioxide, will be formed when the phosphorus is burned without sufficient oxygen. This is of special concern because phosphorus trioxide will react with water to form phosphoric acid and phosphine, which is a very toxic gas. In field conditions, however, the production of phosphine should be minimal.

White phosphorus must be stored under water to prevent it from coming into contact with air. At ordinary pressure and temperatures, it is quite insoluble and does not react with water. It will react with steam, however.

Because white phosphorus is highly reactive with oxygen, it is used to advantage in bursting munitions such as mortar rounds, artillery, and grenades. This same reactive property, however, can present a hazard to personnel so it is always necessary to handle it with caution.

When white phosphorus is ignited, the phosphorus breaks up into minute particles that are dispersed over a large area. The diameter of the particles is generally around 1 μm (a millionth of a meter). The ignition and rapid oxidation of these minute particles of phosphorus creates a large amount of heat. Because heat rises, the smoke is directed upward in a pillar and does not linger near the surface where it would be most effective for screening and obscuring. This was seen as a major defect in the use of phosphorus smoke. In 1944, the problem was solved by reducing the extent to which the particles of phosphorus were scattered. This was done by plasticizing the white phosphorus; the granules of white phosphorus were added to a solution of synthetic rubber (styrene-butadiene, US Military Specification Mil-R-51209 MU 9/11/64), which coated it and separated the granules (Wasti et al., 1978). This material is called plasticized white phosphorus (PWP). When styrene-butadiene rubber is burned, however, the resulting products contain the aromatic ring structure (the phenyl group) (Yon et al., 1983). Phenyls are toxic and carcinogenic and because of this, plasticized white phosphorus has not been produced since 1965.

Red phosphorus is produced from white phosphorus. Liquid white phosphorus is heated at 350 to 400°C in a closed container for several hours. Iodine or sulfur is added as a catalyst. Depending on how it is prepared, the red phosphorus may have a crystalline structure or it may be without structure (amorphous). Commercial RP is primarily an amorphous solid. It varies in color from pale yellowish-red to a dark violet-red. Red phosphorus is not nearly as reactive with oxygen as white phosphorus and is only moderately unstable under normal conditions. It must be heated to produce the reaction that creates the smoke.

Red phosphorus is also used by the military for screening and obscuring. It is a red-colored solid that can be a finely powdered or a massively formed material. Red phosphorus is not as reactive with oxygen as white phosphorus

and is relatively insoluble in water; red phosphorus is more stable and controllable than white phosphorus and requires an igniter to start it.

Plasticized red phosphorus is coated with a butyl rubber, which is actually a copolymer such as isoprene. The degradation products of butyl rubber do not contain the benzene ring structure and are therefore more environmentally acceptable than the degradation products of the styrene-butadiene rubber that was used to coat white phosphorus.

Both types of phosphorus smokes form a dense cloud of white smoke, which consists primarily of the phosphorus oxides, phosphorus pentoxide and phosphorus trioxide. These oxides react with water vapor in the air to form phosphoric- and phosphorous-acid particles, which expand, and, because of their greater size, provide a more effective obscurant.

Properties of red and white phosphorus smoke and their reaction products are shown in Tables 2 through 5. Munitions for disseminating them are discussed in Part 1, Section IV.D., and are listed in Table 6.

2. Hexachloroethane Smoke (HC). A white smoke is produced from burning grained aluminum (Al), zinc oxide (ZnO) and hexachloroethane (C_2Cl_6). The mixture that produces HC smoke is composed of approximately 6.7% grained aluminum, 46.7% zinc oxide and 46.7% hexachloroethane. Most of the smoke itself (about 80% by weight) is zinc chloride ($ZnCl_2$). (The carbon resulting from the initial reactions will, at first, give the smoke a somewhat yellowish color.)

The ratio of hexachloroethane to zinc oxide is usually held constant, but the amount of aluminum can range from 3.6 to 10.1%. The burn time for the smoke will increase when the percentage of aluminum is decreased. When the burn time is increased, there is less smoke produced in the initial reaction and the burning becomes erratic. On the other hand, decreasing the amount of aluminum in the mix will also result in less carbon appearing in the smoke. This results in a whiter smoke, which makes a more effective screen in bright daylight conditions. The percentage of aluminum in the mix, therefore, must be sufficient to prevent slow, erratic burning but in a small enough amount to keep the smoke as white as possible. The ratio of aluminum content to burn time is presented in Table 7.

HC smoke mixtures must be ignited to produce smoke. The heated mixture will continue to burn; the major reaction involved is the formation of aluminum chloride from aluminum and hexachloroethane.

TABLE 2. PHYSICAL AND CHEMICAL PROPERTIES OF ELEMENTAL WHITE PHOSPHORUS.*

Formula: P_4

Appearance: Colorless to yellow, waxy solid

Molecular Weight: 123.90

Melting Point: 44.1 C

Boiling Point: 280.5 C

Crystal Structure: Cubic

Density: 1.828 g/cm³

Autoignition Temperature: 30 C in moist air

Critical Temperature: 695 C

Critical Pressure: 82.2 atm

Heat of Fusion: 600 ± 3 cal/mole P_4 at 317.26 K

Heat Capacity: at 25 C, 22.18 cal/mole/degree
at 44.1 C, 22.73 cal/mole/degree

Heat of Sublimation: 13.4 kcal/mole P_4

Heat of Combustion: 710.2 ± 1.0 kcal/mole P_4

Sublimation Pressure (mm Hg): 0.025 at 20 C
0.072 at 30 C
0.122 at 40 C

Vapor Pressure: 1 mm Hg at 76.6 C

Solubility:

Water: 3 mg/L at 15 C (slightly soluble)

Absolute Alcohol: 2.5 g/L

Ether: 10 g/L

Chloroform: 25 g/L

Benzene: 28.5 g/L

Carbon Disulfide: 1250 g/L

Reactions: Primary combustion product is P_4O_{10} ; this will react to give phosphoric acids, which hydrolyze further to H_3PO_4 in 5 to 10 days. Rate of hydrolysis increases with chain length for linear polyphosphoric acids.

* Berkowitz et al., 1981.

TABLE 3. PROPERTIES OF PHOSPHORIC ACID.*

Material: Colorless, crystalline solid
Melting Point: 42.35 C
Boiling Point: -261 C
Density: -1.8741 g/mL
Heat Capacity: 25.3 cal/deg mole at 25 C
Pure Material: No oxidizing properties below 350 to 400 C
pk₁: 2.15
pk₂: 7.1
pk₃: 12.4

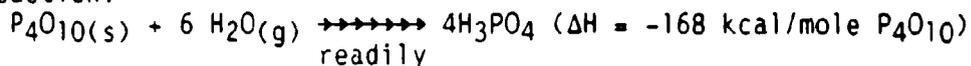
Reactions: Will form ammonium and metal phosphates, fluorine will replace oxygen to form fluorophosphate; phosphate ions will complex metals in solution.

* Berkowitz et al., 1981.

TABLE 4. PROPERTIES OF PHOSPHORUS PENTOXIDE.*

Formula: P₄O₁₀ (H form)
Material: White crystalline material
Sublimation: 360 C at 1 atm
Melting Point: 420 C
Heat Vaporization: 16.2 kcal/mole
Heat of Fusion: 6.5 kcal/mole
Heat of Sublimation: 22.7 kcal/mole
Heat Capacity: 50.6 cal/deg mole at 25 C

Reaction:



will dehydrate other oxyacids
e.g., $\text{P}_4\text{O}_{10} + 12\text{HNO}_3 \rightarrow 4\text{H}_3\text{PO}_4 + 6\text{N}_2\text{O}_5$

* Berkowitz et al., 1981.

TABLE 5. CHARACTERISTICS OF AMORPHOUS RED PHOSPHORUS.*

Appearance: Reddish-brown, amorphous solid
Autoignition Temperature: 260 C
Boiling Point: 280.5 C
Critical Pressure: 43.1 atm
Critical Temperature: 589.5 C
Density: 2.34 g/cm³
Heat of Combustion: 703.2 ± 0.5 kcal/mole
Heat of Sublimation: 19.7 kcal/mole
Melting Point: 589.5 C at 43.1 atm
Molecular Formula: Highly polymeric
Solubility in Cold Water: Very slightly soluble
Sublimation Temperature: 416 C

* Yon et al., 1983.

TABLE 6. DISSEMINATION METHODS OF PHOSPHORUS SMOKE/OBSCURANTS.*

-
1. M2 - 4.2-inch WP/PWP mortar
 2. M328A1 - 4.2-inch WP/PWP mortar
 3. M110 - 155-mm howitzer, WP projectile, (MJ11 E2)
 4. M57 - 81-mm WP mortar, (M57A1)
 5. M375 - 81-mm WP mortar, (M875AZ1M37)
 6. MK4 - 5-inch PWP navy rocket
 7. M60 - 105-mm howitzer, WP projectile, (M6A2)
 8. M302 - 60-mm WP mortar
 9. L8A1 - RP grenade, (12)
 10. M313 - 90-mm WP gun
 11. M416 - 105-mm WP gun
 12. M308 - 57-mm WP rocket, (M3 8A1)
 13. M311 - 75-mm WP rocket, (M311A1)
 14. CBU-88 - RP bomb
 15. XM819 - 81-mm mortar, 28 RP wedges
 16. XM825 - 155-mm WP/felt Wedge projectile
 17. M116M1 - 155-mm howitzer, HC, (M116B1)
 18. M259 - 2.75-inch WP wedge rocket
-

* Yon et al., 1983.

TABLE 7. RATIO OF ALUMINUM CONTENT TO BURNING TIME IN HC SMOKE.*

Aluminum Content (%)	Burning Time (seconds)
9.0	55
8.4	64
8.0	65
7.5	71
7.0	84
6.5	96
6.0	107
5.5	147

* Cichowicz, 1983.

The following reactions occur when the mix is heated:

- The aluminum will combine with the hexachloroethane to produce aluminum chloride, carbon, and heat.
- The aluminum chloride then reacts with the zinc oxide in the mix to produce zinc chloride, aluminum oxide, and heat.
- The zinc chloride then vaporizes into the atmosphere and, when it cools below its condensation point, it produces a gaseous suspension of fine particles, which is the smoke.
- This aerosol absorbs moisture from the surrounding atmosphere, and the particles that make up the aerosol become larger. The larger the particles, the more diluted the visible light spectrum becomes.

The smoke mixture is ignited by a pyrotechnic starter mixture and can be ignited either manually or electrically. Smoke pots can be stacked together to provide a chain ignition. The starter mix can have both thermite and black-powder-burning properties and will be composed of such chemicals and compounds as silicon, potassium nitrate, charcoal, iron oxide, grained aluminum, cellulose nitrate, and acetone.

A white smoke such as this one is actually composed of colorless particles and the white appearance is due to the reflection and refraction of all the visible light rays. As these light rays are scattered by the smoke, the smoke becomes more effective. Therefore, white smoke is a more effective obscurant than black smoke during bright daylight conditions.

Under conditions of high relative humidity, water vapor in the air will increase the effectiveness of HC smoke. The aerosol particles in the HC smoke will dissolve in the air and become liquid. As they do, they grow in size and, therefore, are able to scatter more light rays.

Physical properties of hexachloroethane are listed in Tables 8 and 9.

HC smoke is disseminated by three different munitions systems, artillery rounds, smoke pots, and smoke grenades. Research has shown that a smoke pot lying on its side in a horizontal position will deposit from 5 to 10 times more organic material into the environment than a smoke pot upright in a vertical position (Schaeffer et al., 1986a). Dissemination modes for HC smoke are discussed in more detail of Part 1, section IV.D.

3. Fog Oil (SGF-2). The smoke generated from fog oil (SGF-2) is considered to be a military obscurant. There are two types of fog oil that can be used by the military, SGF-1 and SGF-2, but since 1975 only SGF-2 has been used. SGF-2 is a refined petroleum product in the middle distillate range and is produced from crude petroleum oil. It is a lubricating oil, such as mineral oil and the oils that are used for light automotive and industrial lubrication. These types of oils generally have hydrocarbons with 20 to 50 carbon atoms, and SGF-2 is probably made up of hydrocarbons in the molecular weight range of 240 to 420 atomic units (American Public Health Association, 1985).

Petroleum is not processed specifically to produce fog oil. Rather, the specifications for SGF-2 correspond to those for other products and the oil is drawn from those stocks. What is supplied to the US Army is a light viscosity lubricant, sometimes called "100 pale oil." It is a light amber color and is equivalent in viscosity to a SAE 20-grade motor oil. The fractional distillation of crude oil to produce SGF-2 is similar to that used to produce petroleum products such as gasoline and diesel fuel. It is then deasphalted to remove constituents that would produce a carbon residue.

When SGF-2 is heated in a smoke generator, it vaporizes and then passes through the nozzle of the generator. When it comes into contact with the surrounding air, it cools and condenses. The cooling is so rapid that only very small droplets of oil are produced. The drops are from 0.5 to 1.0 μm in diameter and, because of their small size, a dense white smoke is produced. This vaporization-condensation process is not dependent upon atmospheric moisture for the reaction, and the life of the cloud is dependent solely upon meteorological conditions.

TABLE 8. PHYSICAL PROPERTIES OF HEXACHLOROETHANE.*

Formula: (C₂Cl₆)
 Appearance at 20 C: Colorless, rhombic crystalline solid
 Odor: Camphor-like
 Melting Point: 186.8 C (Triple point - sublimes simultaneously)
 Crystal Density: 2.09 kg/L
 Vapor Density (1 atm): 6.3 g/L at 186.8 C
 Specific Heat at 20 C: 0.266 cal/g/ C
 Heat of Vaporization: 46 cal/g
 Vapor Pressure at 32.7°C: 1 mm Hg
 Solubility:
 Water: Insoluble
 Alcohol: Soluble
 Benzene: Soluble
 Toluene: Soluble
 Petroleum Solvents: Soluble
 Chlorinated Solvents: Soluble

* Cichowicz, 1983.

TABLE 9. PARAMETERS, STABILITY, AND SENSITIVITY OF HC SMOKE MIX.*

Autoignition Temperature: 167 C	Electrical Spark: 0.122 Joules
Decomposition Temperature: 193 C	Card Gap: N.D.
Density (bulk): 1.14 g/cm ³	Detonation Test: N.D.
Density (loading): 1.6-1.9 g/cm ³	Friction: Insensitive
Fuel/Oxidizer Ratio: 0.2:1	Impact Sensitivity: 10 inches
Heat of Combustion: 300-940 cal/g	Burn Time: 9.8 sec/cm
Hygroscopicity: 90% (fair)	Critical Diameter: 1 meter
Thermal Stability: 75 C (poor)	Critical Height: 218 cm
Vacuum Stability: 0.24 mL/gas/40 hr	TNT Equivalency: 0%

HC smoke mix is sensitive to electrical spark, moderately sensitive to impact, and insensitive to friction, strong shock in the card gap test, and mild shock from a number 8 blasting cap in the detonation test. HC smoke failed to burn when exposed to open flame in an ignition and unconfined burning test.

* Cichowicz, 1983.

Physical and chemical properties of fog oil are listed in Table 10. Smoke from fog oil is produced using an M3A3 generator or from spraying the fog oil into the exhaust of a jet-turbine helicopter. Dissemination modes of oil smoke/obscurants are listed in Table 1 and are discussed in more detail in Part 1, Section IV.D.

4. Diesel Fuel. Diesel-fuel obscurant is produced by a middle-distillate oil, which is the same fuel that is used to power diesel engines.

The two types of diesel fuel used for the production of smoke are diesel fuel no. 2 (DF2) and diesel fuel no. 1 (DF1). DF2 is a summer-grade fuel used under warm climatic conditions and DF1 is a winter-grade fuel. Both grades differ in viscosity and boiling range. DF1 has more volatile compounds than DF2. This allows for easier starting in cold weather.

The cetane number for fuel determines the ignition quality of the fuel. The higher the cetane number, the easier it is to start the engine under conditions of low temperature. A low cetane number may result if the crude oil was rich in aromatic compounds or if the fuel is a blend of straight or cracked distillates. When this is the case, cetane improvers are added to further refine the fuel and remove aromatic compounds. Cetane improvers are solvents and may be organic nitrates and peroxides (amyl nitrate, hexyl nitrate, and acetone peroxide) (Liss-Suter et al., 1978a).

Other additives may be present in small amounts. These additives include alkyl nitrates to improve combustibility, surfactants to reduce corrosion of storage vessels, mixed surfactants to reduce gum formation and thereby improve the compatibility of mixed fuel sources, and aromatic amines or phenols to act as antioxidants.

The smoke produced is technically a fog. It consists of 0.5 to 1.0 μm droplets of the oil in suspension in the air. Each individual droplet is translucent but the entire fog is opaque. Physical and chemical properties of diesel fuel are listed in Table 11.

The means to produce fog from diesel fuel are the Vehicle Engine Exhaust Smoke System (VEESS), the M3A3 generator, and jet-turbine helicopters.

5. Infrared Smokes EA-5763 and EA-5769. Infrared smoke is a brass powder that is used as a deflecting device for electro-optical warfare systems. The brass is disseminated as a powder or as flakes. They are coated with palmitic and/or stearic acid. Brass is an alloy of zinc and copper and the brass powder in the infrared smokes is approximately 70% copper and 30%

TABLE 10. PHYSICAL AND CHEMICAL PROPERTIES OF FOG OIL (SGF-2).*

Density at 60 F: 0.920 g/cm
22.4 deg, API

Mean Vapor Pressure at 25 C: 1.6×10^{-5} mm Hg

Viscosity (centistokes)

at 32 F: 300.0	at 60 F: 80.0
at 100 F: 22.5	at 210 F: 3.5

Characterization Factor: 11.4 K

Mean Average Boiling Point: 700.0°F

End Point Distillation Temperature: 870.0°F

Mean Specific Heat of Liquid, from 70°F
to Mean Boiling Point, BTU/lb: 0.58 F

Heat of Vaporization at Mean Boiling Point: 92.0 BTU/lb

Mean Molecular Weight: 300.0 lb/lb-mole

Heat Required to Vaporize**: 3,565.0 BTU/gal

* Muhly, 1983.

** From a liquid initially at 70°F to a vapor having a superheat at 20°F.

TABLE 11. PHYSICAL AND CHEMICAL PROPERTIES OF DIESEL FUEL (DF2).*

Density at 60°F: 0.850 g/cm
: 35.5 deg, API

Mean Vapor Pressure at 25°C: 250.0 mm Hg

Viscosity (centistokes)

at 32°F: 8.3	at 60°F: 5.0
at 100°F: 2.9	at 210°F: 1.2

Characterization Factor: 11.7 K

Mean Average Boiling Point: 510.0°F

End Point Distillation Temperature: 650.0°F

Mean Specific Heat of Liquid, from 70°F
to Mean Boiling Point: 0.55 BTU/lb F

Heat of Vaporization at Mean Boiling Point: 104.0 BTU/lb

Mean Molecular Weight: 205.0 lb/lb-mole

Heat Required to Vaporize**: 2,515.0 BTU/gal

* Muhly, 1983.

** From a liquid initially at 70°F to a vapor having a superheat at 20°F.

zinc. Metal impurities usually total less than 1%. The MX-76 grenade is used to provide infrared smoke.

B. Environmental Transformation and Fate by Major Type of Smoke

1. Phosphorus Smokes. The burning of phosphorus produces the phosphorous oxides, phosphoric pentoxide and phosphorous trioxide. When these combustion products come into contact with moisture in the air, they are transformed into phosphoric acid and phosphorous acid. In the smoke cloud there will also be a certain amount of unreacted phosphorus and small amounts of other chemicals and compounds.

Phosphoric acid and phosphorous acid will not be further transformed upon contact with the water in an aquatic system. The small amount of unreacted phosphorus from the smoke cloud, however, will be rapidly oxidized upon contact with air and is transformed by moisture into H_3PO_2 (hypophosphorous acid) and H_3PO_3 (phosphorous acid). More than 90% of the oxides of phosphorus that have not absorbed atmospheric moisture will absorb moisture from the water in the aquatic system and be bound to any organic material in it.

Phosphoric acid is the most highly soluble of all the reaction products of phosphorous smokes and because of this, it is also the most mobile. This compound has a solubility of 1500 mg/L of water. The fate of phosphoric acid in low concentrations in soil and sediment is governed by pH, calcium carbonate content, particle-size distribution, extractable iron and aluminum, and organic carbon. The phosphoric acid is able to react with aluminum and iron to become one of the more reactive inorganic phosphates. This conversion will generally include an initial rapid stage followed by a second, slower stage that may continue for weeks or months (Van Voris et al., 1986). When phosphoric acid is transformed in the environment, however, the solubility may decrease more than thirty times in the long term (Shinn et al., 1985). This rapid transformation will have a tendency to render the reaction products of phosphorus smokes relatively harmless to plant and animal life.

The adsorbance of the phosphates in soil is dependent upon both the pH of the soil and the clay content. They will be least adsorbed in alkaline soils that are formed from hard limestone and slightly more adsorbed in alkaline soils that are soft and chalky. Metals, such as aluminum, in the soil may serve to break up and immobilize the reaction products of phosphorus smokes.

Soils with a high clay content are generally high in hydrated iron and aluminum as well, and the phosphate will be adsorbed onto these metals. Sand-type soils have a low phosphate-adsorption capacity and the phosphate may actually leach from the soil (Van Voris et al., 1986).

The reaction products of phosphorus smokes may be absorbed by soil particles and plants in the ecosystem. In soil, phosphoric acid can be reduced to phosphorus and nitrogen. Phosphorus and nitrogen are both essential nutrients for the growth of both plants and soil microorganisms. These microorganisms will decompose organic matter and, during the process of decomposition, will cycle important nutritional elements, return organic carbon in the form of CO_2 to the atmosphere, and will detoxify any chemicals that should not be in the environment. Therefore, any large amounts of phosphorus or nitrogen deposited on the soil can potentially disrupt this process and affect the soil's ability to decompose organic matter and detoxify harmful chemicals (Van Voris et al., 1986).

The environmental fates of phosphorus smokes and their reaction products are shown in Table 12.

2. Hexachloroethane Smoke. When HC smoke mix is ignited, 80% of the smoke by weight is zinc chloride and the other 20% is composed of by-products. (See Table 13.) There is a general concern about the safety of these by-products of HC smoke and downwind safety/hazard calculations should be made to determine distances to safe air concentrations. The charts in the appendices will assist the assessor in these calculations. The downwind safety hazard zones that have been established for zinc chloride should allow for sufficient dissipation of these toxic by-products. Research has shown that a single upright smoke pot deposits from several hundred grams to more than a kilogram of material from 5 to 7 m downwind and laterally around the pot. Under conditions of low wind speed, a single pot could deposit as much as 3 kg (Schaeffer et al., 1986a).

Zinc chloride is highly soluble in water. The resulting zinc and chloride ions are of concern. In the aquatic environment, zinc can occur directly from fallout from the smoke or as leachate from soils. High concentrations will not likely be found in flowing waterways, but they may occur in still waters, such as ponds and lakes (Hill et al., 1978). The water soluble form is zinc hydroxide. Because the chloride ions enter a fairly large pool in natural soils and waters, it may be possible to disregard them.

TABLE 12. ENVIRONMENTAL FATE OF PHOSPHORUS SMOKES AND THEIR REACTION PRODUCTS.*

Material	Environmental Transformation	Environmental Fate
Red/White Phosphorus	$P_4 + 5O_2(\text{atmos}) \xrightarrow{\text{combust}} P_4O_{10}$ $P_4O_{10} + 6H_2O(\text{atmos}) \rightarrow 4H_3PO_4$ $P_4 + 3O_2(\text{atmos}) \xrightarrow[\text{combust}]{\text{ignit}} P_4O_6$ $P_4O_6 + 6H_2O(\text{atmos}) \rightarrow 4H_3PO_3$	Oxidation to phosphate
Methyene Chloride	Will react with atmosphere radicals to form phosgene and CO ₂ .	Photochemical decomposition
Phosphorus Pentoxide (P ₄ O ₁₀)	Reacts with atmospheric moisture to form poly-phosphorus acids.	Aquatic and soil deposition to phosphates and lower oxides
Phosphorus Trioxide (P ₄ O ₆)	$P_4O_6 + H_2O \text{ vapor} \rightarrow 4H_3PO_3$	Forms H ₃ PO ₄ , PH ₃ and phosphates
Phosphoric Acid (H ₃ PO ₄)	pK ₁ -2.15 pK ₂ -7.1 pK ₃ -12.4 phosphate	Aquatic and soil deposition, formation of phosphate salts
Phosphine (PH ₃)	Oxidized to form oxy-acids of phosphorus	Oxidized or dissociated

* Yon et al., 1983.

Drinking water standards for zinc are based primarily on aesthetic characteristics. The recommended standard is 5 mg soluble zinc per liter, which is a taste threshold value. At 30 mg/L, the water appears cloudy; at 40 mg/L, a metallic taste is present. Acute gastrointestinal distress occurs at 280 mg/L and higher concentrations (National Research Council, 1979). The nature, frequency, and location of HC smoke testing near water sources should be carefully considered so that safe levels can be maintained in these sources.

Zinc chloride is highly soluble, but the other reaction products, unreacted aluminum chloride and the insoluble forms of zinc and aluminum oxides, are not. When zinc chloride comes into contact with moisture, it will

TABLE 13. CHEMICAL ANALYSIS OF HC SMOKE.*

Ingredients	Mass % of Reagent (Approximate)
Inorganic Constituents:	
Zinc Chloride (ZnCl ₂)	80
Aluminum Chloride (AlCl ₃)	2
Cadmium Chloride (CdCl ₂)	0.15
Lead Chloride (PbCl ₂)	0.09
Gases:	
Hexachlorobenzene (C ₆ Cl ₆)	0.4 to 0.9
Carbonyl Chloride (COCl ₂)	0.10 to 1
Carbon Tetrachloride (CCl ₄)	1 to 3
Hexachloroethane (C ₂ Cl ₆)	0.3 to 5
Perchloroethylene (C ₂ Cl ₄)	3 to 17

* Dierenfeld and Novak, 1980.

hydrolyze rapidly to become hydrochloric acid and zinc oxychlorides. With these compounds, ion-exchange occurs readily in soil and sediments.

Zinc is not readily mobile in soils that are neutral or alkaline. In soils that are acidic, however, the leaching of zinc chloride from the soil to water supplies can be of concern. The soil itself may already have ambient concentrations of zinc, as well.

Dierenfeld and Novak (1986) studied the effect of HC smoke byproducts on the environment. Table 14 lists oral toxicities; the LD₅₀ refers to the acute dosage of a particular compound that causes mortality in 50 percent of the test population. Given the large quantities of lead and aluminum chloride required for oral toxicity (Table 14) compared with calculated environmental chemical loads, these two compounds likely present minimal carcinogenic risk to native faunal populations. However, zinc chloride should be examined in greater detail. Tumors have been shown to develop in mice administered 10 to 20 mg/L of zinc chloride in solution for 5 months. Tumor frequency increased with each subsequent generation, while induction time for tumors decreased.

Excess ingested zinc may also exacerbate existing mineral imbalances by saturating enzyme carrier sites. This may be important to free-ranging species whose nutritional status can already be tenuous. Thus, zinc from HC munitions may pose both an indirect and a direct hazard to installation wildlife.

TABLE 14. ORAL TOXICITY (RAT LD₅₀) OF HC SMOKE MUNITION BYPRODUCTS

Compound	LD ₅₀ (mg/kg)
Hexachloroethane	6000
Hexachlorobenzene	3500
Carbon tetrachloride	1770
Perchloroethylene	885
Carbonyl Chloride	N/A
Zinc Chloride	350
Cadmium Chloride	88
Aluminum Chloride	3700
Lead Chloride (Guinea Pig)	2000

Carbonyl chloride (phosgene) reacts with water vapor in the atmosphere to form HCl and carbon dioxide. However, remaining organic and inorganic constituents should be considered potential environmental contaminants as particulate deposits on ground, vegetation, and water surfaces. Deposition will not be equally distributed, and will probably decline logarithmically over distance in a prevailing wind direction vector from emission source(s).

The chlorinated hydrocarbons and carbon tetrachloride are water-insoluble, but very persistent in the environment. Perchloroethylene has an environmental half-life of about 10 days, hexachlorobenzene has a half-life of between 10 and 90 days, and both hexachloroethane and carbon tetrachloride have half-lives of up to 350 centuries.

Inorganic residues tend to be even more persistent in the environment than organic chemicals. Thus, there is potential for significant bioaccumulation of any of these compounds.

The phytotoxic effects of most HC smoke residues have not been quantified. However, the potential exists for uptake from the soil due to ground deposition and mobilization of chemicals and also direct uptake from the atmosphere. Aerosols of HC smoke have a mean particle diameter of 0.3 to 0.4 μm , a size small enough to directly enter open plant stomata. However, some data on isolated compounds exist from which inferences can be drawn. Various deposition/accumulation patterns occur, depending on the class of chemical and/or plant type, as well as numerous abiotic variables such as

climate or soils. For example, polycyclic aromatic hydrocarbons and lead residues are transported via adsorption to relatively small particles that can be transported atmospherically over long distances from a point-source emission. Plant surfaces retain the particulate matter; the larger the plant surface, the greater the accumulation.

Accumulation of chlorinated hydrocarbons in plants appears to be correlated with the levels of fatty and aromatic substances present in the vegetation. Due to solubility characteristics, chlorinated hydrocarbons are apparently retained within vegetative materials of high lipid content and not remobilized into the environment.

The heavy metals zinc (Zn) and cadmium (Cd) are deposited on and accumulate in plant tissues to a greater degree than the compounds discussed above. They apparently adsorb to a much wider range of atmospheric particle size classes and deposit closer to emission sources than lead.

Selective uptake of zinc and cadmium has been found frequently in lower plants such as fungi and lichens than in higher plants. However, the die-back of German forests has been associated with heavy metal residues in both root and aerial tissues. The prevalence of studies concentrating on the metal content of lower plants may simply reflect their greater tolerance of the metals.

It appears that the inorganic residues of HC munitions may be more detrimental than organic compounds to vegetation on training areas. Not only are quantities found that more closely approach the toxic and carcinogenic potentials in Table 14, but specific phytotoxicities have been identified. However, it must be emphasized that the phytotoxic effects of individual organic chemicals of interest have not been specifically examined yet.

Potential risk should be addressed on an individual installation basis, because various categories of plants will respond differently to the same chemicals. Also, because these chemicals all have the potential to bioaccumulate, it is important to consider both the individual year and cumulative exposure levels. Mixtures of compounds on any given area (based on chemical history) may increase or decrease toxic effects. Heavy metals may be more toxic under natural soil conditions of low nutrient availability and low pH due to the influence of acidity on the solubility of inorganic residues, and, indirectly, their availability to the plant community.

Residual organic and inorganic constituents of HC smoke munitions are potential environmental contaminants as particulate deposits on ground, vegetation, and water surfaces. Chlorinated hydrocarbons and carbon tetrachloride are very persistent in the environment and inorganic residues have significant potential for bioaccumulation. Uptake of the smoke residues from the soil by plants presents another hazardous potential, especially in vegetation with a high lipid content. Heavy metals have been found to be toxic to plants, inhibiting both respiration and root growth.

The carcinogenic potential of residual compounds may also be a risk to faunal populations (Hill et al., 1978). Zinc chloride--the smoke constituent found in greatest proportion--shows the highest exposure levels and may, along with other inorganic constituents, be approaching exposure and accumulation levels of environmental concern. Cumulative effects of yearly deposition may be very important when analyzing the environmental effects of these chemicals.

3. Fog Oils and Diesel Fuels. The smoke that is produced from fog-oil and diesel-fuel generators is a colloidal suspension of very small droplets of oil. The droplets range in size from 0.5 to 1.0 μm in diameter. The actual size is determined by the condensation of the condensing vapor and the rate of cooling. Large amounts of air are drawn into the vapor stream and the resulting cooling and dilution produces a large number of condensation nuclei.

The most serious threat to the aquatic environment from the use of fog oil and diesel fuel is in the formation of a film on the surface of the water. These films are subject to bioaccumulation in aquatic organisms. The aromatic naphthalenes and some of the other hydrocarbons will dissolve in water.

The movement of bottom sediment will spread the oil, destroying bottom plants and animals, causing erosion and further spread of the oil. The polycyclic aromatic compounds can form a tar-like deposit in the bottom sediment. In the aquatic environment, these oils are persistent poisons like DDT, PCB, and other synthetic compounds. They bioaccumulate from prey to predator.

The fallout from oil-smoke clouds, however, would not have the serious implications that an accidental oil spill during testing would have, although there is need for some concern about the toxicity of the aerosol oil products on aquatic life because some types of aquatic biota are quite sensitive.

The reaction products of SGF-2 and diesel fuel will be primarily insoluble polycyclic hydrocarbons. These products have a low mobility in the soil and have low solubility. Because of this, there may be need for concern about their long-term persistence in the soil. Research has shown that plants exposed to oil products may suffer premature leaf drop, bark injuries, root injuries, stunting, reduced fruit yield, premature fruit drop, and oil penetration into the fruit (Kipling and Waldron, 1976). Many common insecticides and fungicides, however, are oil-based.

4. Infrared Smokes. The infrared smoke that is introduced into the atmosphere is a brass powder, and remains a brass powder. The brass powder may be deposited directly on surface water. If there are sufficient mechanisms in the water to promote mixing, the powder will begin to corrode to its component metals. The reaction of brass powder in aquatic systems is determined by the chemical properties of its alloy metals, copper and zinc. Corrosion may be delayed due to the nonwettability characteristics of the brass powder but will continue for approximately three weeks once it begins.

Some of the copper flakes may be so small (less than 0.45 μm in diameter) that they may become colloidal. The sediment in aquatic systems will act as a sink for heavy metals, and the copper may be adsorbed and suspended to this sediment. It will exist there as precipitates such as hydroxide complexes, phosphates, and sulphides. The processes of hydrolysis, precipitation, complexation, and adsorption will reduce ionic copper concentrations in natural waters to very low levels. The pH of the water will have an effect on these processes, but the pH of most natural water systems will not vary to a great degree. In very soft water, the copper will react with bicarbonate and hydroxide to form malachite. When there is a high level of organic material such as humic and fulvic acids in the water, the copper will complex with it to reduce the amount of ionic copper. Therefore, there will be less available ionic copper in aquatic systems that have a low pH, are relatively hard, and have a significant amount of organic matter (Wentzel et al., 1986a).

Like copper, there will be more zinc ions released into aquatic systems that are acidic, soft, and have a low level of organic material in the water (Wentzel et al., 1986b).

The mobility and bioavailability of brass powder in soils is generally dependent upon the pH, the cation exchange capacity of the soil (the tendency

of elements or compounds in the soil to bind up the copper ions), and the amount of organic material in it (Wentsel et al., 1986a). The copper and zinc fractions of the brass powder will not penetrate the top 5 cm of soil until approximately eight months after deposition. The copper will be more mobile and biologically available in soils that are acidic, have a low cation exchange capacity and low levels of organic material (Wentsel et al., 1986a).

V. IMPACT CRITERIA

The impact of proposed S&O testing procedures should be evaluated in light of all applicable federal, state, and local legal standards and requirements to assure that these standards and requirements will be met. The standards and requirements will usually pertain to air quality, water quality, biological resources, and land use.

A. Air Quality

The Federal Clean Air Act (CAA) of 1970 established a program for the creation of air quality standards. This program was established because of public concern about the health aspects of air pollution.

The CAA has been amended to establish National Primary and Secondary Ambient Air Quality Standards (NAAQS) to control particular criteria air pollutants and to protect human health and the environment. Ambient air is defined by the CAA as the portion of the atmosphere that is external to buildings, to which the general public has access. Primary standards protect human health and secondary standards protect human welfare. A federal program was also established to prevent significant deterioration (PSD) of air quality where the air is relatively clean. PSD provisions establish a series of procedures for maintaining good air quality where the air already meets national standards for protecting health and welfare.

Some of the pollutants created by the S&O testing that are controlled by the NAAQS are particulate matter, carbon monoxide, ozone, and hydrogen sulfide. Also included in the impact criteria by the NAAQS are the emissions from stationary internal combustion engines, such as the M3A3 fog-oil generator.

It is unlikely that the smoke testing will violate NAAQS standards unless the testing occurs frequently, on a large scale, or in the same location. State and local standards, however, are quite often more stringent than the federal standards and, in such cases, it will be necessary to adhere to them in addition to the federal standards.

Under the Clean Air Act, the country is divided into 247 Air Quality Control Regions (AQCR), which provide basic geographical areas for the control of air pollution. Each state in which a region is located is required to prepare a State Implementation Plan (SIP) to implement and enforce criteria pollutant standards in that AQCR. A region that has attained the NAAQS for a criteria pollutant is considered to be in "attainment." Regions that have not attained NAAQS for a criteria pollutant are considered to be in "nonattainment" for that particular pollutant.

Most of the NAAQSs specify two different types of limitations: long-term standards for pollutants, such as ozone, which cannot be exceeded on an annual average, and short-term standards for highly toxic pollutants, such as phosgene, which cannot be exceeded for even brief periods of several hours.

It is possible, however, that S&O testing will result in temporary violations of local air quality standards during the period of the individual test. Because of this, it will be necessary to coordinate the smoke tests with the local regulatory agencies for the permits and variances that will be required. The Army environmental coordinator in the office of the Chief of Engineers at each individual test installation should be consulted for assistance with this procedure.

A list of air quality standards set by the EPA can be found in Table 15.

B. Water Quality

The Federal Water Pollution Control Act (FWPCA) of 1972 established basic water quality goals and policies for the country. It is commonly known as the Clean Water Act. FWPCA regulations establish reporting requirements for spills of 270 hazardous substances. Among those hazardous substances are zinc chloride, the primary reaction product of HC smoke, diesel fuel, and hydrogen cyanide, a reaction product of WP/FW.

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) establishes reporting requirements for the release of

TABLE 15. FEDERAL AMBIENT AIR QUALITY STANDARDS FOR CERTAIN CRITERIA POLLUTANTS.

Pollutant	Federal Standard
Particulate Matter	(A) 75 micrograms per cubic meter annual geometric mean. (B) 260 micrograms per cubic meter-- maximum 24-hour concentration not to be exceeded more than once per year.
Carbon Monoxide	(A) 10 milligrams per cubic meter (9 ppm)-- maximum 8-hour concentration not to be exceeded more than once per year. (B) 40 milligrams per cubic meter (35 ppm)-- maximum 1-hour concentration not to be exceeded more than once per year.
Ozone	(A) 235 micrograms (0.12 ppm) per cubic meter. The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.

hazardous substances into the environment, including water, when the release occurs in amounts greater than or equal to the reportable quantity. The reportable quantity for any hazardous substance is one pound, unless otherwise specified by the FWPCA. Elemental phosphorus compounds (white and red phosphorus) are among the most strictly regulated compounds, with limits of one pound. For zinc chloride, the reportable quantity under CERCLA regulations is 5000 pounds or more per 24-hour period.

Quite often, the impact of pollutants on water sources can be determined through the use of computer programs. The programs have been developed through the use of mathematical models, which can simulate the effects of a large number of pollutants.

C. Biological Resources

Various species of fish, wildlife, and plants in the United States have already become extinct as a result of economic growth and development that was unconcerned with environmental conservation. Other species have had their

numbers so depleted that they are in danger of becoming extinct. Because of this, the Endangered Species Act of 1973 was passed. This act was established for the purpose of protecting all species of wildlife and plants that are threatened or endangered. Also protected by the Act are the habitats of threatened or endangered species. These habitats are considered "critical." Some species of wildlife may also be treated as threatened or endangered because they are so similar in appearance to endangered or threatened species.

Lists of species that are protected under the 1973 Endangered Species Act, as amended, are available in Title 50 of the Code of Federal Regulations, Sections 17.11 and 17.12.

D. Land Use

It will be necessary to identify any possible conflicts that will arise between the S&O testing and federal, regional, state, and local (including tribes of Native Americans) land use plans, policies, and controls for the area of the test. The land use aspects of the testing should be compared and possible conflicts should be discussed. State wildlife management policies and prime and unique farmland policies should be identified and evaluated as they relate to the test procedures.

Included in the outline of land use will be a map or photograph of the test area and a description of governmental jurisdictions, infrastructure, wetlands, and proximity to surface water and groundwater.

VI. IDENTIFICATION OF ENVIRONMENTAL EFFECTS

In a certain sense, the purpose of S&O is to contaminate the air. The S&O materials then settle from the air onto water, land, and vegetation. Consequently, the identification of environmental effects must begin with a determination of the concentration and dispersion of the smoke in air. The results of this determination can be used to estimate the deposits on water, soil, and vegetation and the resulting effects on wildlife, vegetation, and people.

Modelling of air dispersion, calculations of concentrations and deposits of material, and a first-order screening of health and environmental effects of S&O has been done (Shinn et al., 1985). The results of these efforts are

presented here and should be used to estimate the environmental effects of a particular test. It is anticipated that the environmental effects generally will not be significant. In addition, some background information about the modelling and calculations will be presented clarify how they may be used. For a detailed explanation of the methods and results see Shinn et al. (1985).

A. Geographic Limits

Because the smoke cloud will carry downwind of the site of generation, it will be necessary to establish the geographic limits of the concentrations of smoke of concern. These limits can be established through the use of information in Appendices B and C. Appendix B provides meteorological information about the various sites where testing may take place. Appendix C provides charts showing the distances to hazardous concentrations of smokes for a variety of conditions, under a variety of wind speeds and Pasquill-Gifford stability categories. The distance to the recommended boundary or Interim Threshold Value (ITV) has been set as 1% of the LC_{50} (the lethal concentration for 50% of animals in an experimental setting). The charts in Appendix C were developed using meteorological data, standard air quality criteria, occupational exposure limits to hazardous materials, and Army operations procedures. The meteorological data were used to determine the probable mixing depth ranges. The air quality criteria and occupational exposure limits were used to determine the ITV (see Appendix C for more detail on how these values were determined). Then, using HAZRD2, an atmospheric dispersion model, the atmospheric consequences of the test under a variety of meteorological conditions was predicted. HAZRD2 was developed for the purpose of predicting the atmospheric dispersion and downwind hazards of smokes and obscurants and can be used as a screening tool upon which to base test criteria (Pennsyle and Winkler, 1984).

The determination of these boundaries may be discussed at the beginning of the EA so the reader will know that the boundaries were not chosen arbitrarily.

B. Air Quality

1. Determine the Minimum Impact Area and the Maximum Airborne Concentration. The fundamental quantities used to assess the potential impact

of the S&O devices are the minimum impact area (A) and the maximum airborne concentration (MAC). The minimum impact area (A) is the smallest area of land that the deployed munition could affect and is the area where the highest concentrations of smoke could occur. The MAC is the average concentration within the smoke plume above the area, A. These quantities have been determined for a number of munitions and smokes and are presented in Table 16. To derive these values, the minimum impact area was first determined. Then, the fill weight of the munition divided by the minimum impact area gave the maximum deposition density (MDD). Finally, the MDD divided by minimum height of the smoke plume yielded the MAC (Shinn, 1985).

The minimum area of impact (A) is conceptually different for bursting and burning munitions. The minimum area is closely defined for bursting devices because of their relatively instantaneous combustion. On the other hand, the minimum impact area for burning devices was defined as a worst-case diffusion occurring during calm winds at night.

The minimum area of impact is usually small, generally under an acre, and when it is small, it is the first indication that the device has a small potential ecological cost.

2. Determine Microscale and Mesoscale Effects. The analysis of the air quality should be done on both a microscale and mesoscale level. The microscale analysis will determine the impact that testing will have on the specific locations of the smoke emission. The mesoscale analysis will determine the impact that testing will have on the entire area and will include the effects of repeated testing.

To determine the microscale impact, the smoke plume should be represented graphically for locations on the site, for one test and over time. The plumes on a given day may or may not overlap each other. This is also true for the plumes from tests on different days. Most test sites will have a combination of overlapping, partially overlapping, and nonoverlapping plumes for a given test. A series of tests will deposit smoke products in the same way. Because of this, it will be necessary to use the appropriate dispersion model (currently HAZRD2) for each source and to add the contribution from each source to the total impact.

The impact of repeated tests can be predicted by estimating the exposure to the environment in terms of atmospheric concentration, the deposition density, total deposition, and the area of impact. This can be accomplished

TABLE 16. MINIMUM AREA OF IMPACT (A) AND MAXIMUM AIRBORNE CONCENTRATION (MAC) OF S&O DEVICES.

Device	Munition	Type	A (m ²)	MAC (mg/m ³)	T (hour)
WHITE PHOSPHORUS TYPES					
1. 4.2-inch Mortar	M2	WP	516	3100	1
2. 4.2-inch Mortar	M328AW	WP/PWP	541	3140	1
3. 60-mm Mortar	M302	WP	166	1820	1
4. 81-mm Mortar	M57	WP	366	2820	1
5. 81-mm Mortar	M375	WP	228	2320	1
6. 90-mm Gun	M313	WP	243	2490	1
7. 105-mm Gun	M416	WP	455	2990	1
8. 120-mm Gun	M357	WP	516	3100	1
9. 105-mm Howitzer	M60	WP	354	2900	1
10. 155-mm Howitzer	M110	WP	778	3470	1
11. 155-mm Howitzer	XM825	WP/FW	12000	24	1
12. 5-inch Rocket	MK4	WP/PWP	718	3390	1
13. 57-mm Rocket	M308	WP	96	1900	1
14. 75-mm Rocket	M311	WP	198	2350	1
15. 2.75-inch Rocket	M259	WP/W	9500	6	1
RED PHOSPHORUS TYPES					
1. Grenade	L8A1	RP/BR	50	13600	0.033
2. 81-mm Mortar	XM819	RP/W	940	139	1
3. 155-mm Howitzer	XM803	RP	11300	26	1
4. Bomblet (submunition)	CBU-88	RP	283000	1.3	1
HEXACHLOROETHANE TYPES					
1. Smoke Pot	M1	HC	9506	77	0.108
2. Smoke Pot	M5	HC	65025	13	0.283
3. Smoke Pot	M4A2	HC	35156	29	0.208
4. Grenade	M8	HC	992	218	0.033
5. 105-mm Howitzer	105M84	HC	52	450	0.033
6. 155-mm Howitzer	M116M1	HC	1190	664	0.038
FOG-OIL AND DIESEL TYPES					
1. Generator, Fog Oil	M3A3	SGF-2	810000	5.9	1
2. Generator, Fog Oil	XM52	SGF-2	810000	8.9	1
3. Smoke Pot, Fog Oil	AN-M7	SGF-2	26200	66	0.175
4. Exhaust, Diesel	VEESS	DF	810000	8.3	1
INFRARED TYPES					
1. Grenade	XM-76	IR	50	10000	0.035

by using the plan of action and the visual representation of the plume to calculate the total area covered by the smoke plume for each test.

For overlapping plumes, the maximum air concentration (MAC), deposition density (MDD), and total deposition (MDD x area) can be calculated by adding the impact of the contribution from each of the overlapping plumes. For nonoverlapping plumes, the total area of impact can be calculated by adding up the areas of the devices that do not overlap. Overall deposition and area of impact will, of course, be greater than that for a single device.

The mesoscale impact is calculated using a scaling principle in atmospheric dispersion:

$$(\text{Concentration \#1}) \times (\text{Area \#1}) = (\text{Concentration \#2}) \times (\text{Area \#2}).$$

The area of impact can be estimated the area that will have an increase in average total suspended particulates (TSP) equal to the national ambient air quality standard (NAAQS). We use a MAC-factor for Concentration #1, the minimum impact area (A) for Area #1, the NAAQS for TSP as Concentration #2, and solve for Area #2 as the mesoscale area of significant effect. The MAC-factor is the maximum airborne concentration (MAC) multiplied by the number of hours of tests per week and divided by 168, the number of hours in a week. The NAAQS is 0.075 mg/m^3 , annual geometric mean.

C. Water Quality

It will be necessary to determine the types and quantities of potential water pollutants emitted during all phases of the testing procedure. The deposition of smoke products in aquatic systems can be estimated by multiplying the estimated deposition velocity of the aerosol particles in the atmosphere (3.6 m/hour) by the airborne concentration (MAC) by the fraction of an hour the concentration is maintained (T). The deposition (D) as mg/m^2 equals $(3.6) \times (\text{MAC}) \times (T)$. The value 3.6 was estimated by Shinn et al. (1985) from the deposition from a cloud with an air concentration of 1000 mg/m^3 passing over a water body 1 m deep for 1 hour. The time T is generally 1 hour, although T does vary depending on the munition; T for various munitions is given in Table 16. Generally, this calculation will reveal that the amounts of materials deposited are not environmentally significant. If this method of estimation were not available, an atmospheric

dispersion model, such as HAZRD2, would be used to determine the amount of test fallout.

D. Soil Deposition

The deposition of S&O on soils is estimated in the same manner as the estimation of deposition on water, by multiplying the estimated deposition velocity of S&O particles in the atmosphere (3.6 m/hour) by MAC, the airborne concentration (mg/m^3 of air), by T, the fraction of an hour the concentration is maintained. Deposition (D) as mg/m^2 equals $(3.6) \times (\text{MAC}) \times (\text{T})$. Smoke residue may be assumed to be incorporated into the top 5 cm of undisturbed soil and into the top 15 cm for tilled soil.

There are many ways in which contamination of the soil can influence biota. The concentration in the soil solution may be high enough to affect soil organisms and microorganisms directly. At lower concentrations, bioaccumulation may occur when contaminants are consumed by soil microorganisms and then are retained by predators or decomposers. Plants may accumulate elevated levels of substances in response to an elevated level in the soil. The contaminants may be toxic to either the plant or the animal eating the plant. Some contaminants may migrate into groundwater or surface water rather than be retained by the soil.

In general, the three pathways mentioned (accumulation in the soil microorganisms, accumulation in plants, and filtering into the water supplies) depend on the contaminant being soluble or mobile in the soil system, so that it is available for uptake or leaching. For this reason, the solubility of smoke products is a first-order indication of the potential environmental impact of the products in the soil. The mobility of smoke materials in soil is listed in Table 17.

1. Phosphorus Smokes. Unreacted phosphorus in soil systems may be transformed over a period of time to many compounds, depending on soil type and the types of metals found in the soil. The level of toxicity of a metal phosphate will depend on the metal. Except for burning of vegetation where high concentrations occur, no data are available on the toxic effects of unreacted phosphorus. Combustion products of phosphorus smoke that are deposited on the soil will be rapidly complexed and immobilized by metals, such as aluminum, or adsorbed by soil particles (Yon et al., 1983).

TABLE 17. THE MOBILITY OF FRESHLY DEPOSITED SMOKE AND OBSCURANT MATERIALS IN SOIL AND SEDIMENTS, IN ORDER OF INCREASING SOLUBILITY.*

Smoke Type	Solubility (mg/L)	Relative Rank
IR (EA-5763 and EA-5769)	0.03	1
SGF-2	14-52	$10^2 - 10^3$
DF	14-52	$10^2 - 10^3$
HC	43	10^8
WP and RP forms	55	10^8

* Shinn et al., 1985.

Phosphorus deposition from a single smoke test of 1-h duration would be 0.02 to 49 g/m² (Shinn et al., 1985). This compares to a typical application of phosphate fertilizer of 3 g/m². Although the upper limit from a single smoke test is an order of magnitude higher than a fertilizer application, this high level of deposition would occur over a very small area (50 m²; Shinn et al., 1985). Therefore, the long-term environmental effect may not be as significant as the deposition rate suggests.

The reaction products of phosphorus smoke are listed in Table 12. One of the constituents, phosphoric acid, will diffuse into the soil after deposition. At normal soil pH values, the acid will dissociate to give polyphosphate anions, which will chelate with positive ions, such as Ca²⁺, Al³⁺, and Fe³⁺, in the soil and also adsorb onto clay particles. These polyphosphates tend to remain tightly bound (Russell, 1973). This ability to chelate with soil cations and clay particles can have a deflocculating effect on soils, which can lead to tight soil compaction, reducing the ability of water to penetrate into the soil. However, the levels of deposition are far below the levels that render the soil impermeable (5 to 10% by weight) and any significant effect is unlikely (Van Wazer, 1961).

Phosphates appear to be relatively immobile in soil. Studies have shown that phosphate fertilizers remain immobile, aside from runoff due to rainfall soon after fertilizer application (Van Wazer, 1961; Russell, 1983). Although the polyphosphoric acids are more water soluble and would be applied more

evenly over the surface than a typical fertilizer, these studies showed that fertilizer applied as polyphosphates was similar to typical fertilizer.

Polyphosphates are not stable in the soil environment; they undergo hydrolysis to orthophosphates. These orthophosphate anions tend to be immobilized by adsorption onto soil particles or by the formation of insoluble phosphate-containing minerals. The quantity of oxalate-extractable aluminum and iron in the soil appears to correlate with its ability to adsorb phosphate. The adsorption capacity is dependent on the type of soil; Rao and Davidson (1982) found that soil adsorbed from 12 to 4420 mg phosphorus per kg soil.

Residual deposition from phosphorus smoke testing is unlikely to significantly affect soil pH. Russell (1973) found little measurable change over a ten-year period where the soil was repeatedly fertilized. Phosphoric acid has been added to irrigation water as a method of application. It appears the levels of deposition would not significantly change soil pH. The pH can be easily monitored and liming or other methods can be used to easily correct any changes.

The above discussion focusses on the effects of a single, 1-h test. Repeated testing in one area over a long period can result in high levels of phosphorus deposition. It is difficult to determine the ability of the soil to take up the amount of phosphorus deposition from frequent testing based on the studies of phosphate fertilization. Repeated testing in the same area could likely lead to severe environmental effects depending on the soil type and climatic conditions. Also, the ability of the soil to immobilize phosphate could be exceeded and runoff resulting from rainfall could transport environmental effects far from the deposition area.

2. Infrared Smokes EA-5763 and EA-5769. In the terrestrial environment, several factors influence the toxicity of brass to vegetation. Of these factors, the most important are soil pH, cation exchange capacity (CEC), and the amount of organic material present. A significantly smaller amount of brass will be toxic to plants than will be toxic in soils with a relatively high pH, a high CEC, and which are low in organic matter. The capacity of organic matter to bind the metal, however, can offset the toxicity of the brass in acidic soils with a high CEC (Wentzel et al., 1986a).

E. Aquatic Toxicity

For aquatic biota, toxicity is characterized by the solubility of the smoke products divided by the TLM_{96} (Threshold Limit, median-96 hours; or the amount of contaminant that is lethal to 50% of the organisms in a system after 96 hours of exposure to it). This calculation will yield the aquatic toxicity quotient (ATQ). If the ATQ is equal to or greater than 1 (unity) then potentially toxic amounts of the substance are present. Otherwise, the impact of the substance will most likely be minimal in terms of acute toxicity. Generally, the ATQ will be less than 1, see Table 18 for the ATQs for S&O. Other effects on the aquatic environment must be determined more subjectively.

1. Phosphorus Smokes. Because of the highly reactive nature of phosphorus, it has been difficult to accurately quantify its aquatic toxicity. If unignited fragments of white phosphorus were to fall into an aquatic system, localized fish kills could occur because white phosphorus is toxic at levels less than 1 part per billion (Canter, 1977). In water, phosphorus is relatively insoluble, although its solubility is dependent upon the dissolved oxygen, temperature, and pH of the water. When dissolved, the oxidation products will be phosphorous acid and phosphoric acid (Lai and Rosenblatt, 1977).

While the reaction products of phosphorus smokes have a generally low toxicity in aquatic organisms, the most serious problem in aquatic systems is not the toxicity of the products, but rather their nutritive quality. These products act as fertilizer in water and may cause an algal "bloom." The plants in the system may grow so rapidly that the microorganisms that decompose them use up most of the oxygen in the water during the work of decomposition. This, in turn, would create a serious lack of dissolved oxygen in the water and could possibly result in a fish kill (Sullivan et al., 1979).

2. Hexachloroethane Smoke. Zinc chloride, the main constituent of HC smoke, can enter aquatic systems directly through fallout, or indirectly as leaching from soil or as runoff. Leaching will only occur, however, in soils that are acid (Cichowicz, 1983). The amount of zinc chloride contamination would depend upon the frequency, nature, and location of the tests.

In soft water, the 96-hour LC_{50} for zinc chloride is much lower than it is for hard water. Because of this, the amount of calcium carbonate ($CaCO_3$)

TABLE 18. AQUATIC TOXICITY QUOTIENT (ATQ) OF S&O TO BIOASSAY FISHES IN ORDER OF INCREASING TOXICITY.

Smoke Type	TLm (mg/L)	ATQ*
WP and WP/FW	100-1000	0.0036-0.036
RP and RP/BR	100-1000	0.0036-0.036
SGF-2	2-50	0.72-1.8
DF	2-50	0.72-1.8
IR (EA-5763 and EA-5769)	0.02-0.10	0.3-1.55**
HC	0.1-10	0.36-36

* ATQ uses the value 3.6 mg/L as an estimate of the amount of smoke products deposited in water 1-m deep from a 1-hour exposure to an air concentration of 1000 mg/m³. The ATQ is the ratio of 3.6 mg/L to the TLm₉₆ for common bioassay fishes. Values near unity or greater are of significant aquatic toxicity.

** The low solubility of IR smoke requires that the ATQ be a ratio of the amount soluble to the TLm₉₆.

in any nearby water sources should be determined. This will be especially important if the soil in the area is acidic (Cichowicz, 1983).

The Environmental Protection Agency has established criteria to protect aquatic life from hexachloroethane contamination. The agency has proposed a standard with a 24-hour average concentration not to exceed 62 µg/l, and a concentration of 140 µg/L not to be exceeded at any period of time (EPA, 1976). The National Research Council (1979) recommends a secondary standard for zinc in water of 5 mg/L.

3. Fog Oil and Diesel Fuel. The deposition of oil from an oil-aerosol cloud would have a minimal negative impact on water sources. Some aquatic biota, however, are quite sensitive to oil-based products and concern should be given to determine if they will be affected by the fallout (Liss-Suter et al., 1978b.)

The greatest area for concern with the testing of fog oil and diesel fuels is the possibility of an unintentional spill. Oil products in water can have serious and far-reaching negative effects. The toxicity and persistence of these products is like that of DDT, PCB, and other synthetic compounds (Liss-Suter et al., 1978b).

There are two categories of carbon compounds that are found in diesel fuel and SGF-2:

- Biologically resistant compounds resist degradation by decomposers. They persist in the environment and are concentrated in aquatic species. The chlorinated and phosphorus compounds are the most toxic.
- Biologically available compounds are broken down under microbial attack. The impact of these compounds is measured by the biological oxygen demand (BOD), the chemical oxygen demand (COD) and total organic carbon (TOC). The amount of dissolved oxygen in an aquatic ecosystem can be seriously depleted by the oxygen used by decomposers in the process of degrading these compounds (Liss-Suter et al., 1978b).

4. Infrared Smokes EA-5763 and EA-5769. Brass powder in water is quite insoluble. The brass will corrode in water, however, and ionic and complexed forms of copper and zinc, which are soluble, will be released. The availability of toxic amounts of these metals will be determined by the pH, hardness, and alkalinity of the water. The toxicity of copper will go up when hardness and alkalinity go down (Wentzel et al., 1986b).

F. Toxicity - Terrestrial Plants

A complex group of factors influence the transfer of smoke from the air to foliar surfaces. Because of this, it is difficult to evaluate plant toxicity based solely on air concentration and exposure duration. Factors that have the greatest effect are mass loading, relative humidity, wind speed, the ability of plants to compensate for cumulative dose episodes, post-exposure leaching, and dosing during rainfall. Of these factors, wind speed was shown to have the most pronounced effect on mass loading and plant toxicity (Van Voris et al., 1986). When a mass loading value is obtained and the exposure duration and air concentration are known, a deposition velocity can be calculated.

The deposition of smoke products on vegetation (also called foliar retention) is calculated in the following manner:

Foliar retention = (NSC value) x (velocity) x (concentration).

- NSC is the accepted Chamberlain "normalized specific concentration."
(This value is 30 to 60 m²/kg dry weight of foliage).

- The velocity of the smoke materials is 3.6 m/hour as above.
- The concentration of the smoke is expressed in mg/m^3 of air.
- Foliar retention is expressed as grams of contaminant per kilogram of dry weight of foliage per hour per day ($\text{g kg}^{-1}\text{h}^{-1}\text{d}^{-1}$), and is used to assess effects due to animal ingestion of plant matter.

1. Hexachloroethane Smoke. Zinc chloride is the main constituent of HC smoke. Low concentrations of zinc are necessary for normal growth in plants, but excess amounts can be toxic. Plants will show a great deal of variability in their ability to tolerate zinc. Some plants that can tolerate nickel and copper cannot tolerate zinc and vice versa (Rorison, 1969). The mechanism for regulating heavy metal toxicity in plants is unknown and because of this, caution would be advised if there are plants on the Endangered Species List in the area of the HC tests. In some plants, delayed germination and retarded growth can result from excess zinc. Leaf injury can occur from exposure to zinc chloride solutions.

2. Infrared Smokes EA-5763 and EA-5769. Studies have shown that excessive deposition of brass powder, broken down into zinc and copper, will stunt plant growth (Wentsel and Guelta, 1986).

G. Toxicity - Terrestrial Animals

Among terrestrial animals, toxic effects may occur through the inhalation of the aerosol particles themselves or through ingestion when the animal eats plants that have had smoke products deposited on them.

Inhalation toxicity is measured by the LC_{50} (Lethal Concentration, 50%; or the amount of inhaled contaminant that is lethal to 50% of the animals in an experimental setting). Generally, the available information involves the inhalation toxicity of the product to laboratory animals. Relative inhalation toxicity may also be expressed by a concentration quotient (CQ), which is the ratio of the airborne concentration (MAC) to the particular LC_{50} value for inhalation toxicity to laboratory animals (Shinn et al., 1985). A CQ less than 1 indicates a relative lack of significance of inhalation of the material, while values near 1 or greater indicate potentially significant toxicity problems. See Table 19 for working data for the LC_{50} s and Table 20 for CQs for S&O devices. Generally, the CQ values are less than 1.

Unless the fallout from S&O testing is deposited on crops, humans are unlikely to directly ingest it. However, animals that feed on plants could be

TABLE 19. RELATIVE INHALATION TOXICITY OF SMOKE AND OBSCURANTS IN TERMS OF THE ONE-HOUR LC₅₀ FOR RATS.

	LC ₅₀ (mg/m ³)
SGF-2 Fog Oil	60000
Diesel Fuel Smoke	26000
RP and RP/BR	4000
WP and WP/FW	2500
IR (EA 5763, EA 5769)	970
HC smoke	333

TABLE 20. AIR CONCENTRATION QUOTIENTS (CQ) FOR RELATIVE INHALATION TOXICITY OF S&O DEVICES IN ORDER OF INCREASING TOXICITY.

Device Type	CQ
SGF-2 Fog-Oil Generator (each hour)	0.0002
Diesel Fuel Generator (each hour)	0.0003
RP Bomblet	0.0003
SGF-2 Smoke Pot	0.0004-0.002
WP/WF Howitzer or Rocket	0.002-0.01
RP/W Mortar or Howitzer	0.006-0.06
HC Smoke Pots	0.04-0.25
HC Grenade	0.7
WP Mortar, Gun, Rocket, or Howitzer	0.7-1.4
HC Howitzer	1.4-2.0
RP/BR Grenade	3.4
IR Grenade	>10

* CQ is the ratio of the airborne concentration (MAC) to the 1-hour lethal concentration LC₅₀ for rats exposed by inhalation. Values near unity or greater indicate potentially significant toxicity problems.

TABLE 21. FOLIAGE INGESTION QUOTIENT (FIQ) FOR RELATIVE ORAL TOXICITY OF S&O TO RATS, IN ORDER OF INCREASING TOXICITY.

Smoke Type	Rat Oral LD ₅₀ (mg/kg)	FIQ*
SGF-2 21000	0.3	
DF 1400	0.5	
RP and RP/BR	1530	4.2
WP and WP/FW	1530	4.2
IR (EA-5763 and EA-5769)	800	8.1
HC Smoke	350	19

* The FIQ assumes that foliage ingestion will provide a dose to a consumer animal of 6500 mg of smoke products per kg of animal body weight for foliage exposed to 1000 mg/m³ smoke-product air concentration for an hour.

exposed if they consume S&O material deposited on their forage. Ingestion toxicity is measured by the FIQ (foliar ingestion quotient), which is defined as the ratio of the amount of substance ingested to the LD₅₀ for oral toxicity for a particular species. LD₅₀ is Lethal Dose, 50%, or the amount of ingested contaminant that is lethal to 50% of the animals in an experimental setting. Again, an FIQ less than 1 is a good indication that ingestion of the material would not present a problem, while values near or greater than 1 indicate potential toxicity problems. See Table 21 for FIQ values of S&O; this table shows that nearly all S&O are significantly toxic when deposited on foliage near the source and consumed by animals while concentrations are still high.

Bioaccumulation may occur when the compounds from the smoke products become a part of the food chain.

1. Phosphorus Smokes. The inhalation of phosphorus smokes can cause severe throat irritation, and skin contact can cause burns and destroy underlying tissue (Wasti et al., 1978). Acute phosphorus toxicity has two stages. The initial stage is gastrointestinal irritation with vomiting. The second stage may result in death from cardiovascular collapse (Dacre et al., 1979). Animals could receive lethal doses of elemental phosphorus if they

ingest unreacted smoke materials. These effects could result, however, only from the small amount of unreacted phosphorus left after the test.

2. Hexachloroethane Smoke. Zinc chloride is the main constituent of HC smoke. Although zinc chloride is added to animal feed as a dietary supplement, excess amounts can delay growth and induce disease. Birds may have the greatest difficulty with zinc chloride. When birds ingest metals, they have a tendency to concentrate the metals in their eggs and this can have severe effects on the survivability of the hatchlings (Cichowicz, 1983).

3. Fog Oil and Diesel Fuel. The toxic effects of oil-based smoke clouds on terrestrial biota will be minimal if the testing is not conducted in one location for an extended period of time. When laboratory animals are subjected to inhalation of fog oil and diesel fuel mists, there are significant toxic effects. Some of these effects are pneumonia, nasal hemorrhaging, convulsions, skin and pulmonary tumors, hair loss, and death. In addition, oil contamination on insects can cause death through suffocation (Muhly, 1983).

4. Infrared Smokes EA-5763 and EA-5769. Studies have shown that excessive deposition of brass powder, broken down into zinc and copper, will cause weight loss in earthworms (Wentzel and Guelta, 1986).

H. Human Acute and Chronic Effects

Although the Army has been using smokes for training and testing since World War II, and there are considerable data concerning the toxicity of the individual compounds, little is known about the fate of the smoke products in combination with each other and under actual deployment circumstances. There are very little data available about possible synergistic or antagonistic effects of smokes and their reaction products on living organisms.

In actual field testing of S&O materials, however, it is unlikely that there would be any acute risk posed through inhalation of the smoke reaction products. When the smoke is ignited, it is immediately diluted with large volumes of air. This will serve to limit and minimize any hazard from inhalation of toxic substances produced by the smokes. Possible hazardous effects should be mitigated by exclusion of personnel from areas of predicted high concentrations.

There are also very few data about the human health risk posed by S&O materials. For most solid-tumor cancers and lymphomas, leukemia, however,

the latency period is 30 years. (The latency period is the time from exposure to the cancer-causing agent until the onset of symptoms.) Because of this, most studies dealing with human cancer risks must be long-term. Therefore, an absence of data does not mean an absence of risk.

The calculation of acute inhalation effects should be determined by using the S&O release for a single test and for each test period. It can generally be assumed that the smoke from one test will have dissipated before another test begins.

For acute effects other than inhalation, it can be assumed that the effect of multiple inputs of pollutants is additive. For a conservative estimate of environmental impact, the removal processes should be ignored and the total deposition for a series of tests should be used as a single one-time input. This will overestimate potential acute effects and will ensure that the calculation for the determination of acute effects will fall within a range of accuracy.

1. Phosphorus Smokes. Phosphorus burns can cause serious local injury from the heat of the burning phosphorus and by the production of phosphoric acid. Systemic injuries can also result from phosphorus burns but the cause of the systemic injury remains unclear (Miles, 1972).

Bentley et al. (1978) found that the most typical toxic reaction from occupational exposure to white phosphorus is necrosis of the jawbone, which has been called "phossy jaw." This condition was common among persons who were employed in the production of phosphorus-based matches in the nineteenth century. It is known that exposure to white phosphorus will cause a loss of bone tissue but it is not clear why the jawbone is primarily affected. It has been speculated that either the route of entry of the phosphorus to the jawbone is through dental caries or infected gums, or that the toxicity is systemic and the jawbone is affected because of its unique vulnerability to infection from the teeth and gums (Bentley et al., 1978). Because of this, it is of great importance that those personnel working with phosphorus smokes have a thorough dental screening to assure good dental health before beginning work with the smokes.

Acute toxic effects in humans have been reported when white phosphorus that is burned at a concentration of 188 to 500 mg/m³ is inhaled. Symptoms include throat irritation, respiratory distress, coughing, nasal discharge, and headache and can last up to three days (Miles, 1972). Direct contact with

the smoke can cause eye irritation as well. Toxicity studies on PWP and RP-BR have not been conducted, but it can be assumed that the toxicity for these products would not be more severe than that for WP (Miles, 1972).

Human inhalation toxicity from phosphorus smoke is presented in Table 22 and human exposure estimates for phosphoric acid are listed in Table 23.

There is a major data gap in studies concerning the composition of phosphorus smokes and human health effects due to intermediate and long-term exposure to the smoke. There have been no long-term studies conducted on the carcinogenicity of WPF or RP-BR smokes. Human exposure investigations have only been concerned with very brief, non-lethal exposures and are quantitatively insufficient.

2. Hexachloroethane Smoke. Acute exposure to high concentrations (80 to 120 mg/m³ for 2 minutes) of HC smoke produces an immediate sense of suffocation, with nose and throat irritation, coughing, and choking. This may be followed by bronchial constriction similar to that of asthma (Weeks et al., 1979).

Chronic exposure to low concentrations causes fever, moderate inflammation of the pharynx and the mucous membranes of the eye, pain in the chest following deep inhalation, headache, slight cough, malaise, and muscular pains. Severe exposure causes nausea and vomiting, dyspnea, cyanosis, and symptoms of pneumonitis and pulmonary edema (Weeks et al., 1979).

Most of the published data concerning the toxicity of zinc chloride, the primary reaction product of HC smoke, have been on reactions to high concentrations of the substance. Symptoms have included lung irritation, burns to the eye and skin, and stomach and liver damage (Berkowitz et al., 1981). Human inhalation toxicity of smoke from zinc chloride is presented in Table 24. A more recent study, however, has shown that HC mixtures contaminated with ammonium chloride are more lethal than zinc chloride. When inhaled in an enclosed area this smoke can cause fatalities through extreme lung irritation (Cichowicz, 1983).

A study done by the US Army Medical and Bioengineering Research and Development Laboratory showed that mice who were given zinc chloride, the primary constituent of HC smoke, in their drinking water for 5 to 8 months developed seminoma, bone marrow cancer, and uterine cancer. The same study showed that it is also possible to induce tumors in fowl by intratesticular injections of zinc chloride (Cichowicz, 1983). However, there have been no reported cases of carcinogenicity in humans due to zinc chloride exposure.

TABLE 22. HUMAN INHALATION TOXICITY OF SMOKE FROM BURNING WHITE PHOSPHORUS.*

Number of Subjects	Concentration of White Phosphorus Smoke (mg/m ³)	Length of Exposure (min)	Health Effects
108	1000	Not specified	Intolerable
108	700	Not specified	Minimum harassing condition
Not specified	592 588	3.5 2	Respiratory distress, nasal discharge, coughing, throat irritation, soreness.
7	514	16	Nose and throat irritation, coughing during exposure.
6	453	10	5 of 6 subjects showed throat irritation. One experienced nausea and nasal discharge during 3 days after exposure.
6	425	15	Nose and throat irritation during exposure but no remarkable effects during 3-day observation period after exposure.
5	408	10	4 of 5 subjects had throat irritation and coughing. One experienced sore throat and cold symptoms during 3-day observation period after exposure.
7	188	5	5 of 7 experienced throat irritation, coughing and slight headache during exposure. After 24 hours, 4 subjects had frontal headache, nasal congestion, throat irritation and coughing. After 2 and 3 days, only one subject showed signs of respiratory irritation.

* Lai and Rosenblatt, 1977.

TABLE 23. HUMAN EXPOSURE ESTIMATES FOR PHOSPHORIC ACID*

Maximum Distance Downwind From Deployment	Concentration (mg/m ³ of P ₂ O ₅)	Health Effects
		Intolerable concentration = 10 ³ mg/m ³
		Minimum harrassing concentration-masks mandatory = 7 x 10 ² mg/m ³
100m	1.46 x 10 ²	Lowest toxic concentration = 10 ² mg/m ³
200m	6.98 x 10 ¹	
300m	4.36 x 10 ¹	
400m	3.06 x 10 ¹	
500m	2.26 x 10 ¹	
600m	1.84 x 10 ¹	
700m	1.51 x 10 ¹	
800m	1.26 x 10 ¹	
900m	1.10 x 10 ¹	
1000m	9.42 x 10 ⁰	
5000m	9.63 x 10 ⁻¹	Phosphoric Acid TLV = 1 mg/m ³

* Berkowitz et al., 1981.

The International Agency for Research on Cancer and the National Cancer Institute have listed a number of HC products or reaction products that are carcinogenic or are suspected of being carcinogenic. These are perchloroethylene, carbon tetrachloride, hexachloroethane, hexachlorobenzene, cadmium and cadmium chloride, and arsenic (Novak et al., 1985). Research

TABLE 24. HUMAN INHALATION TOXICITY OF SMOKE FROM ZINC CHLORIDE.*

Exposure Time	Concentration (mg/m ³)	Dosage (mg-min/m ³)	Health Effects
2 Minutes	80-120	160-240	Nose, throat, and chest irritation. Cough, nausea.
9 Minutes	190	1,700-2,000	Marked throat irritation, some lung congestion, usually requiring hospitalization, observation, and treatment.
5 minutes	4,100	20,000	Severe respiratory irritation leading to "chemical pneumonia" and requiring aggressive treatment.
Not Specified	Not Specified	50,000	Massive respiratory tract injury. May be fatal; death due to shock and pulmonary edema.

Note: Dosage = concentration x exposure time.

* Hill et al., 1978.

conducted for USAMBRDL for a risk assessment at Fort Irwin (Novak et al., 1985) has indicated that there is a serious risk of developing cancer as a result of occupational exposure to HC smoke: 0.55 and 4.3 cancers per 10,000 population for D and F atmospheric stability classes, respectively.

There is no evidence that zinc chloride is mutagenic (causing mutations in offspring).

3. Fog Oil and Diesel Fuel. There is not a great deal of toxicology data available concerning vaporized clouds produced from oil. The data that are available are concerned with combustion by-products and also includes inhalation toxicology for mineral oil (Muhly, 1983).

The military does not allow additives in fog oil, but does allow additives in diesel fuel. A significant amount of the toxicology associated with vaporized oil clouds may be due to these additives (Muhly, 1983).

When oil is inhaled it can cause edema, pneumonia and other diseases. Chronic exposure to the oils and oil mists can cause dermatosis, nasal hemorrhaging, convulsions, hair loss, and death (Muhly, 1983).

There have been many studies done concerning the possible link between inhalation of oil mists and lung cancer in newspaper printers, metal machinists, and other occupationally exposed groups. The conclusion of all these studies has been that there is no association between lung cancer and the inhalation of oil mists. The same research shows, however, that oil particles such as those in the fog-oil smoke, with a droplet size of under 5 μm in diameter, are most likely to be retained in the alveoli of the respiratory system (Roe et al., 1967; Thony et al., 1976; Waterhouse, 1973; Hodgson, 1973; Parkes, 1970; Waldron, 1975; Morris and Maloof, 1952; Bland and Davidson, 1967).

Many studies have shown, though, that there is an association between chronic exposure to lubricating oils and skin cancer (Goldstein et al., 1970; Drasche et al., 1974; Hendricks et al., 1962; Despierres et al., 1965; Decoufle, 1976; Falk et al., 1964; Bryan and Boitnott, 1969; Sante, 1949). The cancer usually develops in the part of the body that is exposed to the oils most frequently, and is usually preceded by a chronic skin rash.

VII. ENVIRONMENTAL CONSEQUENCES

It is possible that major impacts on the biological environment may occur as a result of the S&O testing. Vegetation will undoubtedly be burned and animals displaced or habitats disrupted. General impacts on the biological environment will be on the various community types and their geographical distribution. Specific impacts may occur in the life cycles of rare and endangered species inhabiting the area of the test.

After the impacts of the tests have been identified, they should be explained and assessed. This evaluation is based on the significance of each impact, its reversibility, direct and indirect effects, and short-term, long-term, and cumulative effects. It will include predictions of impacts on air, water, soil, ecological systems, and other aspects of the environmental setting. In addition, the social, aesthetic, economic, and legal impacts should be assessed on a gross scale.

The significance of the tests should be differentiated from the magnitude. The magnitude is a quantitative assessment that can be described in concrete terms such as the minimum area of impact or the environmental concentration. The significance of an impact is more subjective. It is a

determination of the effect of an impact on the environment in terms of the quality of life. In addition, a distinction should be made between possible and inevitable impacts. For example, the possibility of a spill of diesel fuel may be low, but its significance on the environment may be great.

Systematic methods designed to predict the environmental impact of S&O testing can provide organized approaches to assessing these impacts. There are several purposes to using a systematic impact analysis method. Because the environment is a complex system of interrelated physical-chemical, biological, socio-economic and cultural factors, the S&O tests can create complex reactions. An organized method of predicting these impacts can ensure that all the factors that need to be considered are included. Systematic methods of impact analysis can help to identify data needs and plan field studies. They can also be used to evaluate alternatives to the tests on a common basis. Systematic impact analysis methods can be used to evaluate and predict the effectiveness of mitigation measures. Finally, use of systematic methods of impact analysis will help to ensure compliance with NEPA and Army Regulation 200-2.

The consequences of the S&O testing are determined by systematically bringing together data on the physical, chemical, and biological properties of each smoke product with the description of the environmental setting. Each area of the environmental setting that will be affected by the tests can be further subdivided into categories that can be measured and assessed. With this assessment, a prediction can be made about the future status of the environment in 10 or 15 years, both with and without the tests.

Keep in mind that the document being written is an EA. In the scheme of environmental reporting, an EA is written when the impacts of an action are not known in advance to be significant. The information given in the preceding sections should aid in the identification (first-order screening) of significant effects. If significant effects are indicated from the first-order screening, it will be necessary to enlist the aid of meteorologists, biologists, and other scientists to determine the significance with greater precision. (If it appears from the outset that the impacts of the action will be significant, an EIS should be written. An EIS is a more lengthy document; a description of the analyses for an EIS is beyond the scope of this guidebook.)

The assessment should be able to withstand careful scientific scrutiny and should include physical, biological, and social factors. Beneficial as well as adverse environmental impacts should be included.

The environmental impacts must be considered over various time frames and processes. Immediate and direct (primary) impacts should be described first. These impacts are usually easily defined because they are a direct result of the tests.

Cumulative, indirect (secondary), and long-term impacts may then be considered. These impacts are not easily identified or controlled, and in many cases, the secondary impacts can be more serious and far-reaching than the primary impacts. It will be necessary to predict the effect that a direct impact on the environment might have on another environmental area. For example, the fallout of zinc chloride from the HC smoke might cause a direct change in the soil (a primary impact). This change in the soil might then affect the vegetation growing in the soil (a secondary impact).

The cumulative impacts can result in the conclusion that testing would be environmentally unwise. Each individual impact may be insignificant, but taken together they may be damaging to the environment.

A follow-up should be conducted after testing is begun to further evaluate secondary impacts. In addition, there should be a continual evaluation of the effects on the environment of the smoke products as they chemically transform.

A. Air Quality

The effects on the air should not be significant, i.e., they will generally be less than the first-order screening values for inhalation of contaminants. Furthermore, limits should have been place on the testing from the outset that confine the emissions to a certain geographic area so that NAAQS will not be exceeded outside the test area and so that the concentrations will not be hazardous.

B. Water Quality

A water source is considered contaminated if the effects of the pollution are health related. The pollution is considered a nuisance if the effects are

aesthetically displeasing. Nuisance pollution could be that caused by oils or diesel fuels.

It is important to remember that the testing does not have to occur near a body of water for it to have an impact on an aquatic system. Depending on the permeability of the soil in the test area, groundwater under the test site may become contaminated. This groundwater, in turn, may flow into running sources many miles from the test site or may escape through geological fissures in the form of springs.

C. Aquatic Systems

In general, the assessment of the significance of the effects on the aquatic environment should be concerned with three effects of the test procedures:

- The introduction of phosphates, which can interact with existing nitrates, into the water. Both are plant nutrients and may cause an "algal bloom," which is an overgrowth of primary producers such as algae. There would then be a resultant reduction in available oxygen when the system's decomposers use up the oxygen in the process of decomposing the overgrowth of plants.

- The introduction of materials such as oil and diesel fuel into the water. These materials have a low specific gravity (i.e., they are materials that float on water) and because of this, they may come into contact with and suffocate organisms such as algae, vascular plants, and larvae that are specifically adapted to float at the surface of the water. These organisms may be major primary producers and their loss may cause other detrimental changes in the aquatic ecosystem.

- The introduction of toxic materials into the water. This may result in both acute and chronic contamination of the aquatic biota. These effects may be measured by a toxicity quotient. The formula for determining the toxicity quotient was given in Section VI.E., Aquatic Toxicity, in this guidebook.

D. Land Use

Local land use ordinances and regional planning criteria should be considered in assessing the environmental consequences to the land in the test

site. Also included in the assessment should be data from the computer model about limits to harmful deposition concentrations.

E. Species, Populations, Communities, and Habitats

The local environment of the test site will support various species, populations, communities, and habitats. It should be determined whether feeding sites will be destroyed or removed, and whether the plants and animals will be adversely affected. It should also be determined if the tests will result in the destruction of the habitat of any rare or endangered species or whether or not the test will result in the population shift of important communities.

If there are any critical changes that will occur, it will be necessary to discuss and analyze them. The following factors should be emphasized in regard to the different species in the community: the niches that are present in the system and how they are interrelated and the habitats, which determine the kinds of populations that will be able to carry out the function of the niches.

Integrating the individual impacts on the biotic and abiotic components of the environment can be accomplished in three stages: (1) identify the probable impacts of the S&O testing to the abiotic and biotic components of the environment; (2) evaluate the probable impacts of the S&O testing for their direct and indirect influence on niche functions and habitat; and (3) evaluate the probable impacts on niche functions and habitat for their influence on population dynamics of individual populations and general dynamics of the environment.

F. Ecosystems

An ecosystem is the entire life-supporting environment of an area. In assessing the environmental consequences of the tests on the ecosystem, it will be necessary to determine if the addition of nutrients will result in eutrophication of aquatic systems, if productive land will be lost, or if the loss of vegetation will result in disruptions to the entire system.

In predicting potential impacts, it should first be determined how existing vegetation is used by the organisms in the ecosystem. Then, using

that information, it should be determined how direct and indirect impacts of testing will affect that vegetation and the use of it by organisms. Then, the carrying capacity of the area should also be considered. The carrying capacity of a particular environment is the number of animals that existing vegetation (or other environmental factors) can support. It will be necessary to obtain existing literature to adequately assess the carrying capacity of the environment. Then, using that same information, it will be necessary to determine if the carrying capacity will be altered by the impacts of the tests. It should not be assumed that if a population is displaced from one area, it can simply move to another. The organisms from one habitat may not be able to survive in another habitat or their migration may cause the new habitat to become saturated beyond the carrying capacity.

Acute and chronic effects on wildlife due to S&O testing can be predicted by previously conducted long-term epidemiological animal studies using the same S&O products or similar chemical compounds. Review of the chronic effects demonstrated by these studies and their comparison to the environmental setting and the individual test can give an understanding of potential chronic effects to the wildlife in the area of the test. When such data are not available, the potential chronic effects can only be hypothesized at the time of the environmental assessment and monitored with time.

Monitoring for chronic effects should entail observations and quantitative assessments of floral and faunal populations and communities. Chronic maladies within a species will eventually manifest themselves as changes in the population number (both declines and undesirable proliferations), and inter- and intra-species interactions. In addition, there may be effects on the resiliency and fitness of an ecosystem, on species diversity, and on habitat carrying capacity. Any such disturbances should be evaluated.

In wetland areas, the S&O testing procedure may have impacts on both the immediate area and in the general region outside the direct area. In addition, these impacts may be both direct and indirect. This is determined by how the wetland environment is related to the regional aquatic and terrestrial ecosystems.

Quite often, it will be difficult to assess impacts on wetlands qualitatively. It will then be necessary to assess impacts quantitatively. This can be done by predicting such factors as the amount of emergent

vegetation that will be lost through contact with oil or diesel fuel, what percentage of waterfowl carrying capacity will be lost due to contamination, what percentage of detritus available to detritus-feeding organisms will be contaminated with toxic materials, and how much of the runoff from the watershed to other aquatic sources will be polluted.

1. Bioaccumulation. Although contaminant levels may be low enough to avoid acute effects, bioaccumulation over a long time period can have significant ecological ramifications. A thorough literature review of studies should be conducted to investigate the consequences of bioaccumulation in or by populations near the test site.

2. Transport. Contaminants may be transported through the ecosystem by physical processes such as leaching, and through the food chain by biological processes such as bioaccumulation. Therefore, over a long time period there is potential for effects in areas that received no immediate exposure. Water and hydrologic processes are some of the most important contaminant transport mechanisms. Runoff can carry terrestrial deposition into surface waterways, and infiltration into groundwater can occur from terrestrial and aquatic deposition. The contaminants in runoff, surface water, and groundwater, therefore, can then be transported out of the test area.

G. Accidents

The probability of accidents due to S&O testing should be considered. These would include oil spills, range fires, metal corrosion, and the contamination of potable (drinking) water supplies. After describing all possible kinds of accidents, it will be necessary to determine the physical and chemical characteristics of the contamination from these accidents. The environmental impact of the accidents can be determined by conduction analyses similar to the ones described. (It will also be essential to discuss mitigation techniques for possible accidents.)

VIII. CUMULATIVE, LONG-TERM EFFECTS OF REPEATED TESTS

A. Effects of Repeated Testing

The testing of smokes and obscurants is not an event that will occur only once a year, rather it will occur repeatedly at most of the installation

sites. Consequently, it will be necessary to determine the effects that this repeated testing will have on the environment. Several factors need to be considered to accomplish this.

1. Time Scale of Tests. The prediction of the impact of S&O testing at a particular location requires the evaluation of the accumulated deposition over time at that test site and the evaluation of the impact of each test individually. For example, if five devices are tested four times yearly, the deposition from all these tests must be evaluated. It will be necessary, as well, to include the natural environmental removal processes and the inputs from the test through infiltration.

The time scale depends on the type of testing and device, and the specific location of the test. For example, if S&O material from one test becomes unavailable to biota before the next test begins, it will be possible to evaluate each test's impact separately until the ecosystem is no longer able to absorb the contaminants. A single test period is defined as a period of continuous smoke production.

2. Long-Term and Chronic Effects. The most conservative estimate of risk from chronic exposure is to use the duration of exposure time and the total cumulative deposition as the dose. A more realistic estimate, however, should adjust the deposition term by including removal and degradation processes and consider that the concentration of S&O materials are not constant with time. A more complete discussion of chronic effects on humans is found in Section VI.4.

3. Follow-Up. A second, more empirical stage of environmental assessment, conducted at least once a year between cycles of testing, is recommended to provide the following:

- Ensure compliance with legal environmental standards.
- Ensure the well-being of sensitive populations.
- Evaluate the environmental assessment, mitigations, and alternatives.

B. Use of Cumulative Evaluation

1. Recommend Length of Rest Period. If testing has been conducted on a regular basis, it will be possible to use the same methods as were used in the prior year (or test cycle) with new baseline data to determine the number and type of acceptable rest periods for the new cycle.

If testing at this location has not been conducted on a regular basis, it will be necessary to use test methods from another installation that has a similar environment.

2. Recommend Mitigation Measures and Alternatives. The environmental impact of continued testing can be predicted and assessed using new data from the follow-up assessment. From this, alternatives and mitigation measures can be recommended.

The methods of evaluation developed will, in general, overestimate the environmental impact of the tests. If post-test measurements show that the EA overestimated the impact, the methods should not be adjusted. They are representative of a worst-case combination of meteorological and biological conditions and may occur only very infrequently. If the EA has underestimated the environmental impact, the methods used should be reevaluated and assumptions should be reconsidered. It will be necessary to determine if the inclusion of any environmental attributes that were not included will significantly improve results.

IX. SHORT-TERM USE OF THE ENVIRONMENT VERSUS EFFECTS ON LONG-TERM PRODUCTIVITY

A. Unavoidable Adverse Impacts

Risks to the biological communities in the area of the tests will be, to a large extent, unavoidable. It has been observed, however, that some species such as birds and deer will leave the area during the test and return afterwards (Van Voris et al., 1986). Vegetation will undoubtedly be burned, however, and habitats altered.

1. Phosphorus Smokes. The testing of phosphorus smokes will have several unavoidable short-term environmental effects. Vegetation in the area of the test will be burned but should be able to grow back within a month (Van Voris et al., 1986). Wildlife will be irritated by the smoke cloud itself. If unignited fragments of white phosphorus fall into an aquatic system, localized fish kills could occur because WP is toxic at levels lower than 1 part per billion (Canter, 1977). Because of this, it will be necessary to situate the testing of phosphorus smokes in an area that will minimize the possibility of aquatic contamination. Because red phosphorus is not as reactive as white phosphorus, it will present less of a risk to aquatic organisms.

2. Hexachloroethane Smoke. The risks posed by the ignition of HC smoke are generally related to zinc chloride and depend upon the quantities dispersed, the spacing of the devices, the frequency of the tests, and the environmental and meteorological conditions at the site of the test. Recent research has shown that a smoke pot lying on its side in a horizontal position will deposit from 5 to 10 times more organic material into the environment than will a smoke pot that is upright in a vertical position (Schaeffer et al., 1986a). Zinc chloride will be deposited on the ground, vegetation, and waters. It is unlikely, however, that zinc chloride from fallout will occur in quantities sufficient to cause the stunting of vegetation or toxic effects in wildlife.

3. Fog Oil and Diesel Fuel. Aerosols that are composed of droplets that are 1 μm or less do not coat surfaces like conventional oil sprays. Instead, they remain airborne and eventually evaporate or disperse into the atmosphere (Muhly, 1983). Because of this, the risk to the long-term productivity of the biological community in the area of the test will generally be of little significance. If the duration of the test is extended, though, the airborne concentrations of contaminants could be expected to transiently affect natural populations in the area.

B. Restriction of Land Use Options

S&O testing may restrict the use of land on the installation. Other training and testing operations may be affected and there may be an impact on land areas used for habitation.

The test should be discussed as it relates to the master installation land use plans. Military boundaries, land-use policies, and governmental agreements can be defined. The effects on the use of land outside the installation, if any, should be presented. Future land use plans should be addressed.

X. RECOMMENDED ALTERNATIVES

Alternatives to each proposed smoke test should be identified and evaluated. These alternatives will enable similar goals to be accomplished but will have a different or less severe environmental impact. Each

alternative will either modify or relocate the test. In addition, the alternative of "no project" must always be included.

Alternatives must be determined early in the planning stages so that each alternative may be weighed against important environmental factors. Each should be based on the significance (effect on quality of life) and magnitude (a quantitative assessment) of its impacts.

Many EAs have accurate, complete species lists in the environmental setting section but tend to neglect the impact of the alternative actions on those species. It will be impossible to list every potential impact, but the assessor should describe as many general changes as possible that could result in species and their habitat should the alternatives be implemented. It will be of particular importance to describe any changes that will occur to rare or endangered species.

Alternatives do not need to be presented in as much detail as the actual proposed action. It is usually sufficient to include general characteristics of the environment and a statement that explains why the alternative was rejected in favor of the proposed test. Alternatives should be listed in tabular form. Included in the table should be the considerations, impacts, and relative estimates of each alternative.

The Army research and development of smokes will occur in two phases: demonstration/validation and full-scale development. The testing of smokes and obscurants will occur in the demonstration/validation phase. Smokes and obscurants will also be used in training exercises. Each installation at which the tests or training will take place is already operating under a site-specific EA.

A. Phosphorus Smokes Development Alternatives

1. No Action. If the Army were to stop developmental testing of phosphorus smokes, it could not produce these smokes and would be left with only one existing type of classified munition. Safer and more effective phosphorus munitions would not be developed. If safer munitions are not developed, the environmental degradation could be increased at sites where current smokes are used. Obviously, no impact would occur at the testing sites if no new smoke tests are performed.

2. Conduct Indoor Tests. Laboratory tests, while producing valuable data, are not able to completely reproduce field conditions where actual smoke

use would take place. These tests would eliminate direct impacts to the environment from testing. A concern instead would be disposal of waste products.

3. Conduct Tests at Another Site. The Army has identified a number of sites for testing S&O with the purpose of minimizing environmental effects. Moving tests to another location could result in more significant environmental effects. Limitation of testing to only a few locations does not permit examination of S&O properties under a wide enough variety of conditions to fully evaluate usefulness.

B. Hexachloroethane Smokes Development Alternatives

1. No Action. Hexachloroethane smoke presents many safety hazards and the Army has directed that it be modified or eliminated to minimize these hazards. Testing will be required to determine if newly developed HC smoke products are less hazardous. The elimination of HC smoke without a replacement would possibly endanger national security; the Army would be deprived of its white smoke capability and its screening capability in floating pots.

2. Conduct Indoor Tests. Laboratory tests, while producing valuable data, are not able to completely reproduce field conditions where actual smoke use would take place. These tests would eliminate direct impacts to the environment from testing. A concern instead would be disposal of waste products.

3. Conduct Tests at Another Site. The Army has identified a number of sites for testing S&O with the purpose of minimizing environmental effects. Moving tests to another location could result in more significant environmental effects. Limitation of testing to only a few locations does not permit examination of S&O properties under a wide enough variety of conditions to fully evaluate its usefulness.

C. Fog Oil and Diesel Fuel Development Alternatives

1. No Action. If fog oil and diesel fuel S&O are not developed, the Army will not be able to meet its urgent need to increase obscurant

abilities. Obviously, no negative environmental effects would occur at the testing sites if no new smoke tests are performed.

2. Conduct Indoor Tests. Laboratory tests, while producing valuable data, are not able to completely reproduce field conditions where actual smoke use would take place. These tests would eliminate direct impacts to the environment from testing. A concern instead would be disposal of waste products.

3. Modify Existing Systems. Research and development of new systems for producing petroleum-based smoke is currently under way. These new systems will enhance present systems and will exceed the limits of the current systems. Nonetheless, these systems need to be tested.

4. Conduct Tests at Another Site. The Army has identified a number of sites for testing S&O with the purpose of minimizing environmental effects. Limitation of testing to only a few locations does not permit examination of S&O properties under a wide enough variety of conditions to fully evaluate its usefulness.

D. Infrared Smokes EA-5763 and EA-5769

1. No Action. If infrared smokes are not developed, the Army will not be able to meet its urgent need to increase obscurant abilities.

2. Conduct Indoor Tests. Laboratory tests, while producing valuable data, are not able to completely reproduce field conditions where actual smoke use would take place. These tests would eliminate direct impacts to the environment from testing. A concern instead would be disposal of waste products.

3. Conduct Tests at Another Site. The Army has identified a number of sites for testing S&O with the purpose of minimizing environmental effects. Moving tests to another location could result in more significant environmental effects. Limitation of testing to only a few locations does not permit examination of S&O properties under a wide enough variety of conditions to fully evaluate its usefulness.

E. Training Alternatives

1. No Action. If the Army were to stop training in the use of S&O, it would eventually have no personnel with the expertise to use these munitions. Safer and more effective use of the munitions would not be developed.

2. Conduct Training at Another Location. Training in the use of S&O must take place in a variety of field locations so that personnel will be able to use the munitions in a manner appropriate to the condition. The Army has identified a number of locations where relatively limited environmental impacts will take place. These locations provide a balance among differing meteorological, topographical, and vegetational conditions. If all S&O training were conducted at only a few locations, the experience of personnel would be unduly limited. Also, the cumulative effect of more tests in fewer locations could lead to more severe environmental effects at those locations.

XI. MITIGATION

The Environmental Assessment will include suggested mitigation efforts. These efforts can be described in five parts.

A. Statement of the Problem

The statement of the problem to be mitigated will require that the preparer of the EA recognize any potentially undesirable consequences of the test. Such consequences can include the following:

- Exceeding standards of air quality.
- Exceeding standards for water quality.
- Threatening a rare, endangered, or sensitive wildlife or vegetation population.

B. Change in the Action (Mitigation)

Mitigation efforts alleviate adverse environmental impacts. They must be identified and described in sufficient detail so that the Office of the Chief of Engineers will be able to evaluate it. Mitigation efforts will necessarily

need to conform to each specific site and smoke being tested. However, some mitigation efforts would include

- Locating the test away from bodies of water or aquatic systems. (Special precautions will need to be taken in testing floating smoke pots.)
- Posting notices so that people and domestic animals within the exposed area can be moved out.
- Wearing hearing protection devices, thick working gloves, safety goggles, and gas masks. The wearing of gas masks is the most important factor in reducing the risk of adverse health effects in smoke training and testing.
- Restricting testing based on meteorological conditions, time of day, and location to minimize the introduction of pollutants into the atmosphere and restrict the smoke cloud to the military reservation.
- Using the minimum amount of smoke material necessary to conduct the test.
- Conducting the testing indoors during early phases of developmental testing.
- Monitoring areas of heavy use for changes in vegetation or other environmental factors.
- Notifying the local Air Pollution Control Authority, the Post Fire Department, the Post Forester, airfield control tower, and other appropriate agencies.
- Setting up communication systems between the smoke operators and headquarters to monitor the cloud.
- Establishing procedures to minimize skin contact with the smoke mix.
- Monitoring the test area for soil erosion if extensive areas of vegetation are burned.
- Avoiding sensitive resources.
- Establishing procedures for storage and disposal of hazardous materials.
- Reducing the duration of tests.
- Reducing the number of tests.
- Rotating test locations within the site to minimize impacts.
- Scheduling the personnel conducting the tests to reduce cumulative exposures.

These mitigation measures are effective for many environmental consequences. In addition, they generally will not interfere with the goals of the test. Mitigation efforts should be envisioned for the whole environment at once, so that complementary changes can be made. In this way, less drastic changes will be sufficient.

C. Impacts of the Mitigation

The mitigation effort will have impacts of its own on the environment and on the test. If, for example, the test must be relocated so as to avoid a sensitive population, there may be fewer monitoring stations at the new location. This will reduce the resolution of data (degree of detail) collected. In addition, the use of a new location may require the building of an access road. The cost, time delay, and environmental impact of the road construction would have to be included.

D. Estimated Benefits of the Mitigation

The benefits of the mitigation must be estimated. It should be determined if it will make a difference in areas of concern.

E. Evaluation of the Mitigation

The benefits of the mitigation can be weighed against its costs. Also to be considered is the cumulative benefit of all mitigation efforts taken together.

XII. RECOMMENDATION FOR A FNSI

If it is clear from the material presented in the EA that the environmental effects will not be significant, it is proper to make a recommendation that a finding of no significant impact be made. The recommendation need not be lengthy and may refer to mitigation measures that will be taken to prevent any significant effects.

XIII. REFERENCES

The references section should include all documents to which reference was made and all persons and agencies whose information provided facts or methods of analysis presented in the EA. The reference format should be consistent, and should provide sufficient information for the reader to be able to obtain the referenced material.

GLOSSARY

- ABIOTIC - The nonliving components of an ecosystem.
- ABSORPTION - The ability of a smoke to absorb light at certain wavelengths.
- ADSORPTION - The surface retention of solid, liquid, or gas molecules, atoms, or ions by a solid or liquid.
- AEROSOL - A gaseous suspension of fine solid or liquid particles.
- AIRFLOW TRAJECTORY - The path travelled by a parcel of air as it is moved by the wind over time.
- AIR POLLUTION DISPERSION POTENTIAL - Ability of the atmosphere to spread and dilute pollutants both horizontally and vertically.
- ALGAL BLOOM - An overgrowth of primary producers in an aquatic system.
- AQUATIC TOXICITY QUOTIENT (ATQ) - A measure of environmental impact that includes both the amount of substance present and its toxicity.
- ARTESIAN AQUIFER - Groundwater that is held under pressure between layers of impermeable rock.
- ATMOSPHERE - The gaseous mass or envelope surrounding the Earth and retained by the Earth's gravity.
- ATMOSPHERIC STABILITY - The tendency of the air to resist overturning. An air mass is stable if a displaced parcel will return to its original position.
- BENTHOS - The bottom-dwelling life of an ocean or freshwater environment.
- BIOACCUMULATION - The process of amassing or building up of a contaminant in the biota of an ecosystem.
- BIOLOGICAL OXYGEN DEMAND (BOD) - The amount of oxygen that is needed by bacteria in the process of decomposing organic material in a sample of water held at 20 degrees Celsius over a five-day period.
- BIOME - A large community of plants and animals that will usually exist together under certain climatic conditions.
- BIOTIC - The living components of an ecosystem.
- CARBON MONOXIDE - An invisible, toxic, odorless gas formed from the incomplete combustion of gasoline, coal, and other products.
- CARNIVORE - An animal that consumes meat.
- CARRYING CAPACITY - The number of animals that the existing vegetation in an ecosystem can support.

CEQ - The Council on Environmental Quality, an agency established by NEPA for the purpose of assisting and advising the President on environmental and ecological matters.

CHEMICAL OXYGEN DEMAND (COD) - The demand for oxygen caused by chemical reactions in water. This increases with respiration, combustion, and decomposition of organic matter.

CLIMATOLOGY - The weather pattern of a particular region summarized over a period of many years.

COLLOID - A suspension of finely divided particles that do not settle out of, and cannot be readily filtered from, the uniform medium in which they are suspended.

COMMUNITY - A collection of different and interacting populations.

CONCENTRATION QUOTIENT (CQ) - The ratio of the environmental air concentration to the particular LC₅₀ value for inhalation lethality to laboratory animals.

CONDENSATION NUCLEI - Atmospheric suspensions that facilitate condensation because of their chemical affinity for water.

CRITICAL HABITAT - The habitat of an animal on the Endangered Species List.

DISTILLATION - A heat-dependent process used to purify or separate a fraction of a relatively complex mixture of substances.

ECOLOGICAL SUCCESSION - The predictable, orderly process of development or change among species, structures, and community processes.

ENDANGERED SPECIES ACT OF 1973 - A program established to protect all species of wildlife and plants that are threatened or endangered.

ENVIRONMENTAL ASSESSMENT - The written analysis describing the environmental impacts of the proposed actions of an agency.

ENVIRONMENTAL IMPACT STATEMENT - A report that identifies and analyzes in detail the environmental impact of a proposed agency action and feasible alternatives to that action.

EMISSION INVENTORY - A list of source locations and rates of pollutants emitted from either a given activity or industrial plant, or all sources in a given area or region.

EPISODE DAYS - Number of days meeting certain pre-specified characteristics of poor air-pollution-dispersion potential.

EROSION - The group of processes including weathering, dissolution, abrasion, corrosion, and transportation, by which earthy or rock material is removed from any part of the earth's surface.

EUTROPHICATION - The process whereby the algae of a body of water becomes highly productive due to the input of large quantities of nutrients. Subsequent decomposition of this organic matter depletes the water of oxygen essential to other aquatic life.

EXTINCTION - The amount of dilution at which it is no longer possible to see a smoke.

FAULT - A break in the continuity of a rock formation, caused by a shifting or dislodging of the earth's crust, in which adjacent surfaces are differentially displaced parallel to the plane of fracture.

FEDERAL CLEAN AIR ACT OF 1970 (CAA) - A program for the creation of National Ambient Air Quality Standards (NAAQS).

FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (FWPCA) - A program to establish basic water quality goals and policies.

FNSI - The Finding of No Significant Impact, a document that briefly presents reasons why an action will not have a significant effect on the environment and, thus, will not be the subject of an Environmental Impact Statement.

FOLIAR - Pertaining to leaves.

FOLIAR INGESTION QUOTIENT (FIQ) - The ratio of the amount of substance ingested, to the LD50 for oral toxicity for a particular species.

FOLIAR RETENTION - The deposition of smoke products on foliage.

FOOD CHAIN - The sequential consumption of one organism by another.

GEOLOGY - The structure of a specific region of the Earth's surface.

GROUNDWATER - Water located in the zone of saturation under the water table.

HABITAT - The area or type of environment in which a plant or animal normally occurs or lives.

HEAD WIND - A wind blowing toward the frontline of troops.

HERBIVORE - An animal that consumes only plants.

HIGH-AIR-POLLUTION-POTENTIAL ADVISORY - A watch issued by an air pollution control agency requesting reduced emissions due to poor air dispersion conditions (low mixing depths and wind speeds).

HUMIC ACIDS - Acids formed from humus, the material resulting from partial decomposition of plant or animal matter and forming the organic portion of soil.

HYDROCARBON - An organic compound that contains only hydrogen and carbon, e.g., oil.

IGNEOUS - Rocks solidified from a molten state.

IONIC - Pertaining to an atom or group of atoms, or molecule having a net electric charge acquired from gaining or losing electrons from an initially neutral configuration.

INORGANIC - Involving neither organic life nor the products of organic life.

INVERSION - A state in which the air temperature increases with increasing altitude, holding surface air down along with its pollutants.

LANDFORMS - The many features such as mountains, plains, and plateaus, that taken together make up the surface of the earth.

LC₅₀ - The amount of a substance that is lethal to 50% of the laboratory animals in an experimental setting.

LEACH - To remove or be removed from, by the action of a percolating liquid.

LENTIC - Running sources of water such as streams, rivers and creeks.

LOTIC - Impounded sources of water such as ponds, lakes, and reservoirs.

MASS CONCENTRATION - The mass of smoke per unit volume of air (usually given in micrograms per cubic meter).

MASS LOADING - The maximum amount of material deposited on a filter or substrate.

MAXIMUM ATMOSPHERIC CONCENTRATION - The highest mass per unit of a substance (solid, liquid, or gas) observed by field equipment or predicted by a model.

MAXIMUM DEPOSITION DENSITY - Highest mass of material deposited per unit area of ground.

MESOSCALE - Of or pertaining to scales of about 10 to 100 kilometers.

METAMORPHIC - Rock masses created by heat or pressure.

METEOROLOGY - The science of the earth's atmosphere, climate, and weather conditions.

MICROSCALE - Of small scale.

MINIMUM IMPACT AREA - Smallest possible area of significant air pollutant impact from a source or activity.

MITIGATION - That which will cause the effects of an action to become less harsh or severe.

MIXING DEPTH - The distance above the earth to which pollutants can mix during a given time period.

MODEL - A mathematical method to predict the behavior of natural or artificial systems.

NECROSIS - The death of living tissue.

NEKTON - Large, strong-swimming aquatic animals.

NEPA - The National Environmental Policy Act, enacted in 1970, establishing criteria for evaluating and controlling how human activities affect the environment.

NICHE - The ecological role of an organism in a community.

NITROGEN DIOXIDE - A brown, toxic gas formed from fuel combustion.

NORMALS - Mean values of parameters (usually temperature and precipitation) observed over a period of thirty years or more.

NUISANCE POLLUTION - Pollution that is not health related, but is aesthetically displeasing.

OMNIVORE - An animal that consumes both plants and meat.

ORGANIC - Of, or designating carbon compounds.

OXIDATION - The combination of a substance with oxygen.

OXIDE - A binary compound of an element with oxygen.

PARTICLE SIZE DISTRIBUTION - The distribution of the sizes of particles in the smoke.

PERMEABILITY - The state of having openings or interstices through which material can pass.

pH (potential of hydrogen) - A logarithmic scale measuring the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, with the number increasing as alkalinity increases and decreasing as acidity increases.

PHOTOCHEMICAL OXIDANT - A pungent, colorless, toxic gas; the oxygen component of photochemical smog (mostly ozone).

POPULATION - A collection of organisms of the same species.

PLANT ASSOCIATION - An association of different kinds of plants usually found together with one type of plant as the dominant species.

PRECIPITATION - Any form of water or ice particles falling to the ground.

PYROTECHNIC - Of or caused by an ignited explosion.

RELATIVE HUMIDITY - The amount of water vapor in the air compared to the total amount that the air can hold at that temperature.

RELIEF - The variations in elevation of any area of the earth's surface.

SALINITY - Pertaining to the amount of salt dissolved in a fluid.

SEDIMENT - Material that settles to the bottom of a liquid.

SEDIMENTARY - Rocks formed from sediment.

SEISMIC - Of or caused by an earthquake.

SOLVENT - A liquid in which another substance is dissolved.

SPECIFIC CONDUCTANCE - Ability of a specific amount of water to transport electricity proportional to the number of ions in the water.

SPECIFIC GRAVITY - The ratio of the density of a liquid or gas substance to the density of water, a reference most commonly used.

STABILITY - The capacity of particulate suspensions to be held up in the air for a prolonged period of time without settling and without being broken up.

SULPHUR DIOXIDE - A heavy, pungent, colorless gas formed from the combustion of coal, oil, and other products.

SURFACE WATER - Water that is located above the water table and is exposed to air.

SYNOPTIC - Of or pertaining to the scale of major weather systems (highs, lows, and fronts).

SYSTEMIC - Occurring throughout the entire organism.

TAIL WIND - A wind blowing away from the frontline of troops.

THERMAL - Using, producing or causing heat.

TOTAL ORGANIC CARBON (TOC) - Total amount of carbon contained in organic matter, including water, alcohol, gasoline, and kerosene.

TOTAL SUSPENDED PARTICULATES (TSP) - Air pollutants suspended in the form of solid and liquid particles including smoke, dust, mist, fumes, and spray from many sources.

TOPOGRAPHY - The features of a place or region.

TURBID - Having sediment or foreign particles stirred up or suspended.

VOLATILE - Evaporating rapidly at normal temperatures and pressures.

WATER TABLE AQUIFERS - Groundwater that is not held under pressure.

WAVELENGTH - In a periodic wave, the distance between two crests or other points of corresponding phase in consecutive cycles.

WETLAND - A land where an excess of water is a dominant factor determining the nature of soil development and the types of plant and animal species living at the soil surface.

WIND ROSE - A diagram that shows the distribution of wind direction and speed by frequency for a given site over a period of time.

ZONE OF SATURATION - The area underground in which all openings such as crevices and pores are filled with water.

ZOOPLANKTON - Microscopic, freefloating aquatic animals.

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APPENDIX A: SUMMARY OF ARMY REGULATION 200-2

1. The Chief of Engineers has the primary staff responsibility for coordinating and monitoring NEPA activities within the Army. Through the Assistant Chief of Engineers, this office is the Army staff point of contact for environmental affairs.

It is the responsibility of the office of the Chief of Engineers to

a. Provide assistance and advice on the preparation and processing of environmental documentation through the identification and quantification of environmental impacts and selection of impact mitigation techniques.

b. If necessary, to designate a single agency or lead office to have the responsibility for preparing and processing environmental documentation when more than one DA agency is involved. It will also assign DA lead agency responsibility when non-DA agencies are involved.

c. Review and comment on Environmental Impact Statements (EIS) submitted by other DOD components and other federal agencies.

d. Monitor proposed DA policy and program documents that have environmental implications to determine if an EIS or an Environmental Assessment (EA) is required and to insure that environmental considerations are integrated into the decision-making process.

e. Maintain liaison with the Office of Management and Budget (OMB), CEQ, The Environmental Protection Agency (EPA) and other federal, state and local agencies with respect to their environmental policies that may affect DA. This will assist in the identification and evaluation of applicable regulatory policies for proposed actions.

f. Maintain a current record of actions for which EISs have been prepared or are under preparation, and those actions of national concern for which a Finding of No Significant Impact (FNSI) has been rendered.

g. Retain a copy of each draft and final EIS prepared by the DA. The EIS will be retained until the proposed action and any mitigation program is complete or the information is no longer valid.

h. Direct the preparation of EISs, as appropriate, to insure adequate consideration of environmental impacts.

i. Comment on EISs within those areas of assigned staff responsibility and technical capability.

j. Resolve issues in determining if a public hearing is appropriate for the proposed action and assign, when necessary, the responsibility for the hearing to an appropriate office.

2. Headquarters Department of the Army has the responsibility to

a. Assess proposed programs and actions to determine their environmental consequences and initiate the preparation of necessary environmental documentation. Environmental documents will be circulated and reviewed at the same time as other planning documents.

b. Coordinate appropriate environmental documents with other DA staff agencies as well as to the office of the Chief of Engineers.

c. Designate, record and report to the Office of the Chief of Engineers the identity of the agency's single point of contact for NEPA considerations.

d. Maintain a current record of staff agency actions on which EISs have been prepared, or are being prepared, and those actions of national concern for which FNSIs have been prepared.

e. When requested, assist in the review of environmental documents prepared by DOD and other DA or federal agencies.

f. Coordinate proposed directives, instructions, regulations and major policy publications that have environmental implications with the Chief of Engineers.

3. The Judge Advocate General (TJAG) has the responsibility to provide legal advice and assistance, as requested, in the interpretation of NEPA and CEQ regulations, and to provide an interface with the Department of Justice on NEPA related litigation.

4. The Comptroller of the Army (COA) has the responsibility to establish necessary procedures to insure compliance with the requirements for environmental exhibits and data in support of annual authorization requests.

5. The Surgeon General (TSG) has the responsibility to coordinate the environmental review as it relates to health and welfare aspects of proposed EISs submitted to HQDA. To identify and evaluate environmental impacts, DA

agencies are encouraged to draw upon the special expertise that is available within the medical department, including the US Army Environmental Hygiene Agency.

6. The Chief of Public Affairs (SAPA) has the responsibility to
 - a. Provide guidance on the issuance of public announcements required by AR 200-2 including NOIs, scoping procedures and FNSI, and public involvement activities.
 - b. Review proposed news releases on actions of national interest or impact.
 - c. Arrange for the issuance of news releases on actions of national interest or scope to the national news media.

7. Major field commanders have the responsibility to monitor proposed actions and programs for accomplishment within their command and for assuring that appropriate environmental documents are prepared and, as necessary, forwarded to HQDA.

8. All Army commands and agencies have the responsibility to
 - a. Establish, as necessary, internal procedures for analyzing environmental consequences of continuing proposed actions and programs that would implement their mission. Environmental documents should be prepared, coordinated, and processed by the technical staff.
 - b. Establish, as necessary, internal procedures to insure that proposed regulations, directives, instructions, and other major policy publications, which implement their function or which implement issuances by higher headquarters, are evaluated for environmental consequences before publication.

APPENDIX B: METEOROLOGICAL DATA FOR S&O SITES

The meteorological data used to create the following charts were gleaned from tapes provided by the National Climatic Data Center, National Oceanic and Atmospheric Administration. The sites at which the original data were recorded are presented in Table B-1. The charts are presented by the seasons, winter - December, January, and February; spring - March, April, and May; summer - June, July, and August; and fall - September, October, and November, and by the Pasquill-Gifford stability categories, A - extremely unstable; B - unstable; C - slightly unstable; D - neutral; E - stable; and F - extremely stable.

Additional depth of mixing layer data by stability class and season are presented in the final chart in this appendix. These data are for sites that also may be used for S&O testing in the future. If testing is to be conducted at these sites, these and additional meteorological data, such as wind speed and frequency of occurrence, are available in the Handbook for Chemical Hazard Prediction (US Army Materiel Development and Readiness Command, 1980).

TABLE B-1. METEOROLOGICAL DATA FOR SITES.

Sites	Years	Daily observations/ stability data	Mixing depth data
Ft Benning, GA	66-70	On-site	Montgomery, AL
Ft Campbell, KY	79-83	On-site	Nashville, TN
Ft Hood, TX	79-83	On-site	Stephenville, TX
Ft Knox, KY	79-83	On-site	Salem, IL
Ft Lewis, WA	6/60-5/62	On-site	Seattle, WA
Ft Sill, OK	79-83	On-site	Oklahoma City, OK
Ft Polk, LA	79-83	On-site	Lake Charles, LA
Ft Carson, CO	60-64	Colorado Springs, CO	Denver, CO
Ft McClellan, AL	81-83	Birmingham, AL	Centreville, AL
Ft Jackson, SC	79-83	Columbia, SC	Athens, GA
Ft Ord, CA	64-68	San Francisco, CA	Oakland, CA
Ft Greeley, AK	79-83	Fairbanks, AK	Fairbanks, AK
Ft Irwin, CA	79-83	Edwards AFB, CA	Mercury, NV
Howard AFB, Panama	66-70	On-site	Balboa-Albrook AFB

Fort Benning

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.4	0.0	1016
	B	6.0	1.1	1076
	C	12.5	2.2	971
	D	43.0	3.2	673
	E	4.7	3.2	755
	F	33.4	0.0	239
SPRING	A	3.2	1.7	1771
	B	12.5	2.2	1484
	C	17.1	2.7	1520
	D	29.5	3.2	1130
	E	3.9	3.2	806
	F	33.8	0.0	200
SUMMER	A	8.3	1.1	1654
	B	18.0	1.7	1523
	C	17.9	1.7	1417
	D	17.3	2.2	810
	E	2.4	2.2	621
	F	36.1	0.0	304
FALL	A	1.7	0.6	1446
	B	14.1	1.7	1383
	C	14.6	2.2	1261
	D	24.6	3.2	947
	E	3.7	2.7	853
	F	41.3	0.0	222

Fort Campbell

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	0.0	861
	B	3.2	1.1	863
	C	9.8	2.2	739
	D	56.9	3.9	526
	E	6.3	3.2	695
	F	23.8	1.1	288
SPRING	A	2.0	1.1	1824
	B	8.4	2.2	1463
	C	14.3	3.2	1452
	D	45.5	4.4	868
	E	4.2	2.7	800
	F	25.5	0.0	201
SUMMER	A	5.9	1.1	1693
	B	16.9	2.2	1726
	C	21.6	2.2	1583
	D	19.3	3.2	822
	E	3.0	2.7	598
	F	33.3	0.0	337
FALL	A	1.0	0.0	1214
	B	9.8	1.7	1214
	C	17.1	2.2	1107
	D	31.7	3.9	685
	E	3.9	2.7	724
	F	36.5	0.0	246

Fort Carson

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	--	--
	B	2.7	1.7	1134
	C	12.2	3.2	897
	D	46.8	5.5	751
	E	24.3	4.4	482
	F	14.1	2.7	75
SPRING	A	0.2	0.0	3276
	B	5.2	3.2	2511
	C	12.7	4.4	2839
	D	55.1	6.0	1497
	E	15.6	3.9	481
	F	11.3	2.7	98
SUMMER	A	1.0	2.2	2667
	B	8.8	3.2	2374
	C	18.3	5.0	2109
	D	43.7	5.0	1070
	E	16.5	3.9	309
	F	11.7	2.7	110
FALL	A	0.2	0.0	2406
	B	5.9	2.2	1715
	C	13.7	3.9	1315
	D	43.9	5.5	1117
	E	21.9	4.4	309
	F	14.4	2.7	89

Fort Greeley

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	0.0	--
	B	0.0	0.0	103
	C	10.0	0.0	46
	D	33.0	2.7	150
	E	11.4	2.7	426
	F	45.6	0.0	26
SPRING	A	0.3	0.0	2229
	B	6.2	1.7	1538
	C	16.6	2.2	1056
	D	50.9	4.4	801
	E	11.5	3.2	485
	F	14.6	1.7	69
SUMMER	A	0.6	0.0	2590
	B	8.3	2.2	2219
	C	17.0	2.2	1742
	D	61.5	3.9	1098
	E	6.3	2.7	676
	F	6.3	1.7	144
FALL	A	0.0	0.0	--
	B	1.3	0.0	1506
	C	9.8	1.7	327
	D	57.7	2.7	432
	E	11.7	2.7	608
	F	19.5	1.7	85

Fort Hood

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.3	0.0	1057
	B	4.2	1.7	964
	C	10.3	3.2	929
	D	52.3	4.4	706
	E	9.7	3.9	678
	F	23.1	1.7	312
SPRING	A	1.8	1.7	1813
	B	6.4	2.7	1394
	C	12.7	4.4	1474
	D	51.9	5.0	995
	E	8.1	3.9	802
	F	19.2	1.1	384
SUMMER	A	5.9	1.7	2126
	B	14.7	2.7	1934
	C	20.0	3.2	1582
	D	22.9	4.4	1210
	E	7.9	3.9	892
	F	28.6	1.7	494
FALL	A	1.9	0.6	1984
	B	11.4	1.7	1702
	C	13.8	2.7	1560
	D	31.8	4.4	1074
	E	7.2	3.9	965
	F	33.9	1.1	336

Fort Irwin

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.9	0.0	1782
	B	11.5	1.1	1404
	C	12.5	1.7	1618
	D	24.0	5.5	1630
	E	7.8	4.4	1268
	F	43.3	0.0	523
SPRING	A	2.5	0.0	2998
	B	6.6	2.7	3070
	C	12.4	5.0	2652
	D	37.5	7.1	2240
	E	12.3	4.4	738
	F	28.7	1.1	129
SUMMER	A	1.1	2.2	3765
	B	5.7	3.9	3621
	C	13.9	5.5	3244
	D	30.0	6.5	2104
	E	15.6	4.4	63
	F	33.6	1.1	47
FALL	A	2.4	0.0	2485
	B	12.0	1.7	2463
	C	11.0	3.2	2611
	D	20.3	6.0	2078
	E	9.7	4.4	647
	F	44.5	0.0	77

Fort Jackson

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	0.0	1125
	B	3.0	1.7	1083
	C	9.4	3.2	1057
	D	53.6	4.4	797
	E	9.5	3.9	675
	F	24.5	1.7	202
SPRING	A	1.2	2.5	1927
	B	8.9	3.2	2013
	C	15.2	4.4	1848
	D	42.0	4.4	1474
	E	10.6	2.7	928
	F	22.1	1.7	229
SUMMER	A	3.3	2.2	1977
	B	13.7	3.2	1934
	C	19.9	3.9	1937
	D	29.8	3.2	1190
	E	8.3	2.7	734
	F	24.9	1.7	350
FALL	A	0.5	0.0	1928
	B	8.3	2.7	1526
	C	13.6	3.9	1495
	D	39.5	3.9	1071
	E	7.6	2.7	807
	F	30.5	1.7	141

Fort Knox

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.2	0.0	670
	B	3.5	1.1	762
	C	11.6	2.2	741
	D	62.2	3.9	645
	E	5.5	3.2	1065
	F	16.9	0.0	524
SPRING	A	2.6	1.1	1377
	B	10.3	2.2	1341
	C	16.6	3.2	1344
	D	53.0	4.4	964
	E	3.4	3.2	1166
	F	14.1	0.6	298
SUMMER	A	6.8	1.1	1424
	B	21.7	2.2	1367
	C	26.8	2.2	1166
	D	23.6	3.2	730
	E	1.8	2.7	--
	F	19.3	0.0	185
FALL	A	1.2	0.0	1121
	B	11.8	1.7	1108
	C	19.3	2.2	976
	D	36.4	3.2	857
	E	3.7	2.7	1029
	F	27.5	0.0	333

Fort Lewis

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	--	--
	B	19	0.0	619
	C	8.5	0.0	775
	D	63.8	2.2	578
	E	3.8	3.2	1074
	F	22.0	0.0	714
SPRING	A	1.1	0.0	1613
	B	5.0	1.7	1740
	C	10.4	1.1	1714
	D	58.9	2.2	1219
	E	4.3	3.2	1180
	F	20.2	0.0	837
SUMMER	A	4.3	0.0	1634
	B	16.2	2.2	1325
	C	17.5	2.2	1410
	D	31.0	2.2	1209
	E	2.7	2.7	1089
	F	28.3	0.0	372
FALL	A	0.6	0.0	1226
	B	5.5	1.1	770
	C	13.0	1.1	801
	D	47.8	2.2	885
	E	3.6	3.2	990
	F	29.6	0.0	161

Fort McClellan

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.0	--	--
	B	1.3	2.7	1048
	C	8.5	3.2	852
	D	60.5	5.0	637
	E	9.7	4.4	627
	F	20.0	0.0	261
SPRING	A	0.9	2.2	1889
	B	5.4	3.2	1626
	C	15.7	4.4	1587
	D	47.2	5.5	1060
	E	7.2	3.2	708
	F	23.6	0.0	219
SUMMER	A	2.4	2.2	1851
	B	10.9	3.2	1744
	C	20.6	3.2	1736
	D	30.8	3.2	1167
	E	6.7	2.7	861
	F	28.6	0.0	329
FALL	A	0.6	0.0	1511
	B	6.8	2.7	1312
	C	15.4	3.9	1312
	D	38.3	3.9	789
	E	7.0	3.2	589
	F	31.8	0.0	168

Fort Ord

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.1	0.0	938
	B	4.2	1.7	604
	C	12.4	2.2	571
	D	46.3	4.4	508
	E	11.9	3.9	804
	F	25.1	1.7	178
SPRING	A	0.5	2.2	1106
	B	6.6	2.7	849
	C	9.8	5.0	680
	D	61.2	6.5	976
	E	11.1	4.4	896
	F	10.8	2.2	431
SUMMER	A	0.5	2.2	645
	B	6.2	3.2	598
	C	17.2	7.1	554
	D	58.2	6.5	737
	E	11.9	4.4	588
	F	6.0	2.7	429
FALL	A	0.1	0.0	836
	B	7.5	2.2	666
	C	10.5	2.7	630
	D	49.8	5.5	692
	E	12.8	4.4	843
	F	19.3	1.7	242

Fort Polk

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.5	0.3	812
	B	8.3	1.7	817
	C	15.6	2.2	701
	D	44.3	2.7	490
	E	4.5	2.7	527
	F	26.8	0.6	247
SPRING	A	3.1	1.1	1436
	B	12.2	2.2	1182
	C	17.3	2.7	1181
	D	39.6	3.2	720
	E	4.1	2.7	583
	F	23.7	0.6	338
SUMMER	A	10.6	1.1	1609
	B	22.8	1.7	1454
	C	19.4	1.7	1352
	D	12.9	2.7	509
	E	1.9	2.7	539
	F	32.4	0.0	434
FALL	A	2.4	0.6	1391
	B	16.1	1.7	1111
	C	18.1	2.2	968
	D	26.0	2.7	717
	E	3.5	2.7	492
	F	33.8	0.0	216

Fort Sill

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	0.1	0.0	1206
	B	2.4	1.1	945
	C	8.8	2.7	897
	D	54.4	6.0	713
	E	9.2	3.9	720
	F	25.0	1.1	288
SPRING	A	1.1	1.1	1798
	B	6.0	2.7	1437
	C	13.1	4.4	1480
	D	51.6	6.5	1038
	E	8.1	3.9	755
	F	20.1	1.1	387
SUMMER	A	2.8	2.2	2121
	B	11.6	3.2	2160
	C	21.5	4.4	1980
	D	30.2	5.5	1509
	E	12.3	4.4	637
	F	21.7	1.7	358
FALL	A	0.4	0.6	1838
	B	5.5	2.2	1560
	C	12.3	3.9	1746
	D	45.5	6.0	973
	E	10.1	4.4	699
	F	26.3	1.1	331

Howard AFB

	Pasquill Stability Category	Percent Frequency of Occurrence	Median Wind Speed (m/sec)	Median Mixing Depth (m)
WINTER	A	18	0.0	1659
	B	6.8	2.7	1240
	C	18.6	4.4	1586
	D	25.2	5.5	1427
	E	20.1	4.4	987
	F	27.5	2.2	970
SPRING	A	5.0	0.0	1287
	B	9.7	3.2	1251
	C	16.9	5.0	1640
	D	23.7	5.5	1445
	E	16.7	4.4	1062
	F	28.0	1.7	1027
SUMMER	A	8.8	1.1	1035
	B	16.1	2.7	951
	C	14.7	2.7	1017
	D	15.8	3.9	712
	E	8.2	3.2	976
	F	36.4	0.0	967
FALL	A	7.1	0.0	1065
	B	14.9	2.2	1028
	C	14.9	2.7	1046
	D	15.4	3.2	620
	E	7.0	3.2	1055
	F	40.5	0.0	925

Height of Mixing Layer

Season	Stability	AAD	DPG	EWA	JHI	LBG	NAP	PBA	PAD	RMA	UAD	EUR
WIN	A	820	540	780	2000	740	430	780	1020	1020	370	700
	B	820	540	780	2000	740	430	780	1020	1020	370	700
	C	710	377	750	2000	785	440	705	550	550	345	450
	D	600	215	720	2000	790	450	630	85	85	320	200
	E	420	100	530	1250	640	320	520	85	85	290	150
	F	170	50	180	500	430	130	160	85	85	280	100
SPR	A	1500	2310	1720	2000	1500	1170	1480	2780	2780	170	1200
	B	1500	2310	1720	2000	1500	1170	1480	2780	2780	1900	1200
	C	1060	1277	1285	2000	1215	840	1065	1480	1480	1160	750
	D	620	245	850	2000	930	510	670	185	185	420	300
	E	360	150	470	1250	560	320	510	185	185	220	200
	F	170	100	140	500	340	120	160	185	185	200	150
SUM	A	1670	3625	1970	2000	1530	1440	1770	3290	3290	2455	1500
	B	1670	3625	1970	2000	1530	1440	1770	3290	3290	2455	1500
	C	1080	1892	1245	2000	1005	895	1220	1785	1785	1427	1000
	D	490	200	525	2000	480	350	670	180	180	400	500
	E	440	100	360	1250	340	250	550	180	180	145	300
	F	310	80	210	500	250	140	220	180	180	130	200
FAL	A	1340	1470	1300	2000	1230	990	1270	2010	2010	1145	1000
	B	1340	1470	1300	2000	1230	990	1270	2010	2010	1145	1000
	C	945	845	925	2000	975	715	975	1050	1050	667	650
	D	550	220	550	2000	720	440	680	95	95	190	300
	E	380	100	400	1250	470	280	550	95	95	135	200
	F	160	80	130	500	280	100	140	95	95	115	150

AAD - Anniston Army Depot; DPG - Dugway Proving Ground and Tooele Army Depot; EWA - Edgewood Area;
 JHI - Johnston Island; LBG - Lexington - Blue Grass Army Depot; NAP - Newport Ammunition Plant;
 PBA - Pine Bluff Arsenal; PAD - Pueblo Army Depot; RMA - Rocky Mountain Arsenal; UAD - Umatilla Army Depot;
 EUR - USAEUR

APPENDIX C: DISTANCE TO INTERIM THRESHOLD VALUES (ITV)
FOR MUNITIONS UNDER VARIED METEOROLOGICAL CONDITIONS

Charts showing distances to hazardous concentrations of smokes have been derived for a variety of munitions, using the HAZRD2 model, under a variety of wind speeds and four Pasquill-Gifford stability categories with corresponding heights of mixing layers (HML): Stability A - mixing layers over 200 m, Stability C - mixing layers over 200 m, Stability D - mixing layers over 50 m, and Stability F - mixing layers over 25 m. The wind speeds used were from 1 to 10 m/s.

From these charts, a distance to an Interim Threshold Value (ITV) can be obtained. The ITV has been set as 1% of the LC₅₀ value for inhalation that was determined for these munitions by researchers (Wentzel et al., 1986b). These ITV values are comparable to the Short Term Exposure Limit (TLV-STEL) standard used by the government. Examples of LC₅₀ to STEL ratios are presented in Table C-1 (Canter, 1977; Hunt et al., 1984; Sax, 1984).

The smokes and munitions modeled using specific ITV values are presented in Table C-2. To determine the distance to the ITV, select the chart containing the munition and atmospheric stability under which the test will be

TABLE C-1. RATIOS OF STEL TO LC₅₀.

Substance	STEL(ppmv)	LC ₅₀ (ppmv)	Ratio
Ethylene	1,000	950,000	1:950
Ammonia	35	30,000	1:850
Nickel Carbonyl	0.1*	35	1:350
Phosgene	0.2	50	1:250
Hydrogen Fluoride	6	1,276	1:212
Sulfur Dioxide	5	1,000(LCLo)	1:200
Nitrogen Tetroxide	3	315	1:105
Chlorine	3	293	1:98
Fluorine	2	185	1:93
Carbon Dioxide	15,000	657,190	1:44

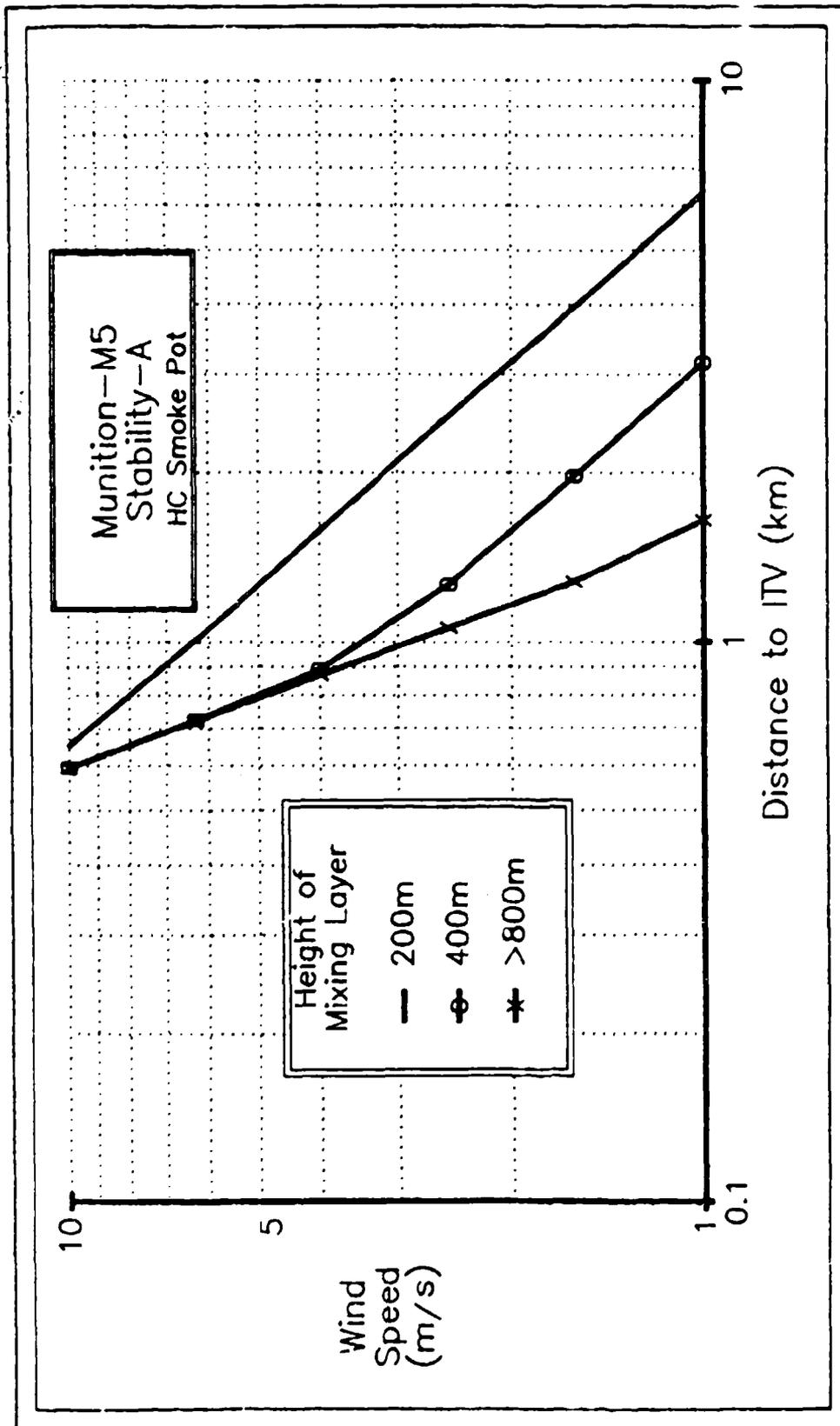
* Value interpolated from TLV standard. Ratio between TLV and STEL is generally between 1:1.5 to 1:2. The more conservative ratio of 1:2 was used for this calculation.

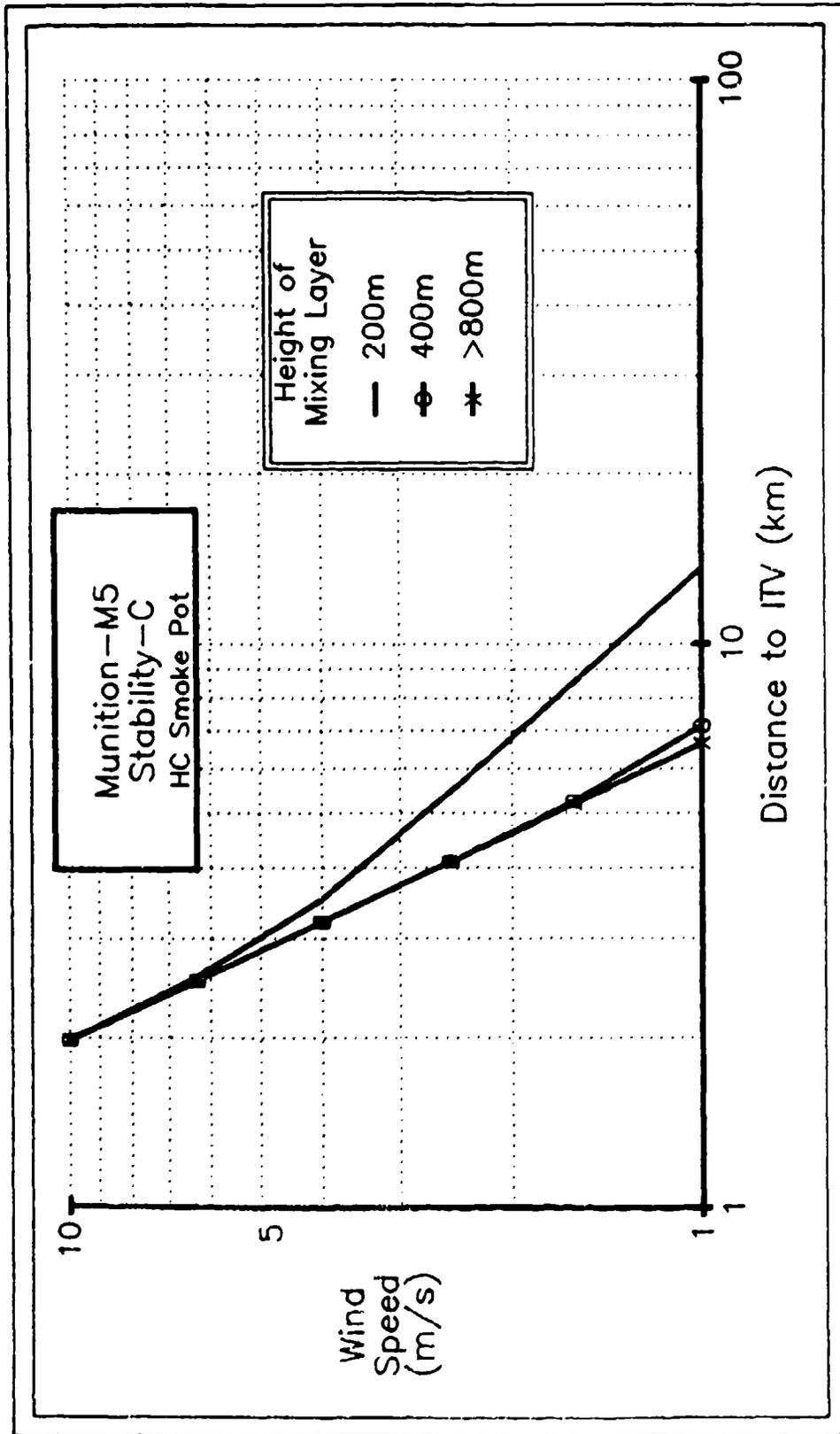
conducted. Determine the height of mixing layer from the HML table for the particular site. Find the corresponding HML line on the chart, read the wind speed on the y-axis, intersect the line and read down to the x-axis for the distance to the ITV. This shows the distance to the outer boundary of the area that needs to be controlled.

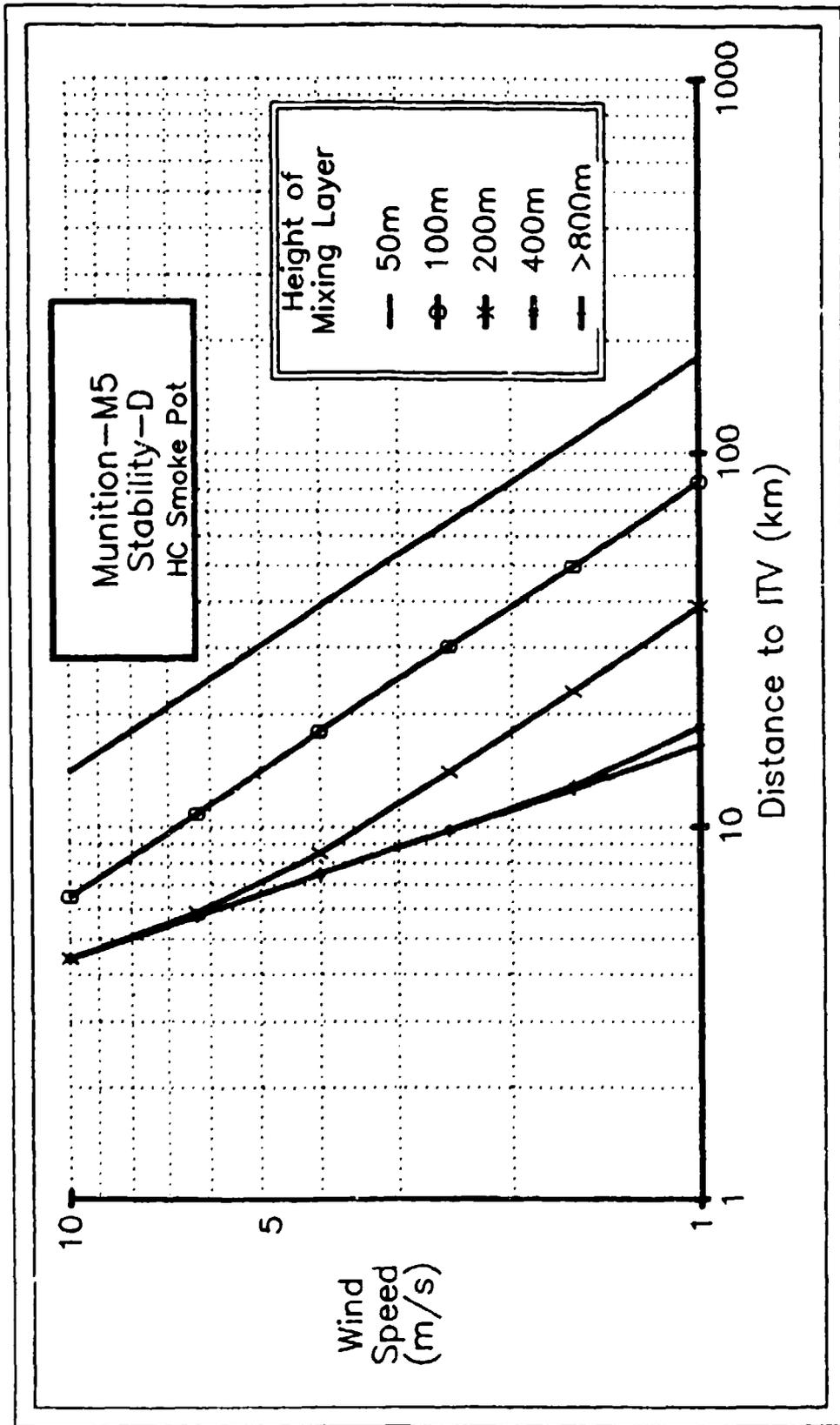
TABLE C-2. SMOKES AND MUNITIONS MODELED USING HAZRD2.

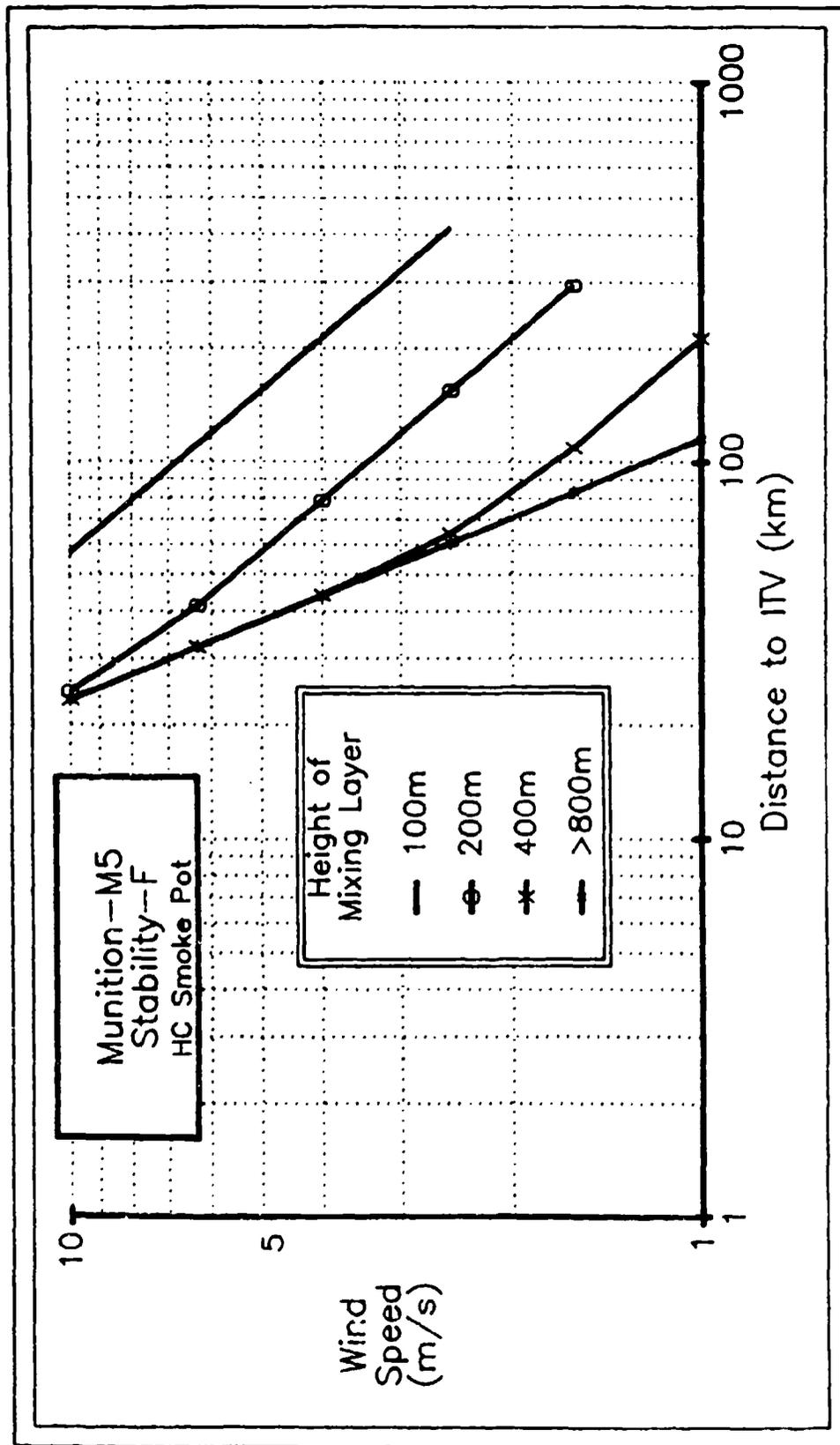
Smoke Type	ITV Value	Munition	Page number
Hexachlorocethane	3.33 mg/m ³	M5	129
		M116M1	133
		105M84	137
White phosphorus	25 mg/m ³	MK4	141
		M2	145
		M57	149
		M60	153
		M110	157
		M259	161
		M302	165
		M308	169
		M311	173
		M313	177
		M328AW	181
		M357	185
		M375	189
M416	193		
Red phosphorus	40 mg/m ³	CBU-88	197
		L8A1	201
		XM819	205
Infrared	9.7 mg/m ³	XM76	209
Fog oil	600 mg/m ³	M3A3	213
		XM52*	
		AN-M7*	
Diesel fuel	260 mg/m ³	VEESS*	

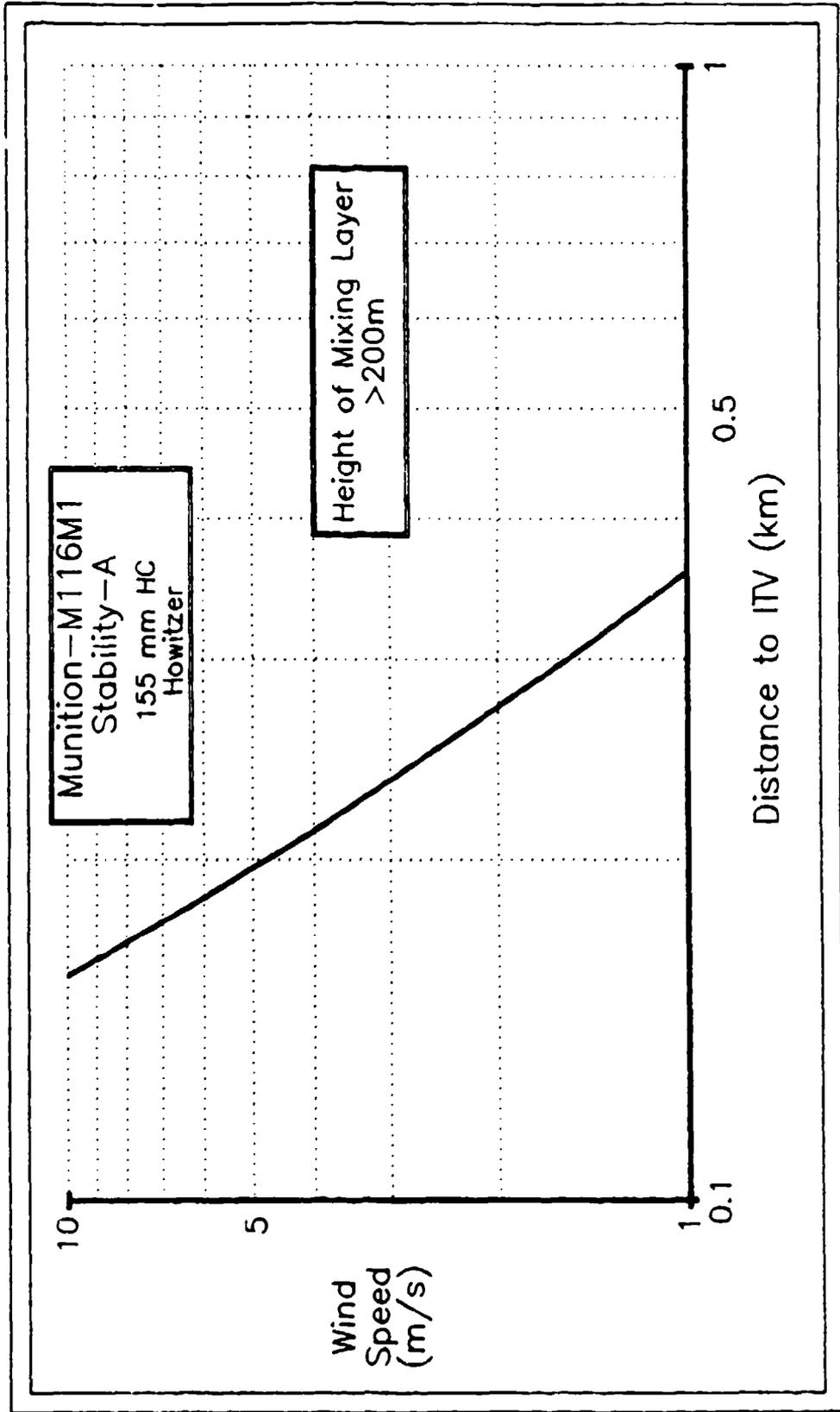
* Data on XM52, AN-M7, and VEES were not contained in the HAZRD2 computer code; therefore, they were not simulated.

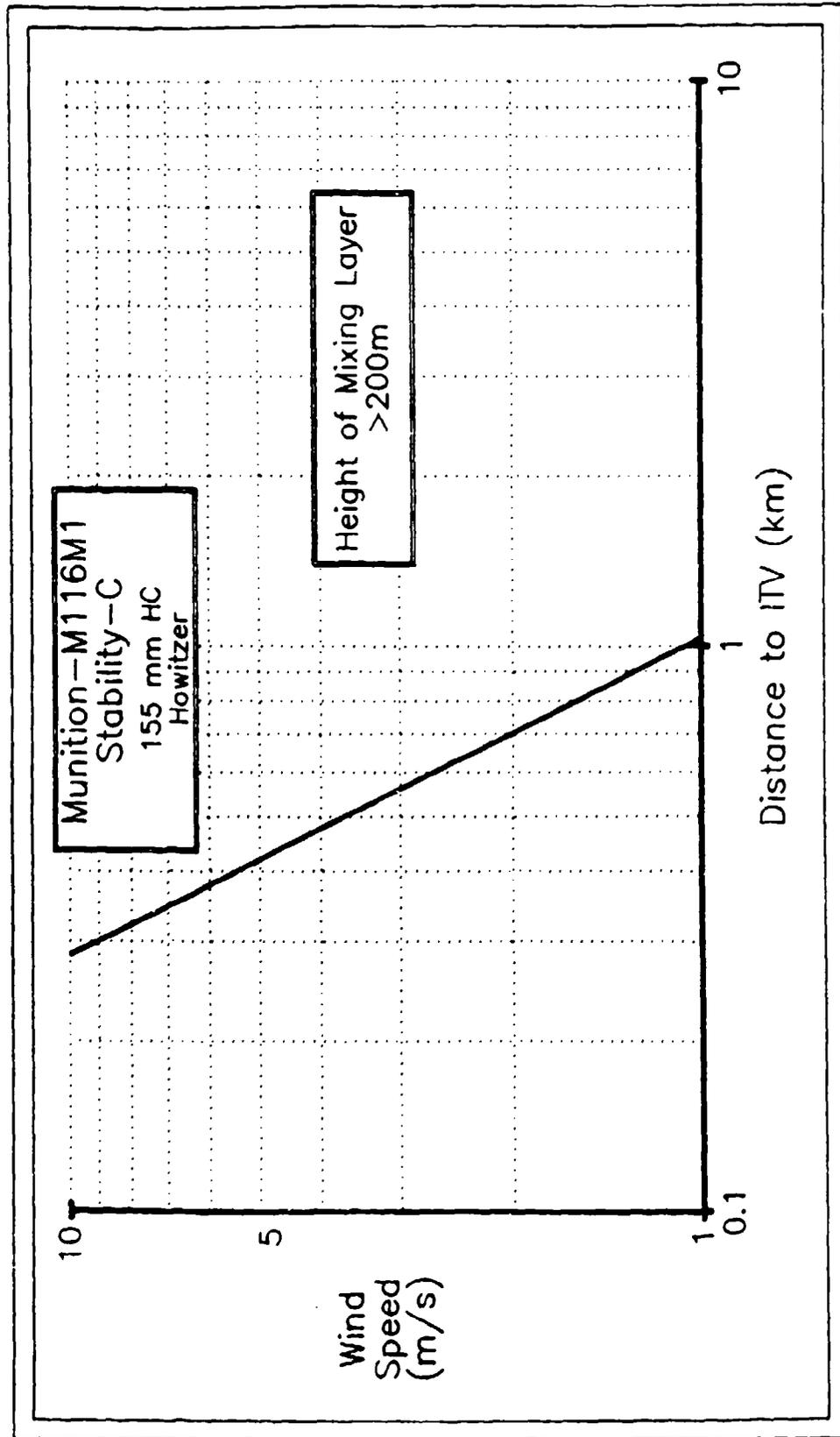


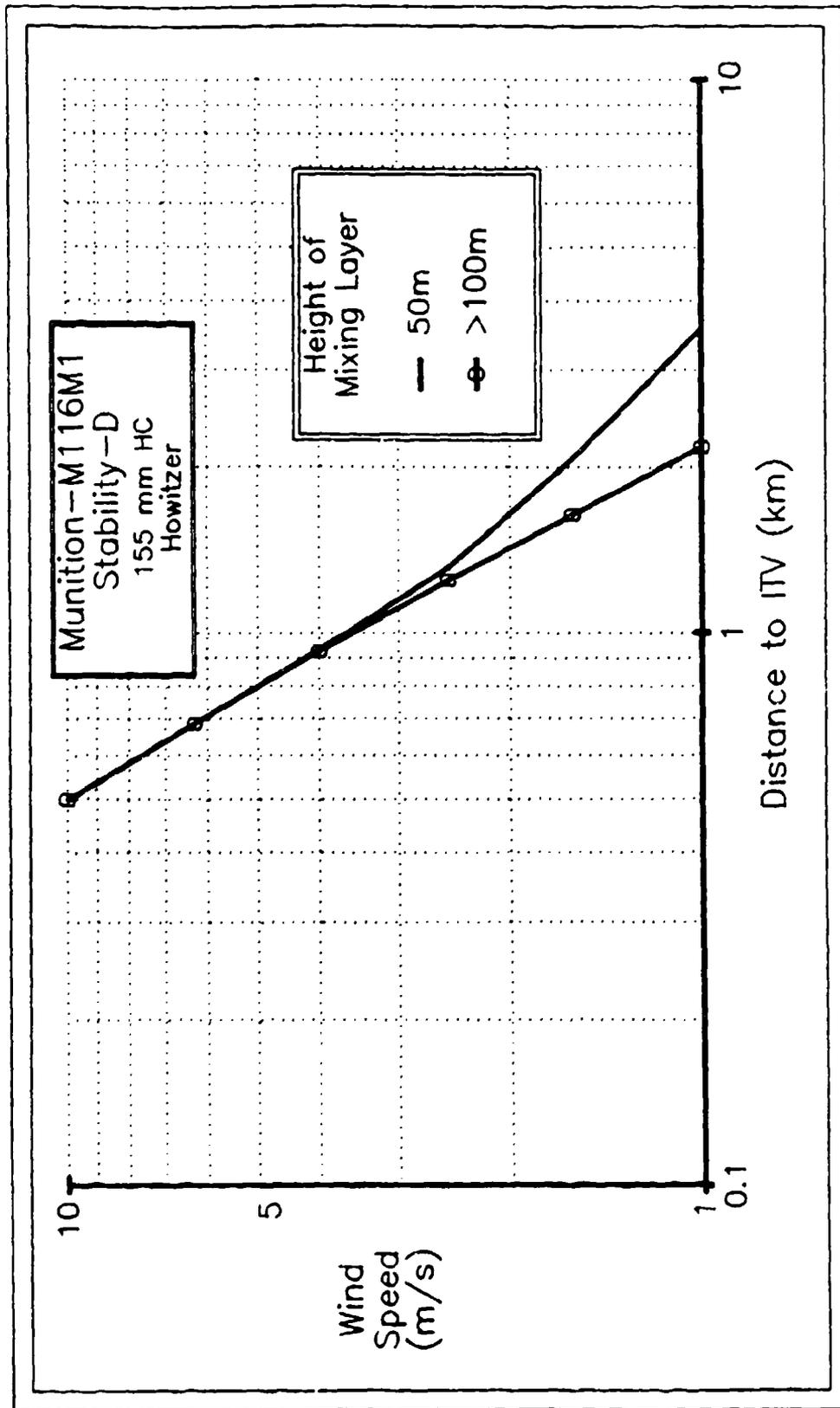


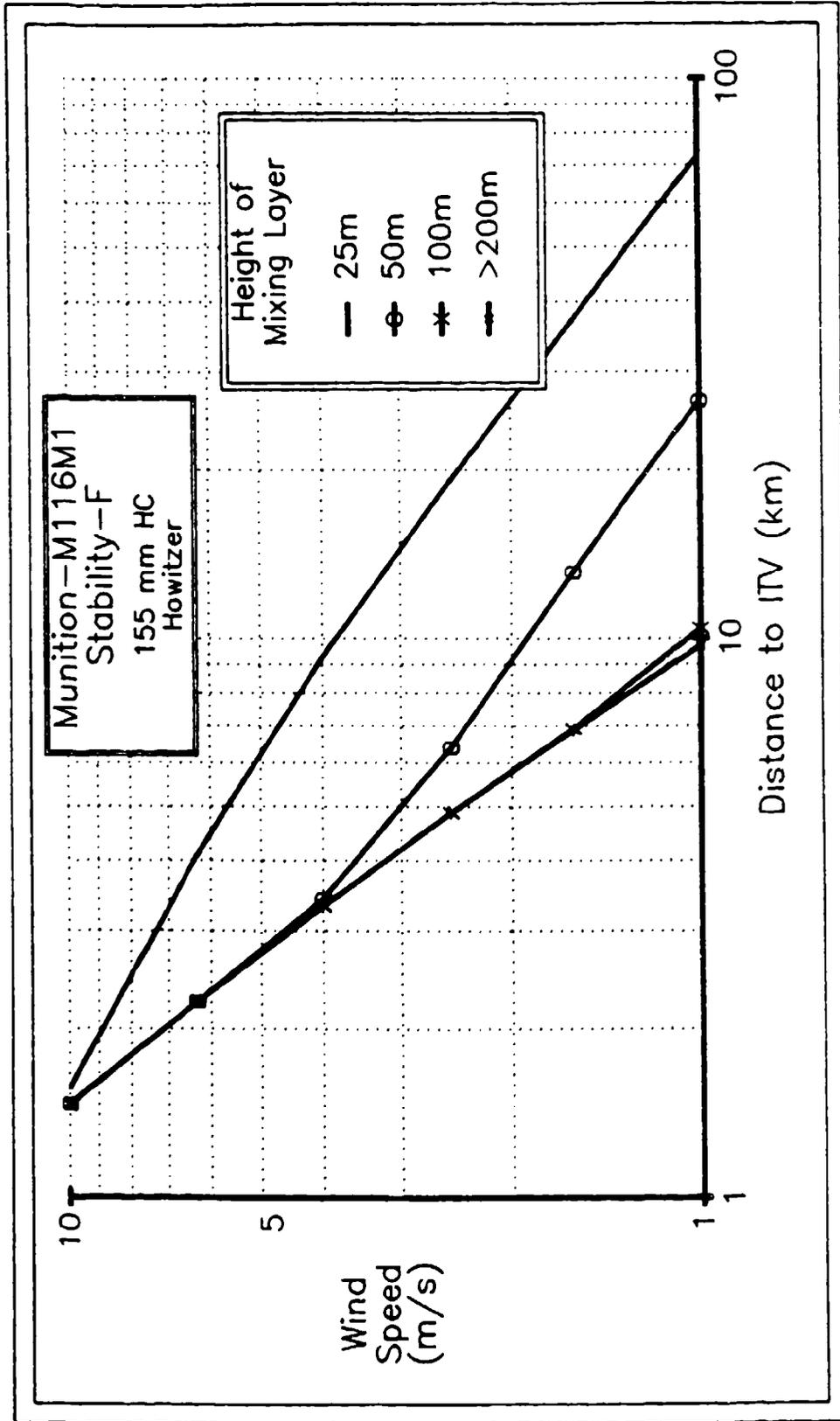


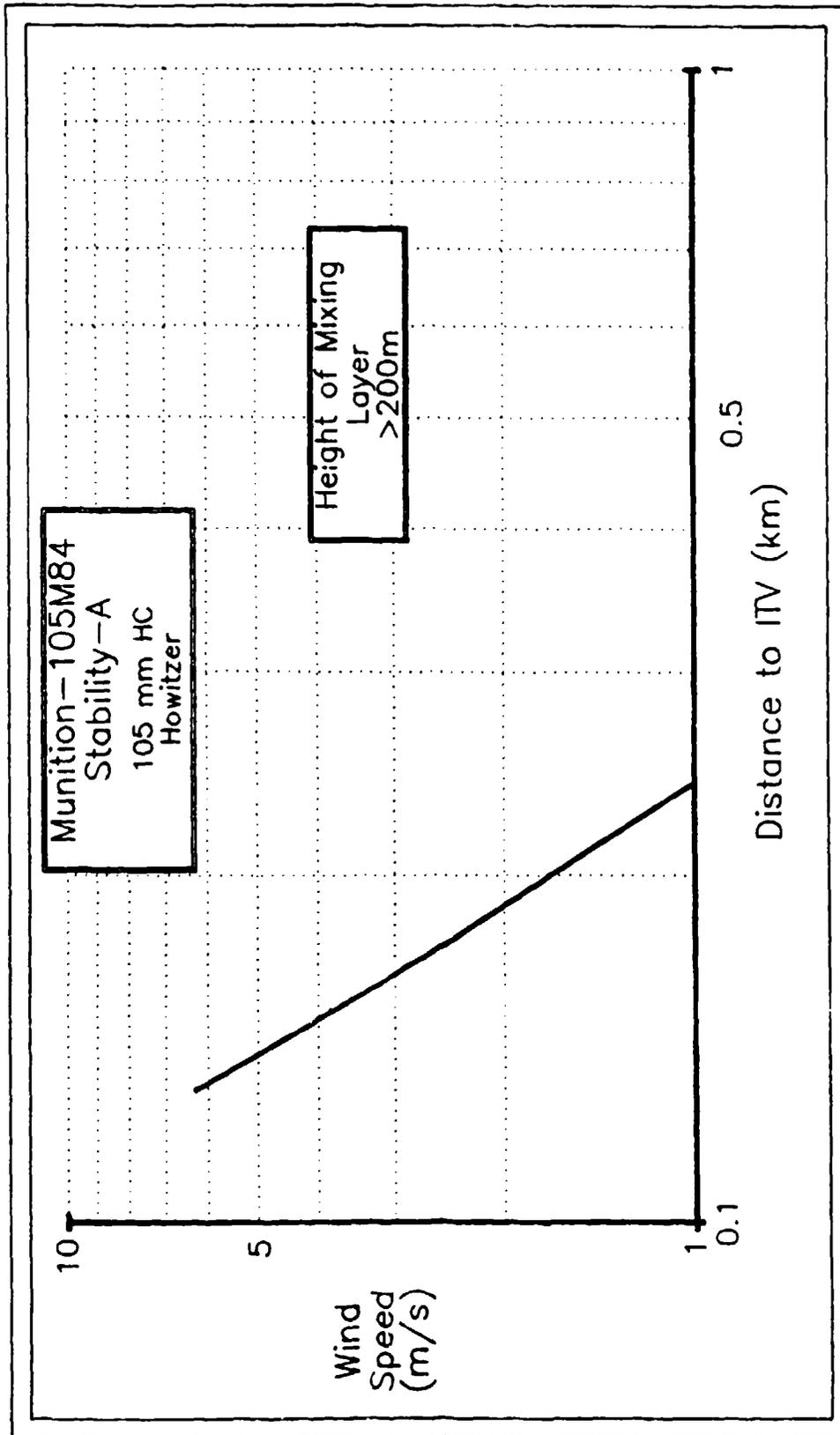


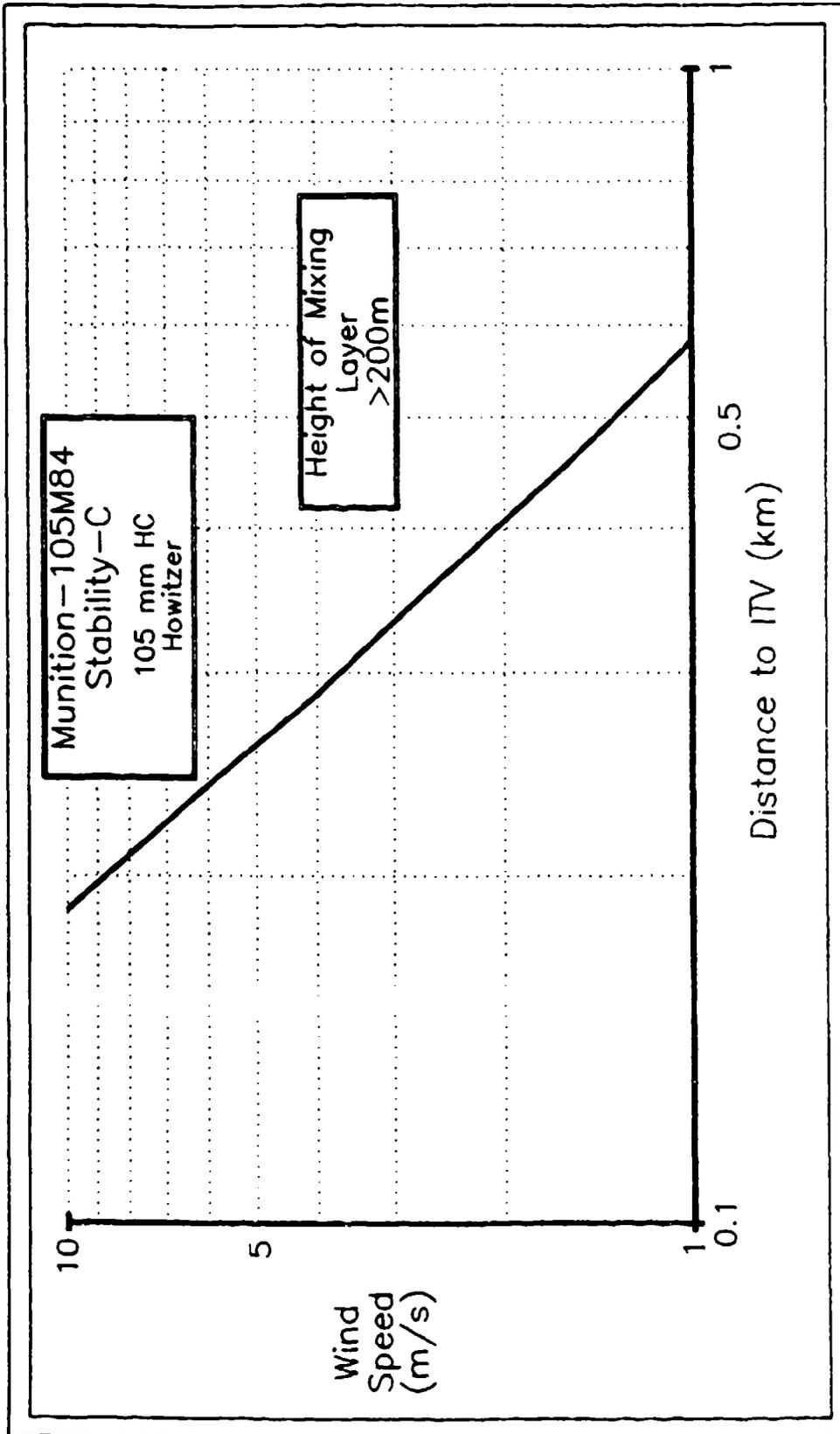


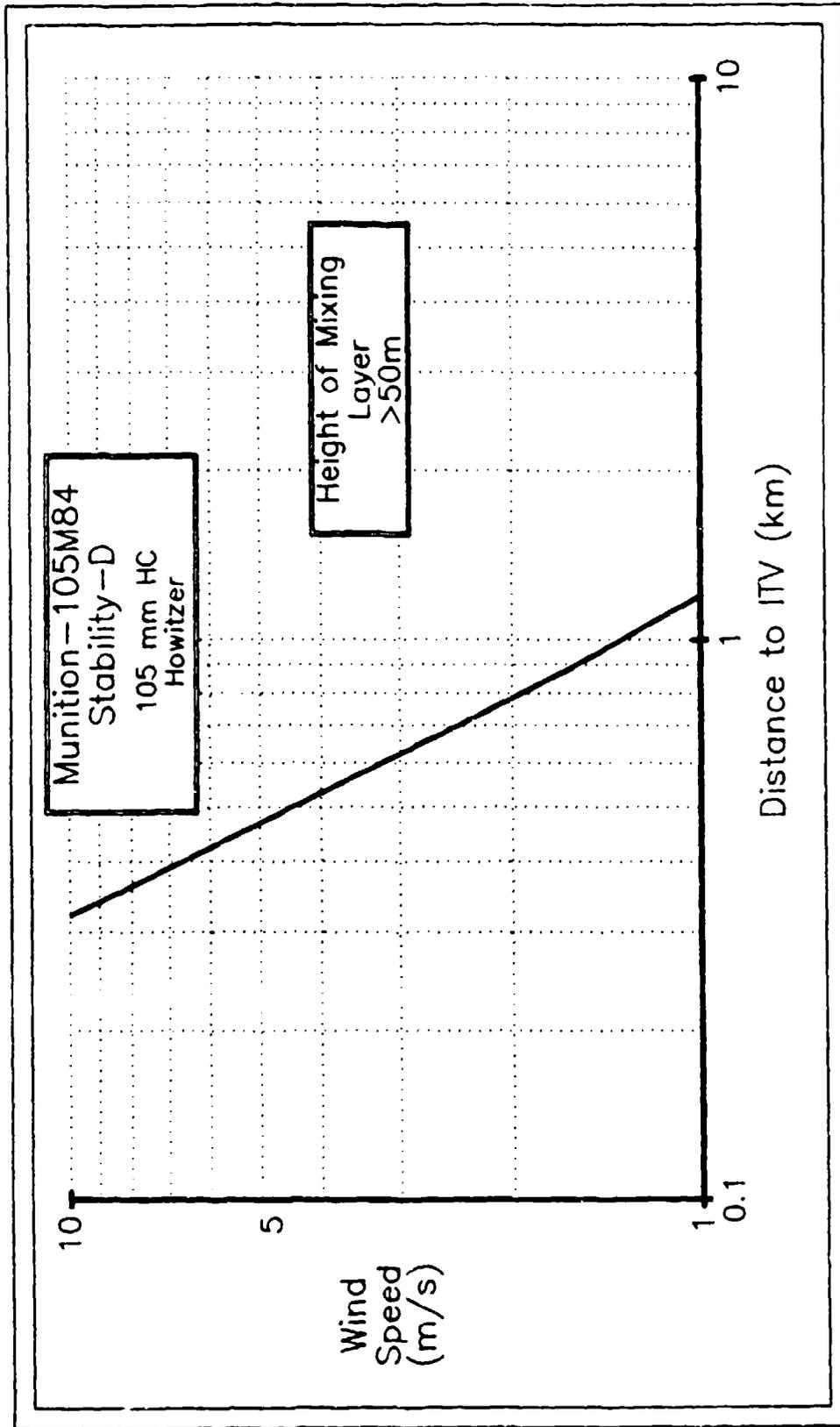


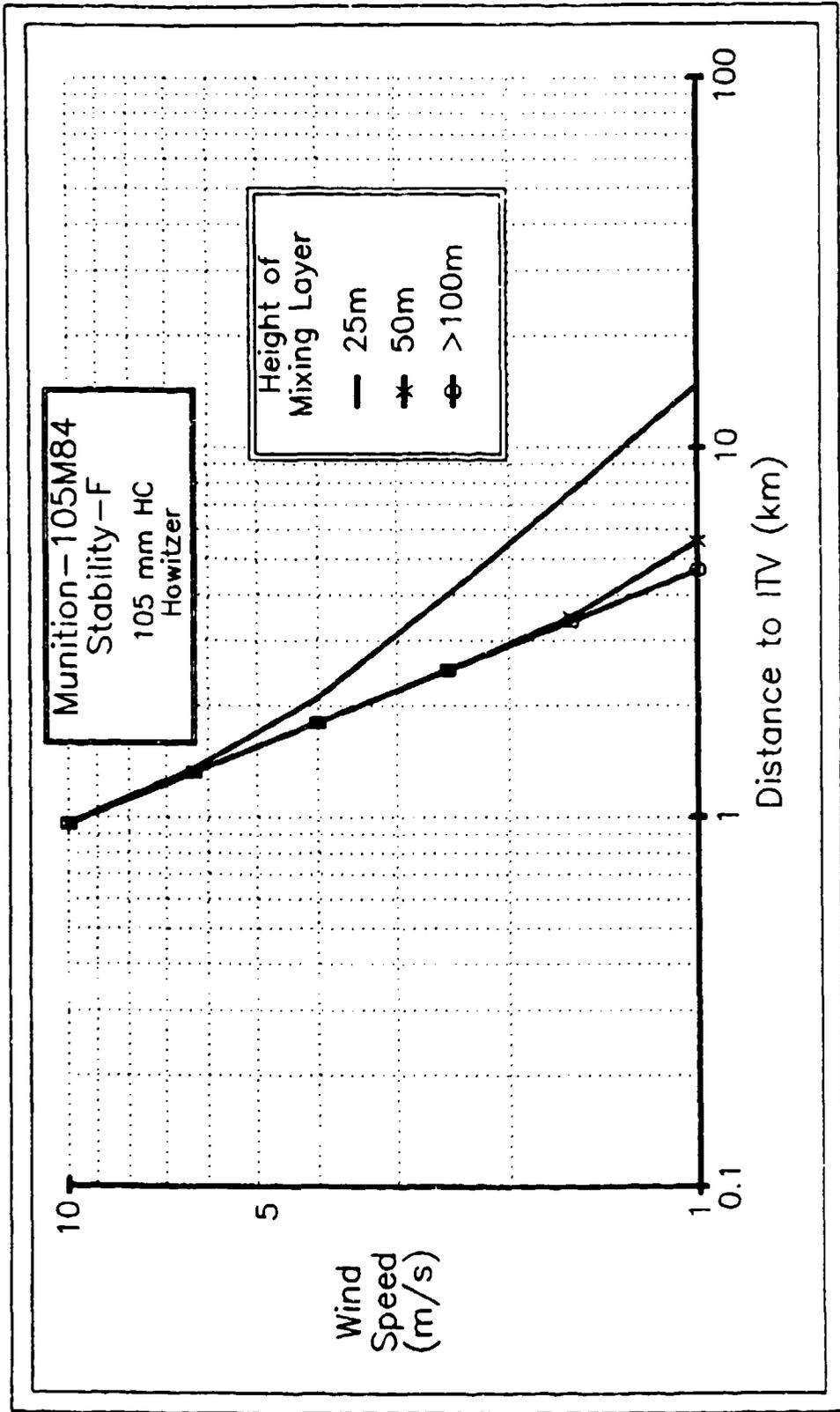


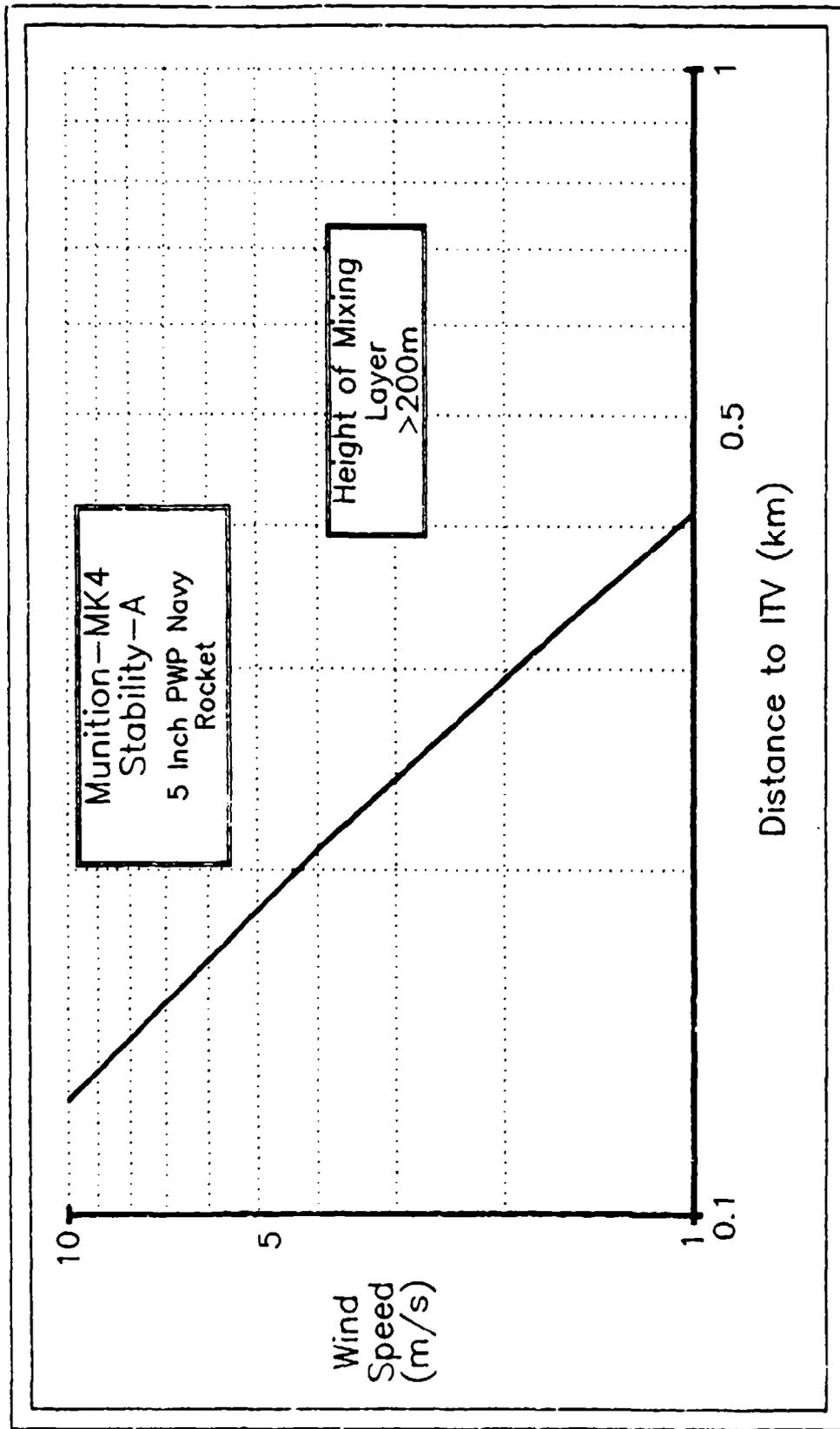


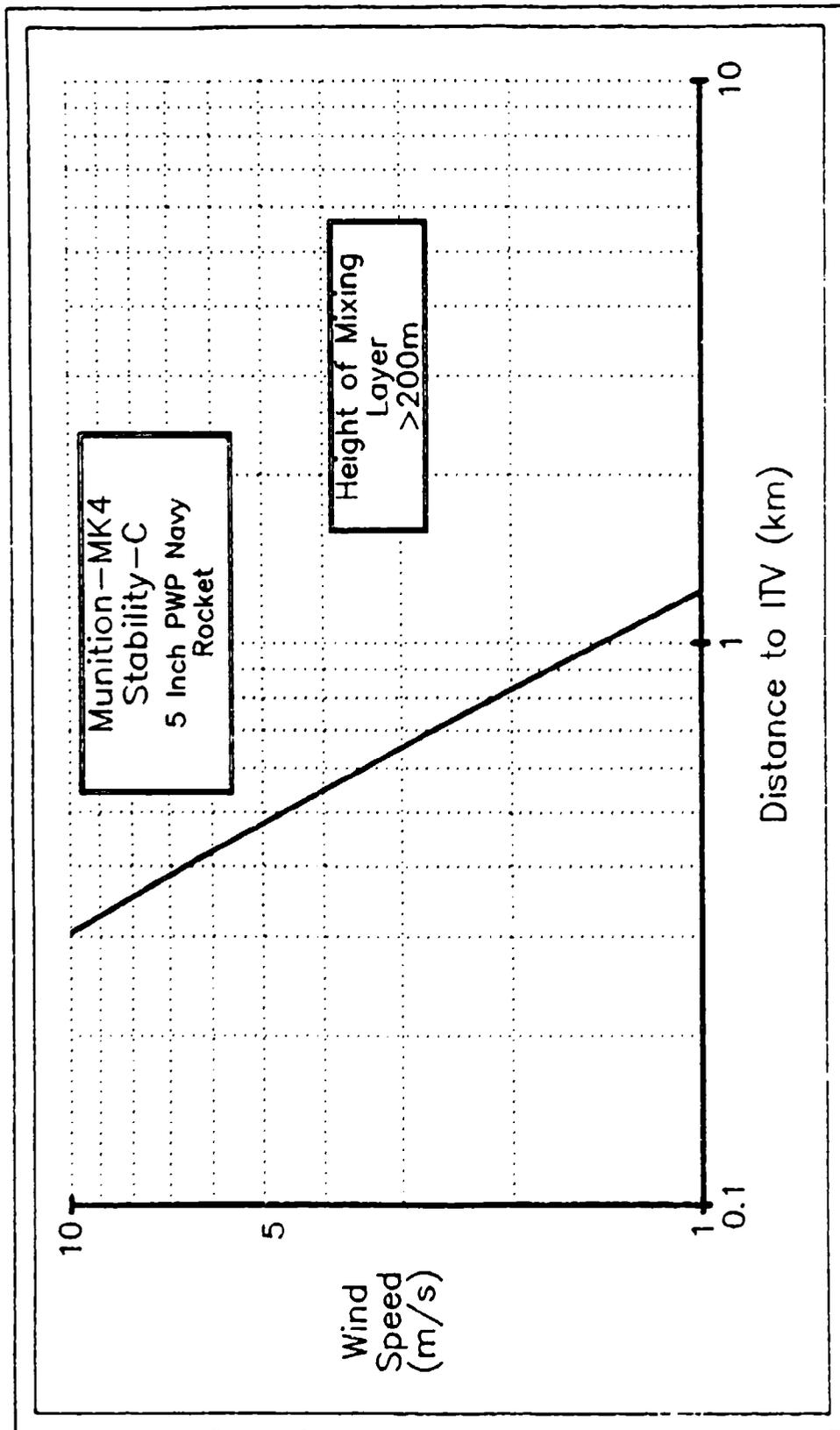


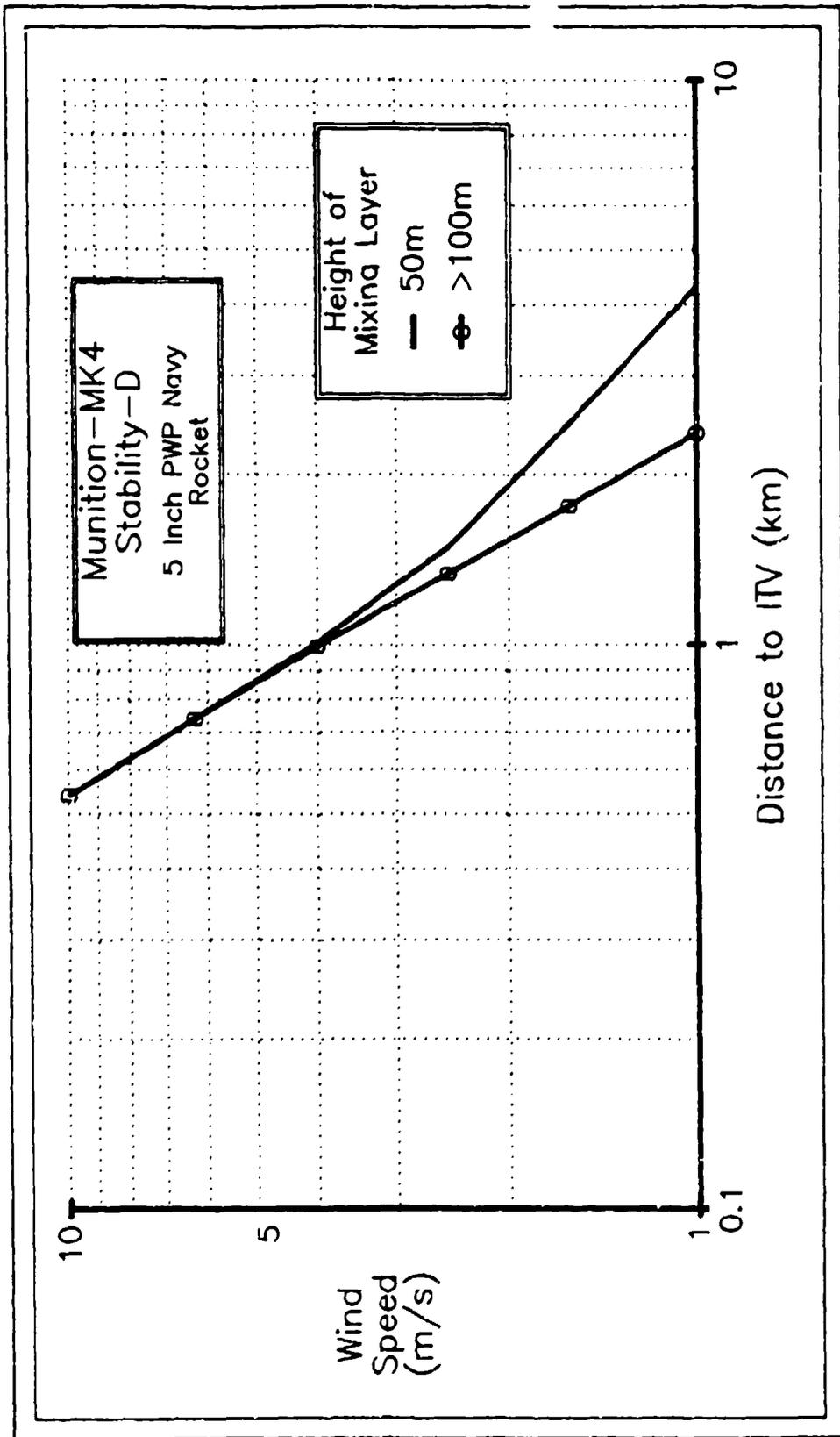


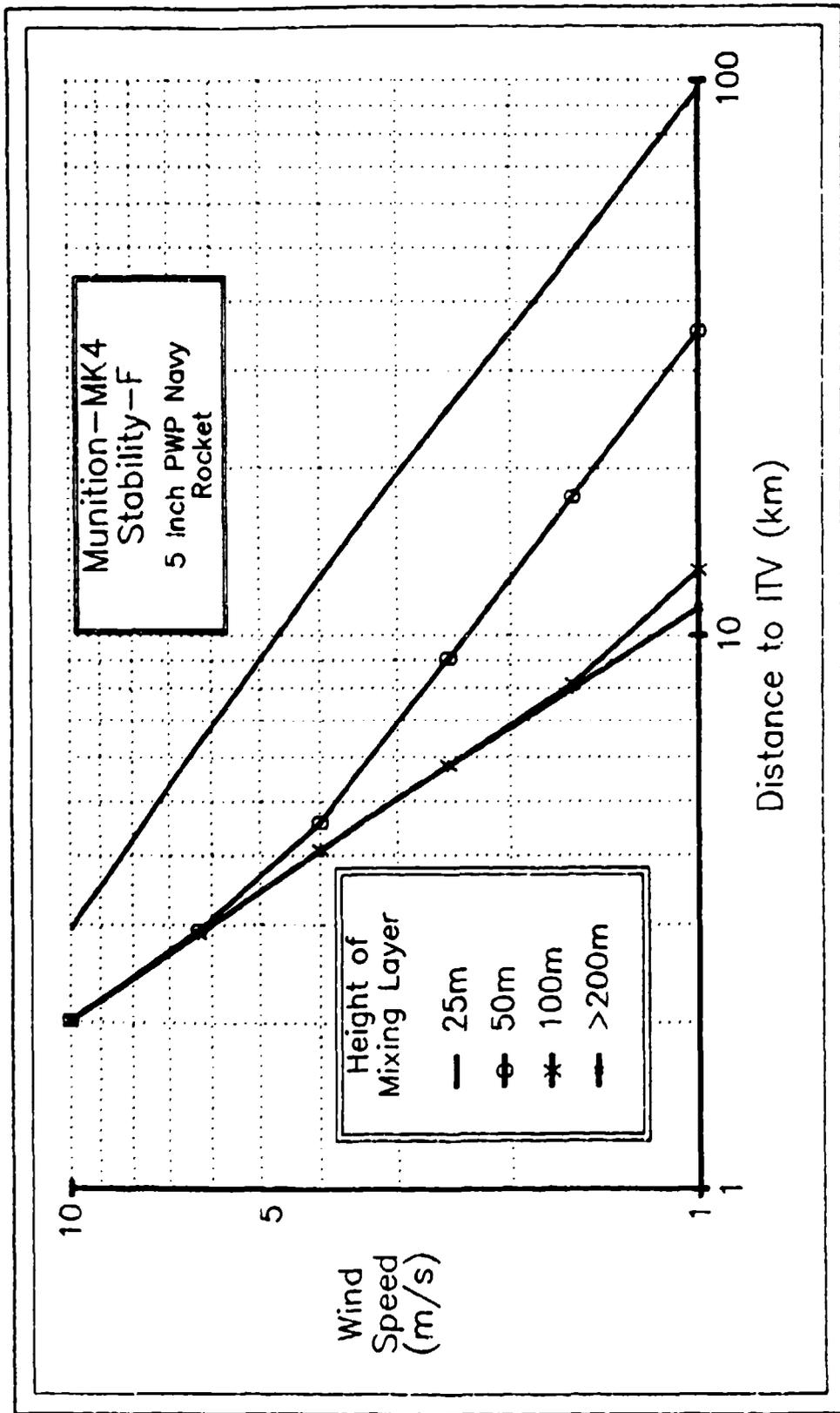


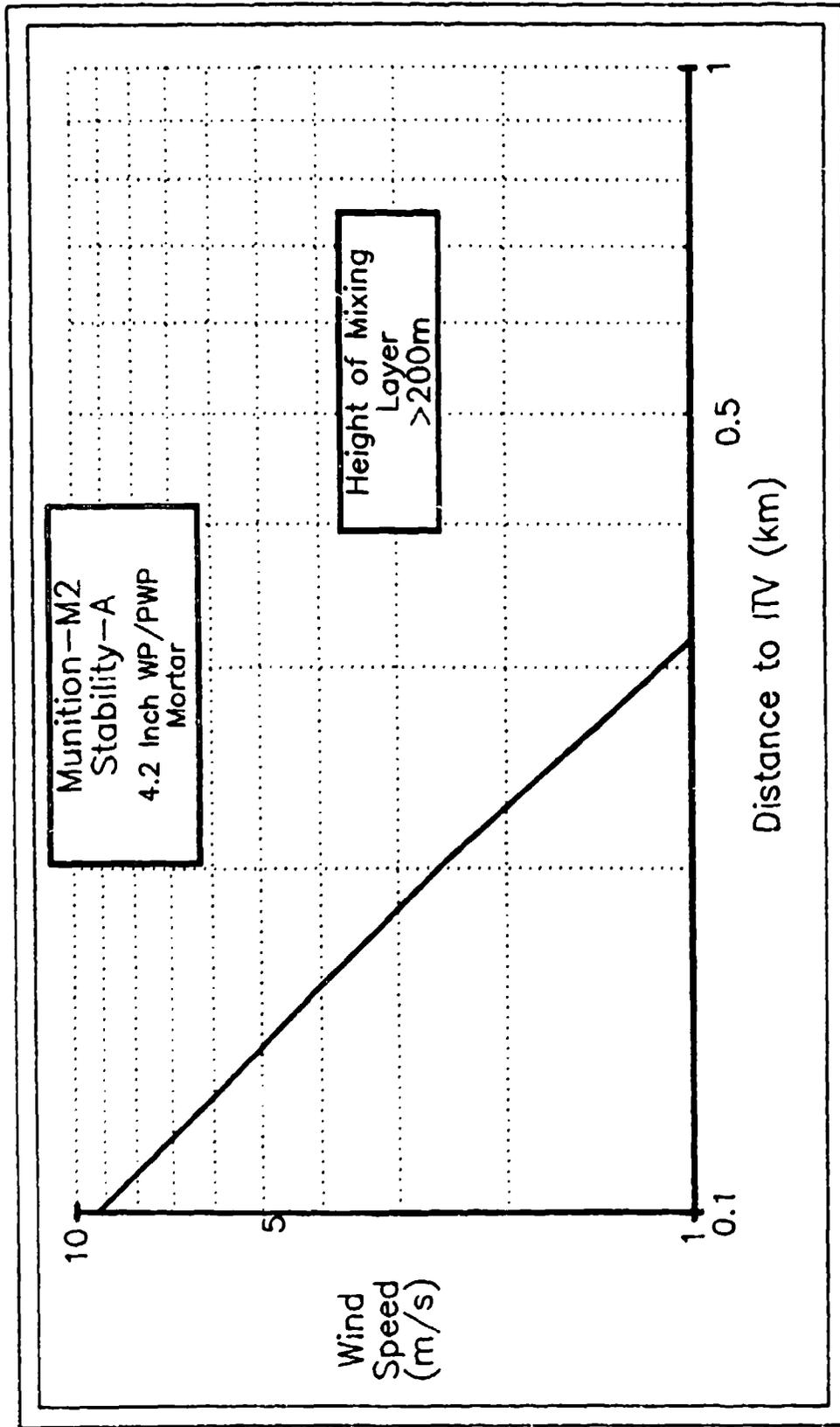


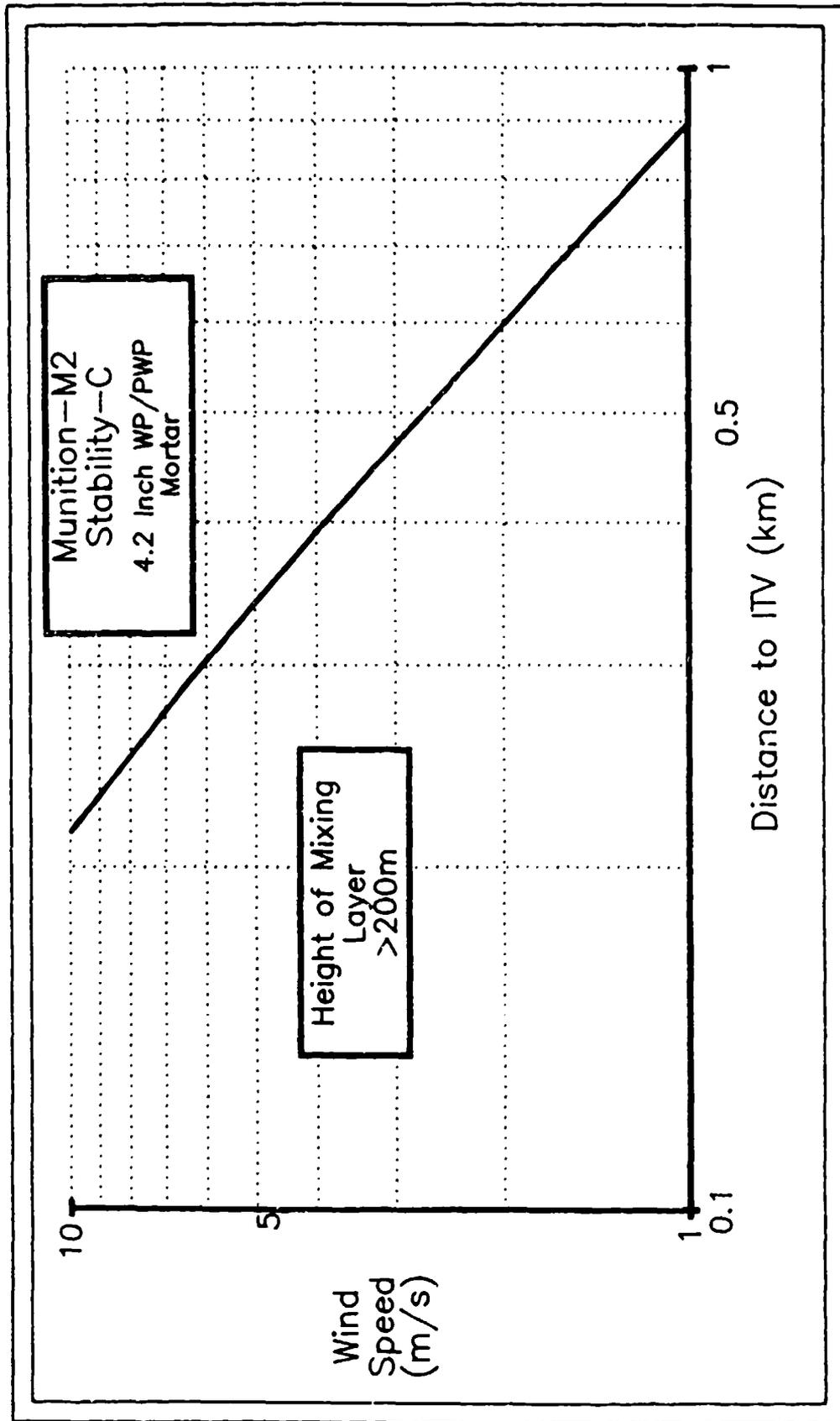


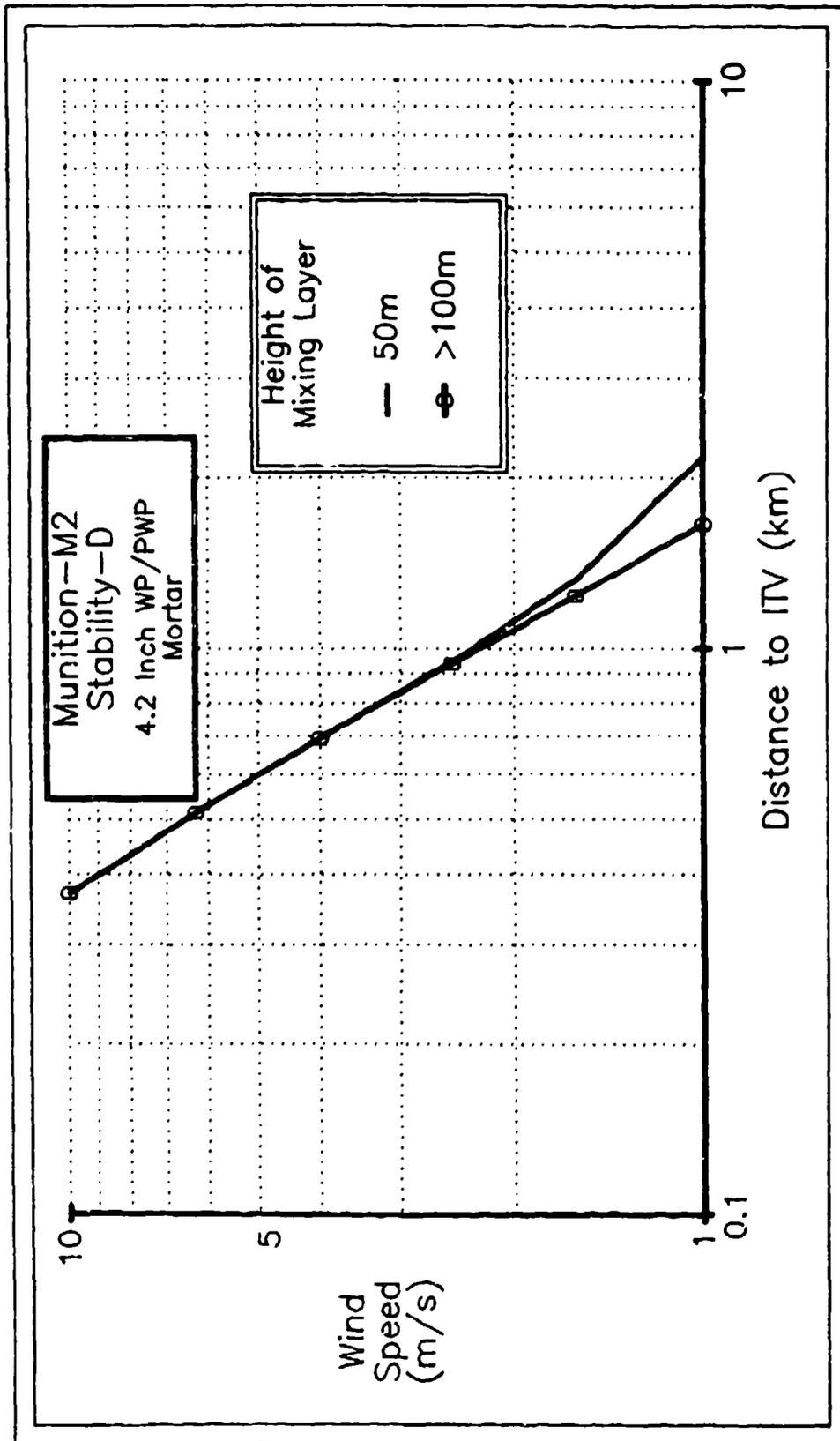


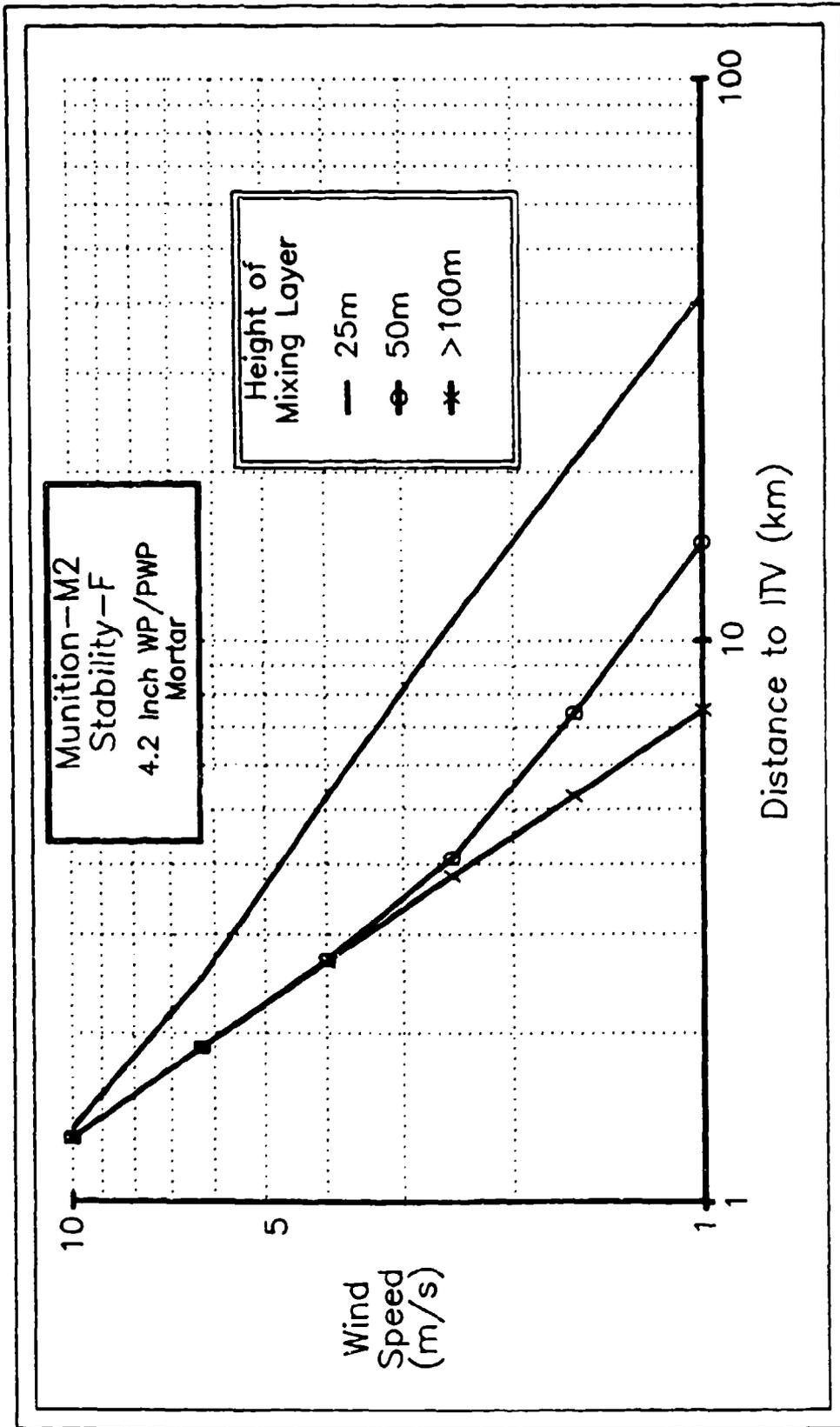


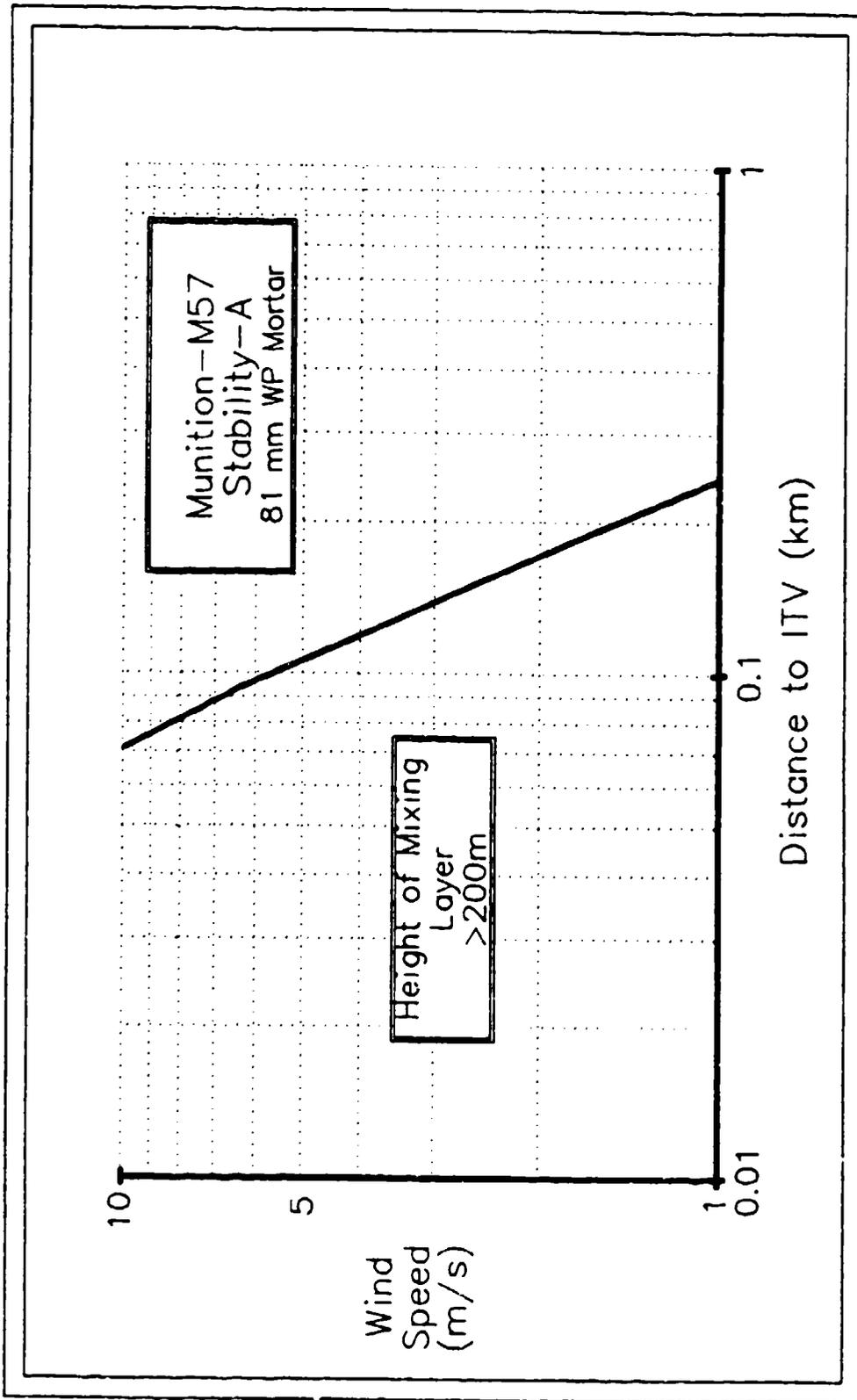


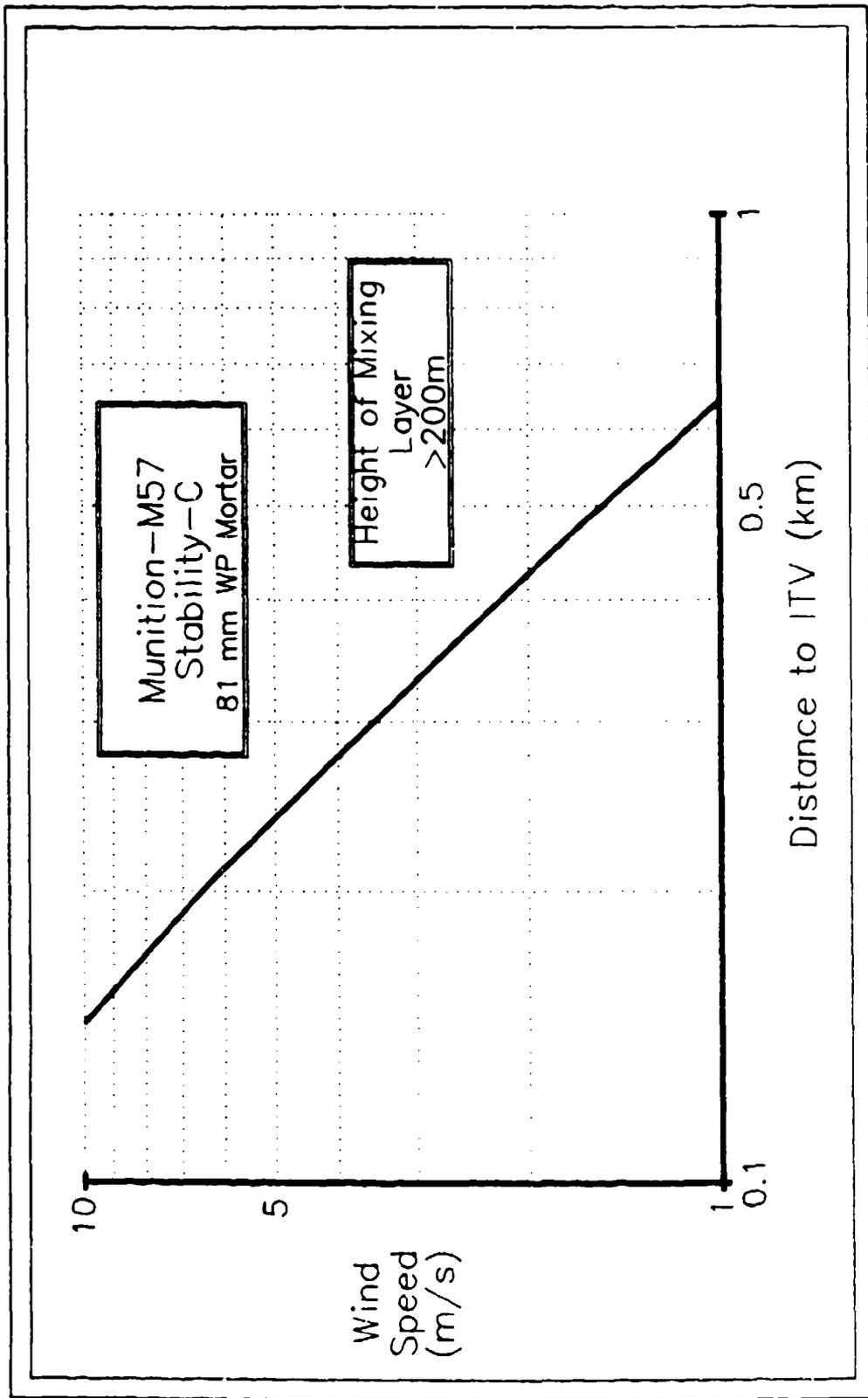


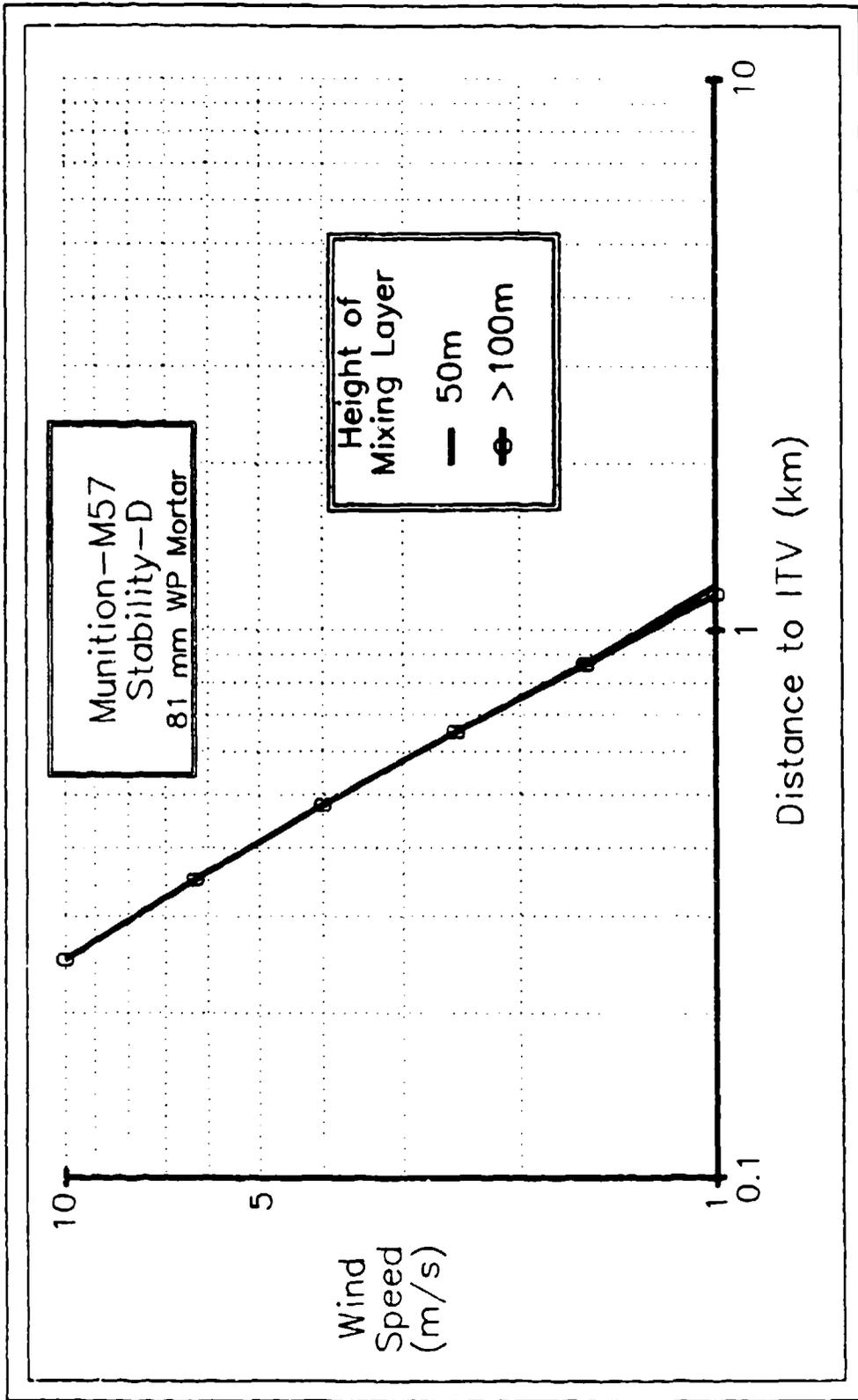


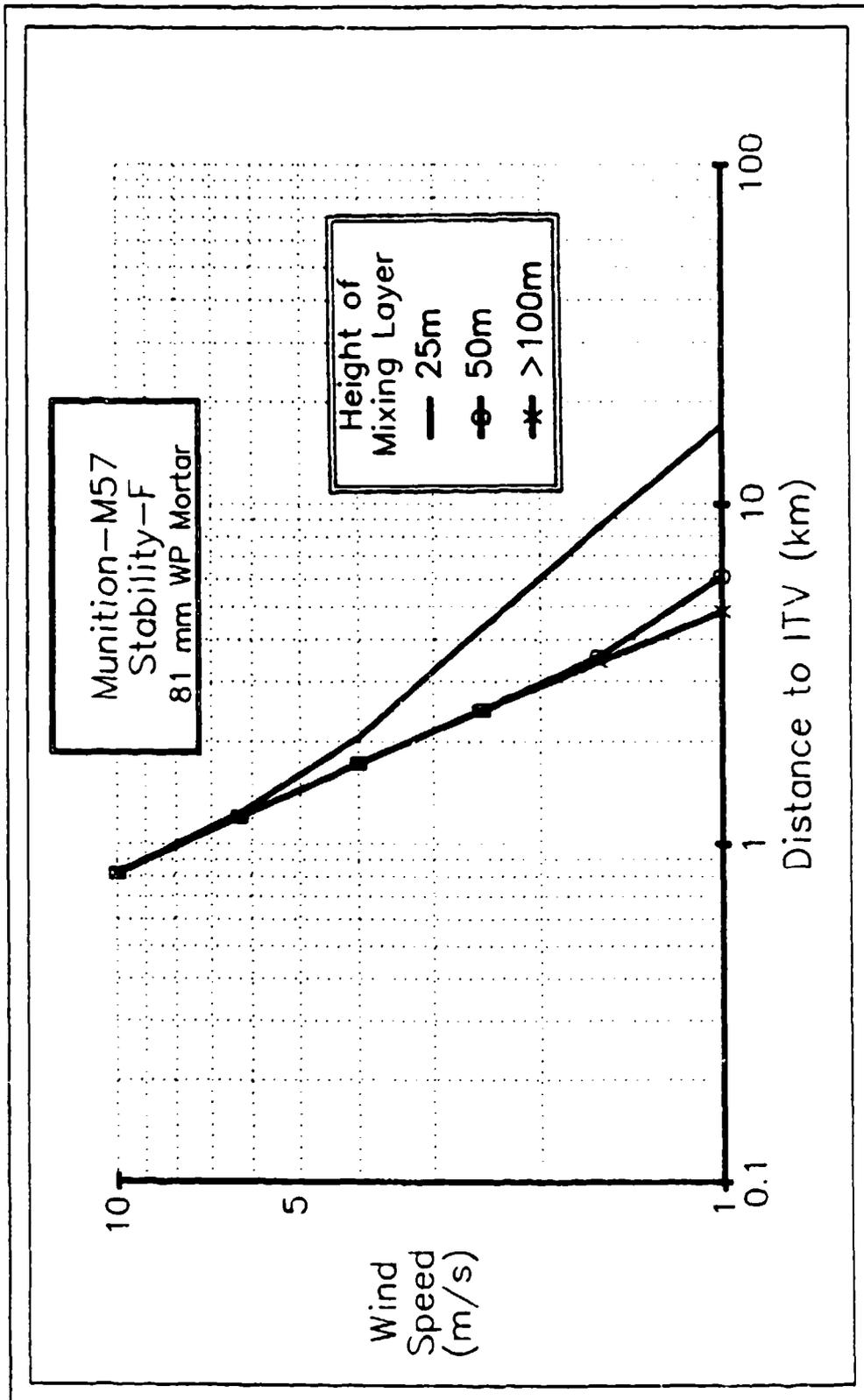


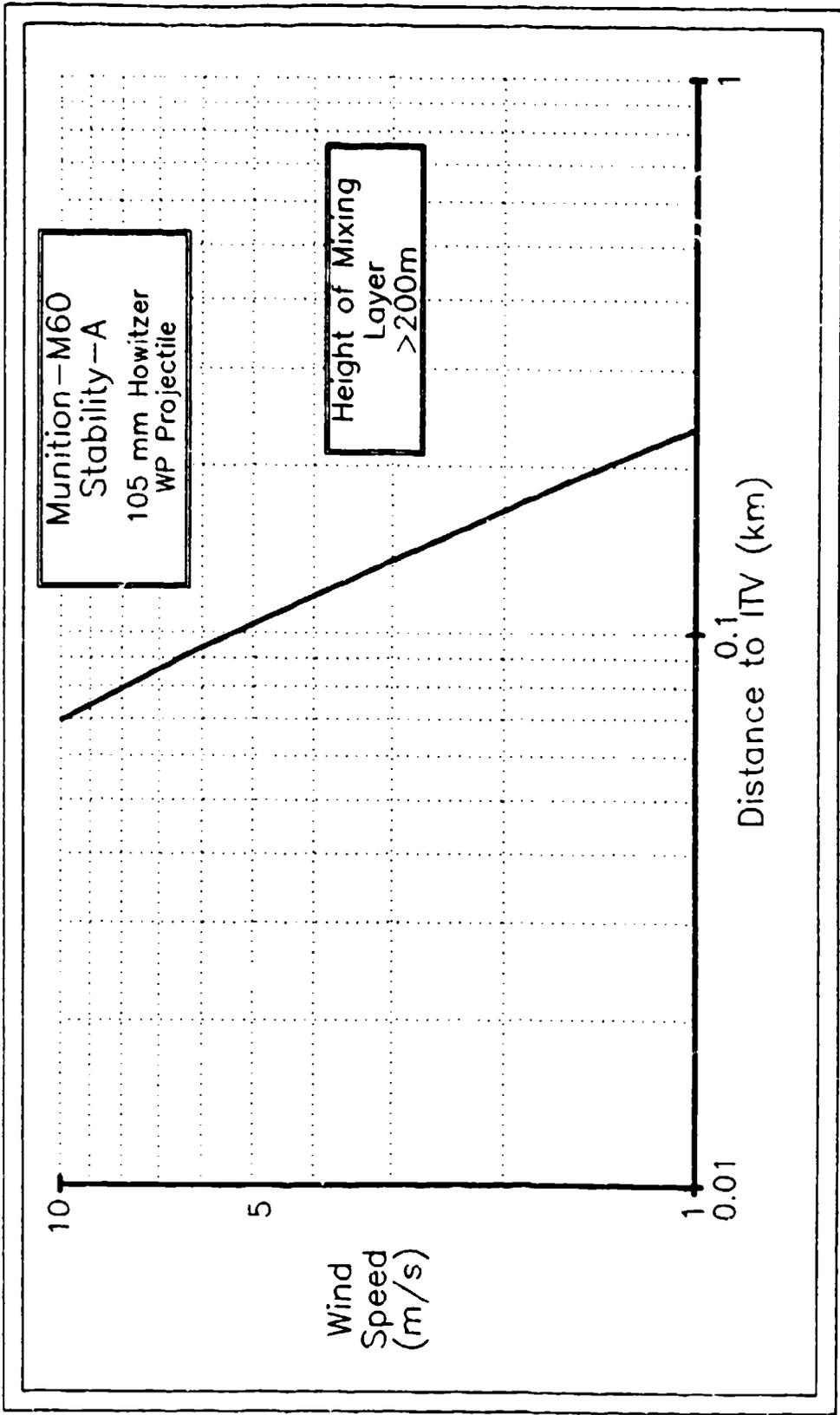


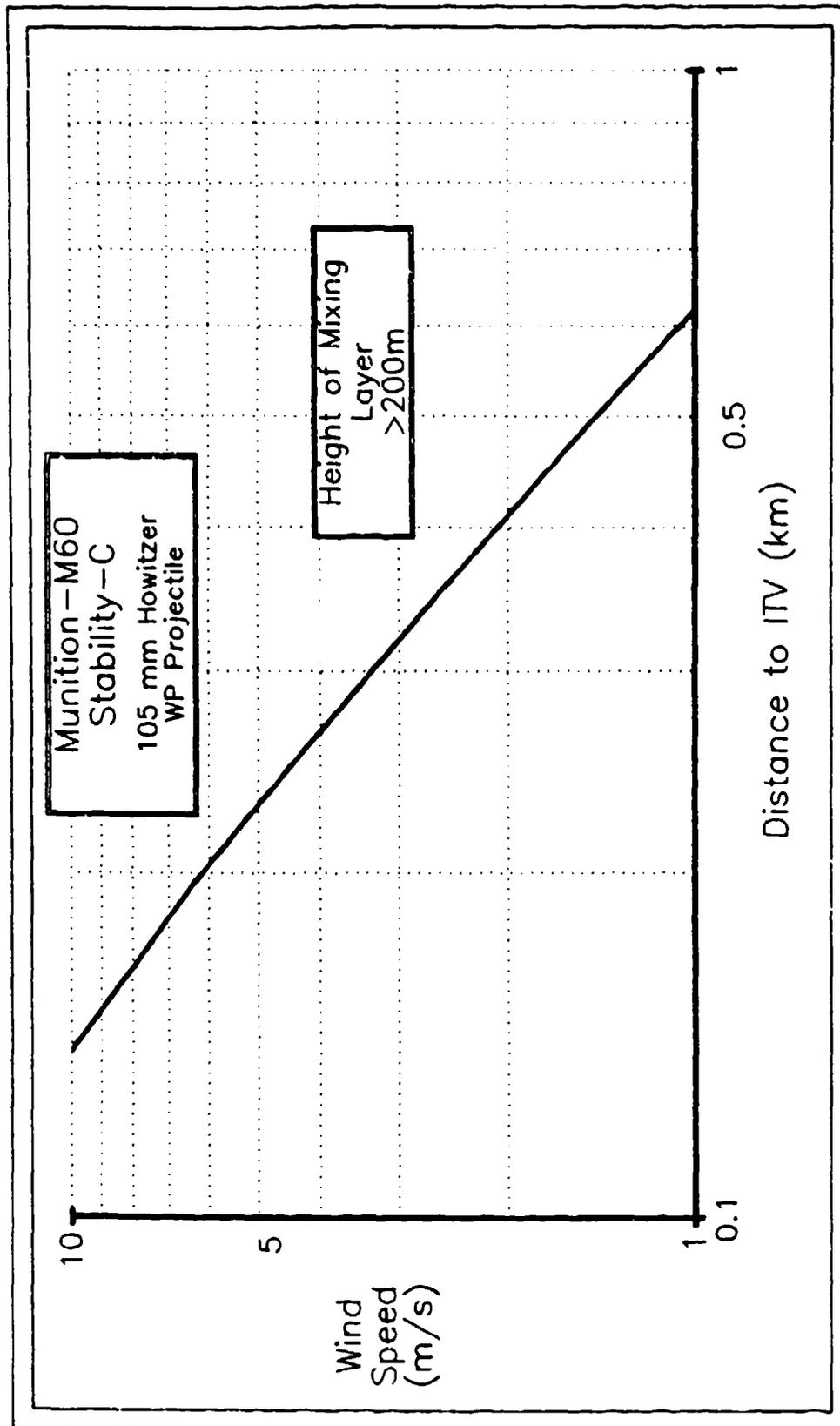


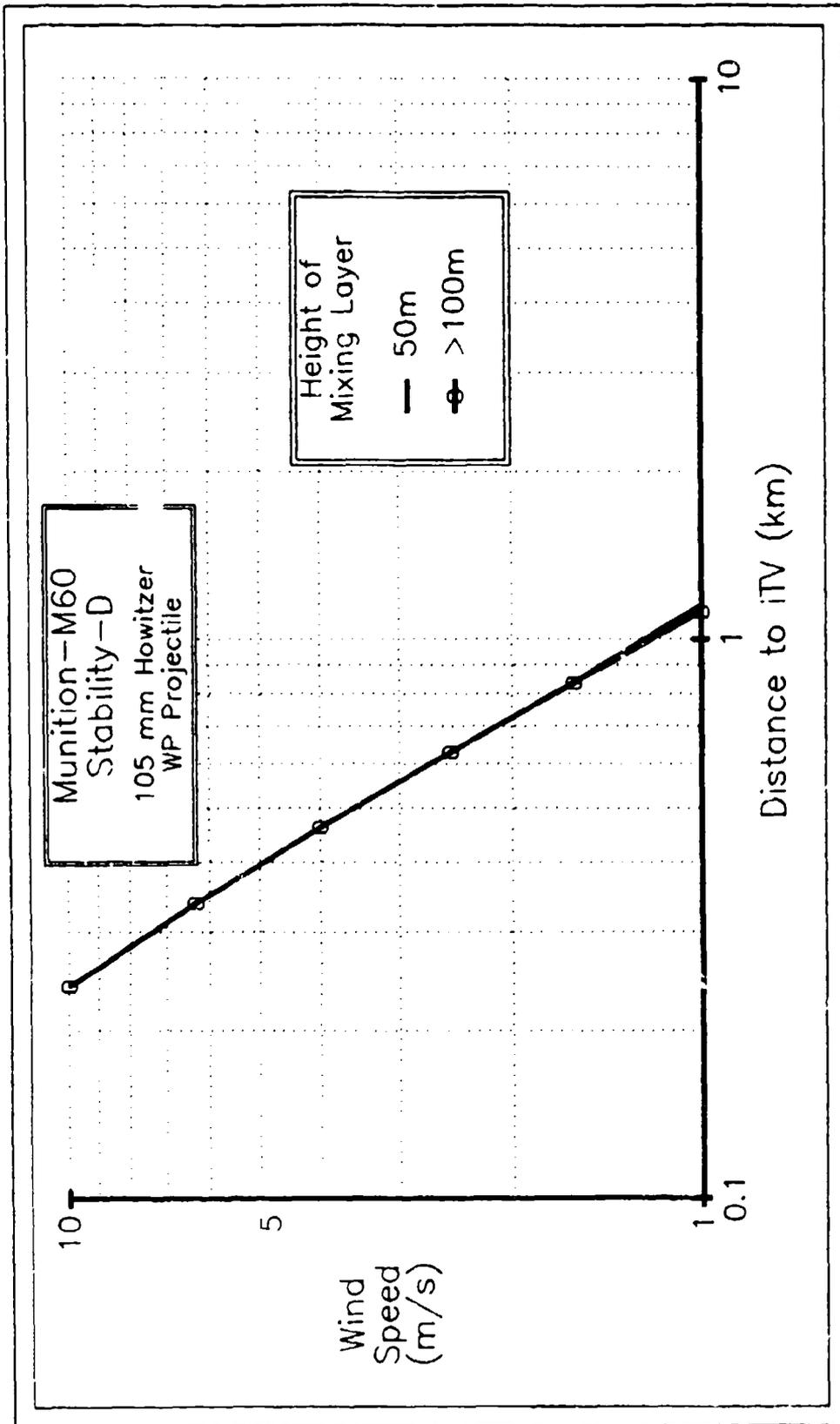


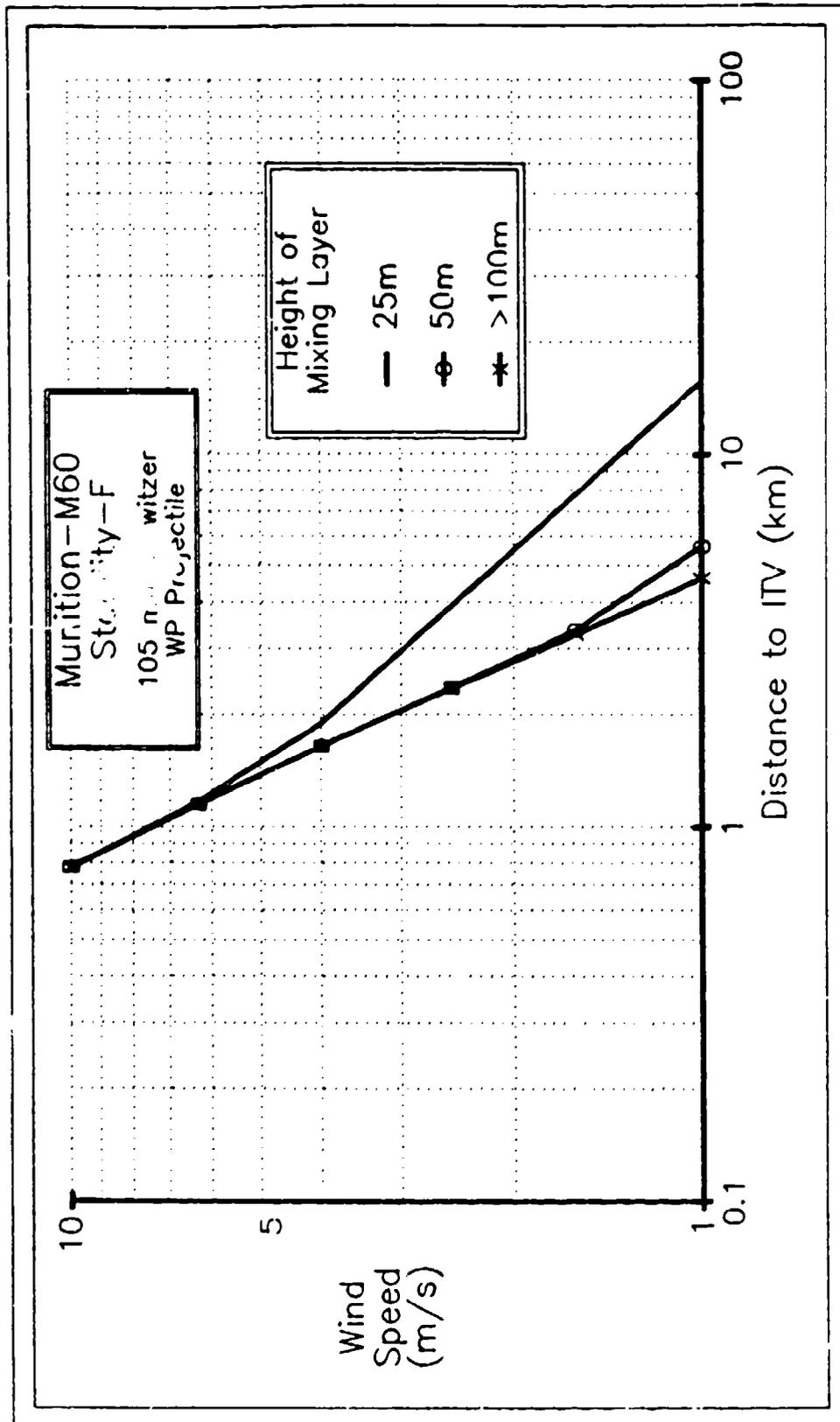


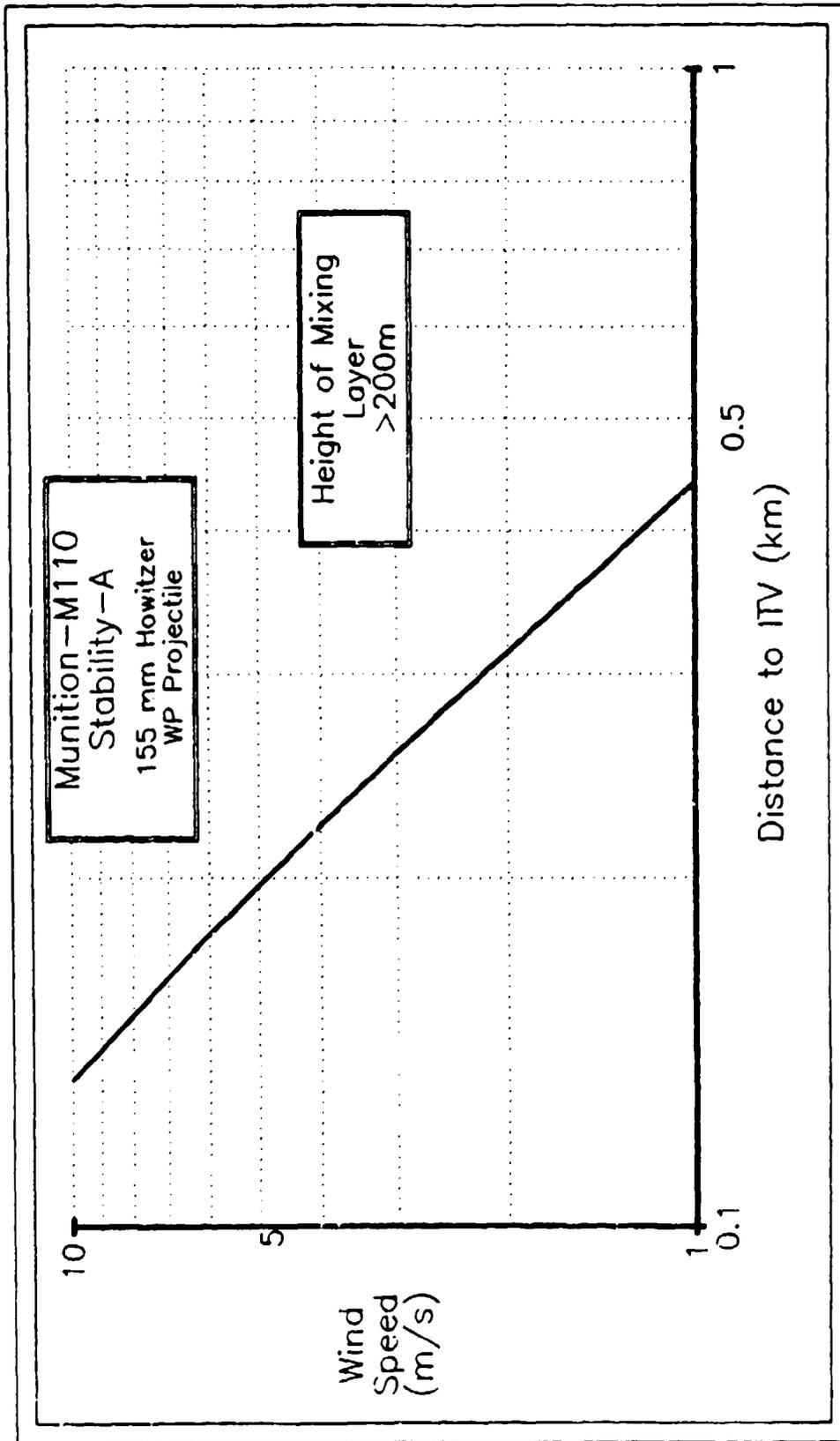


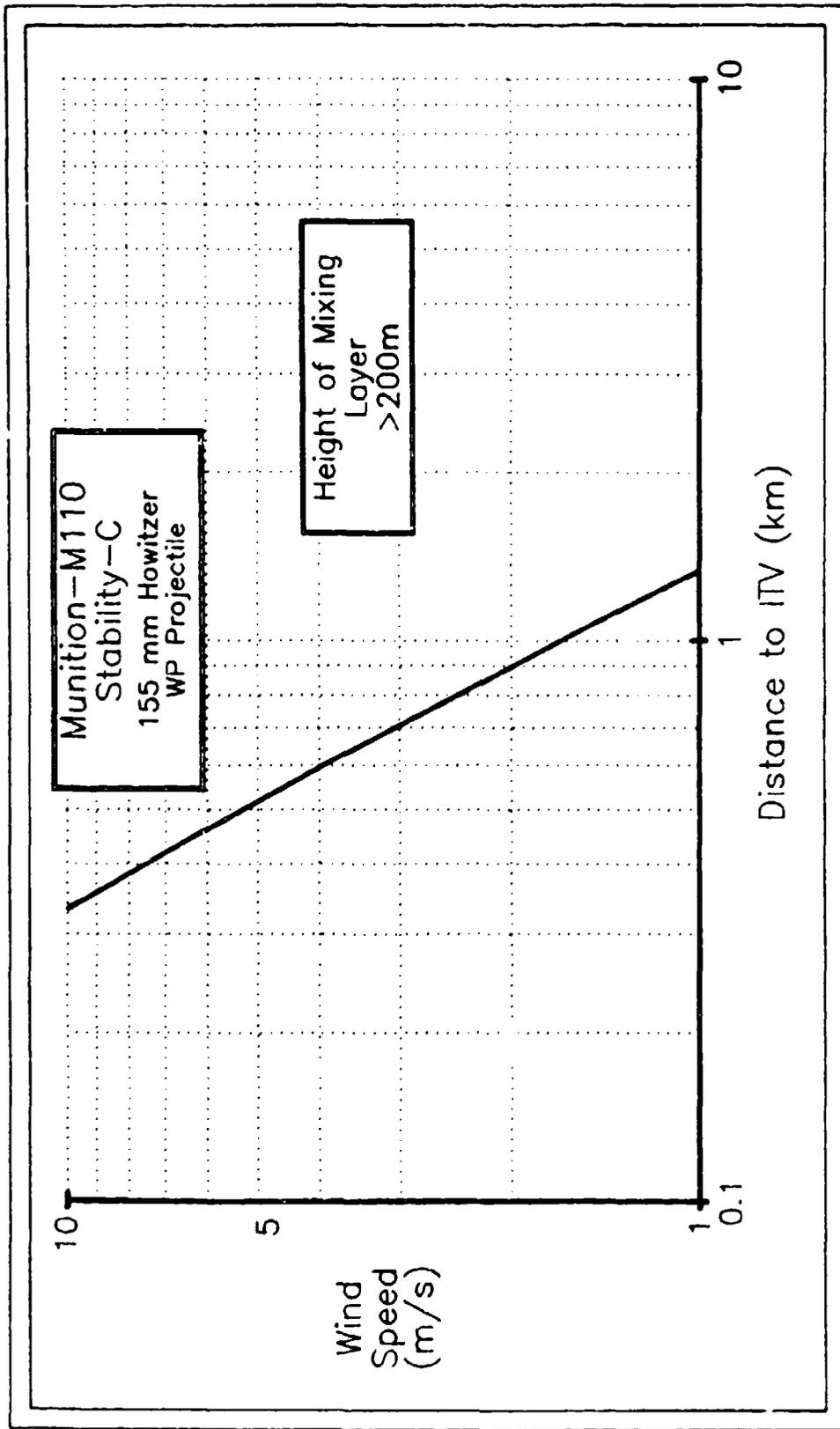


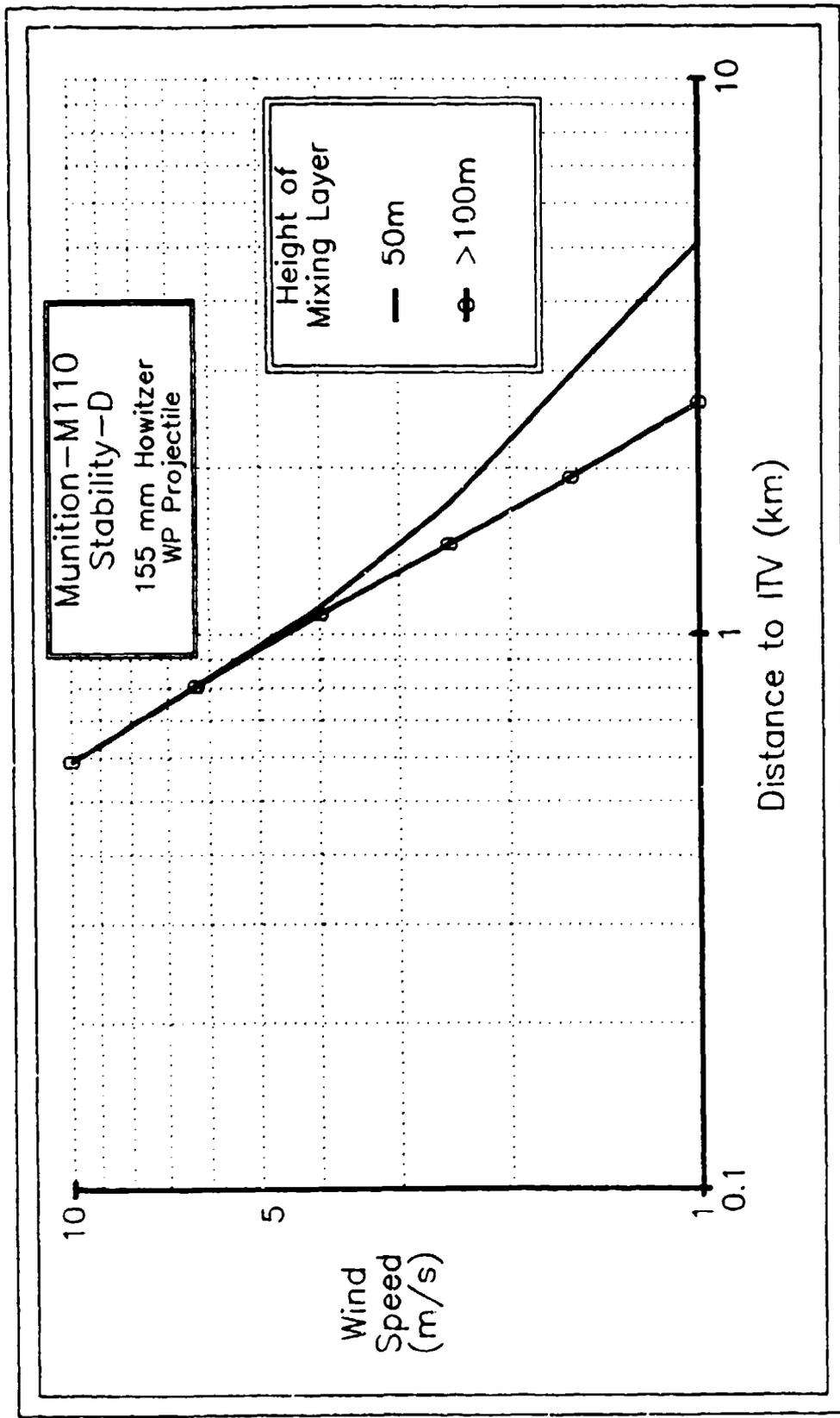


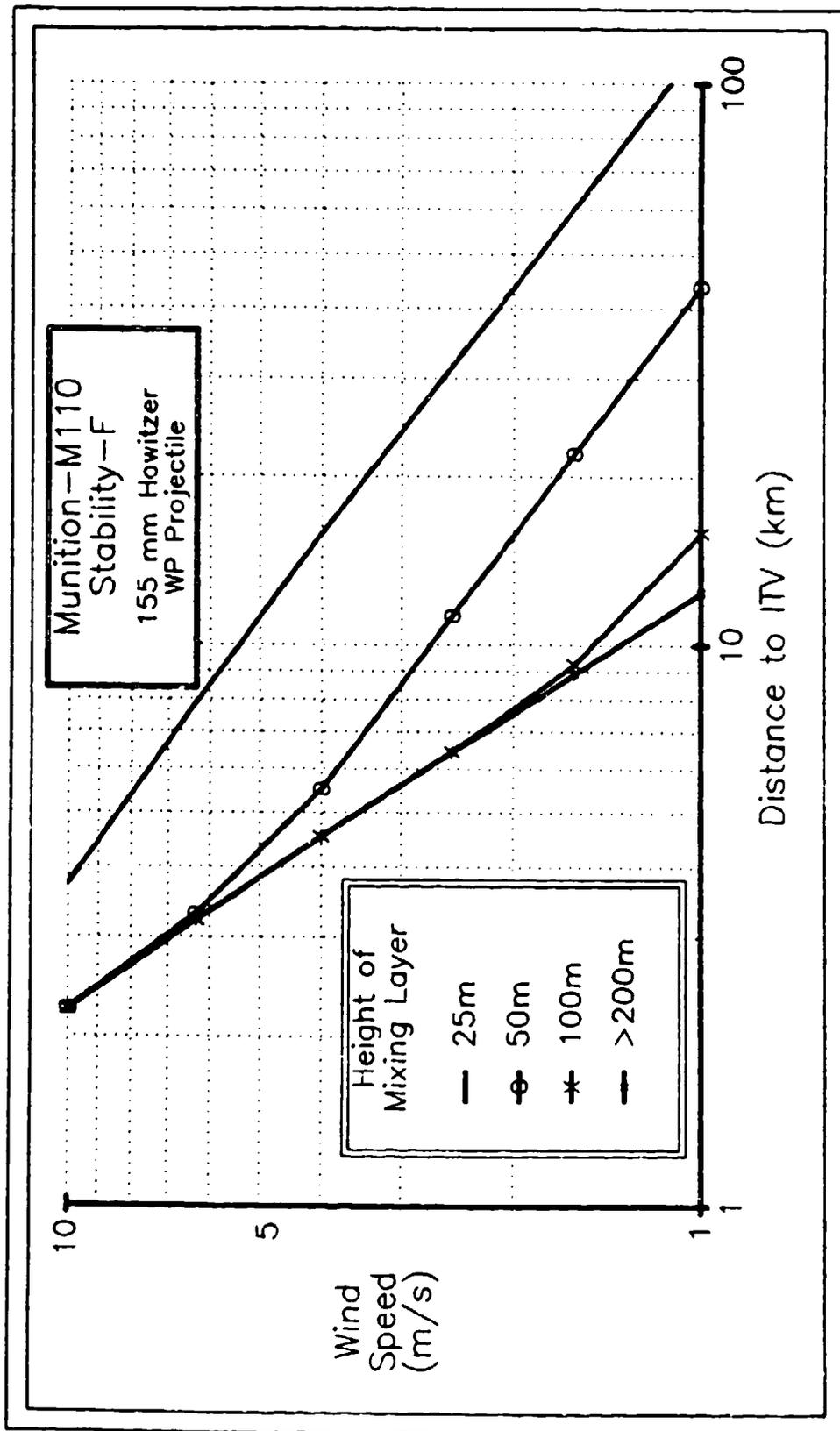


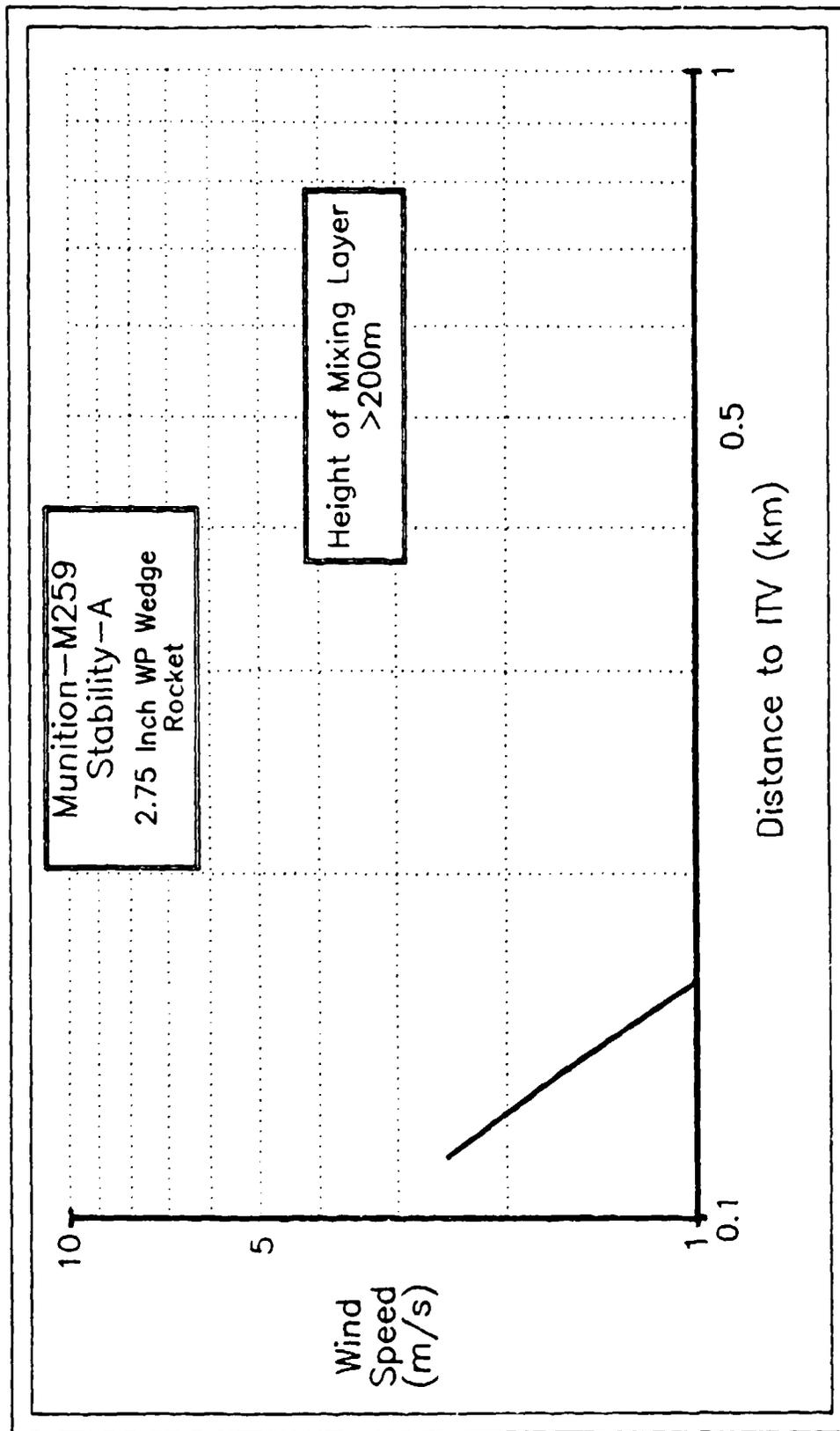


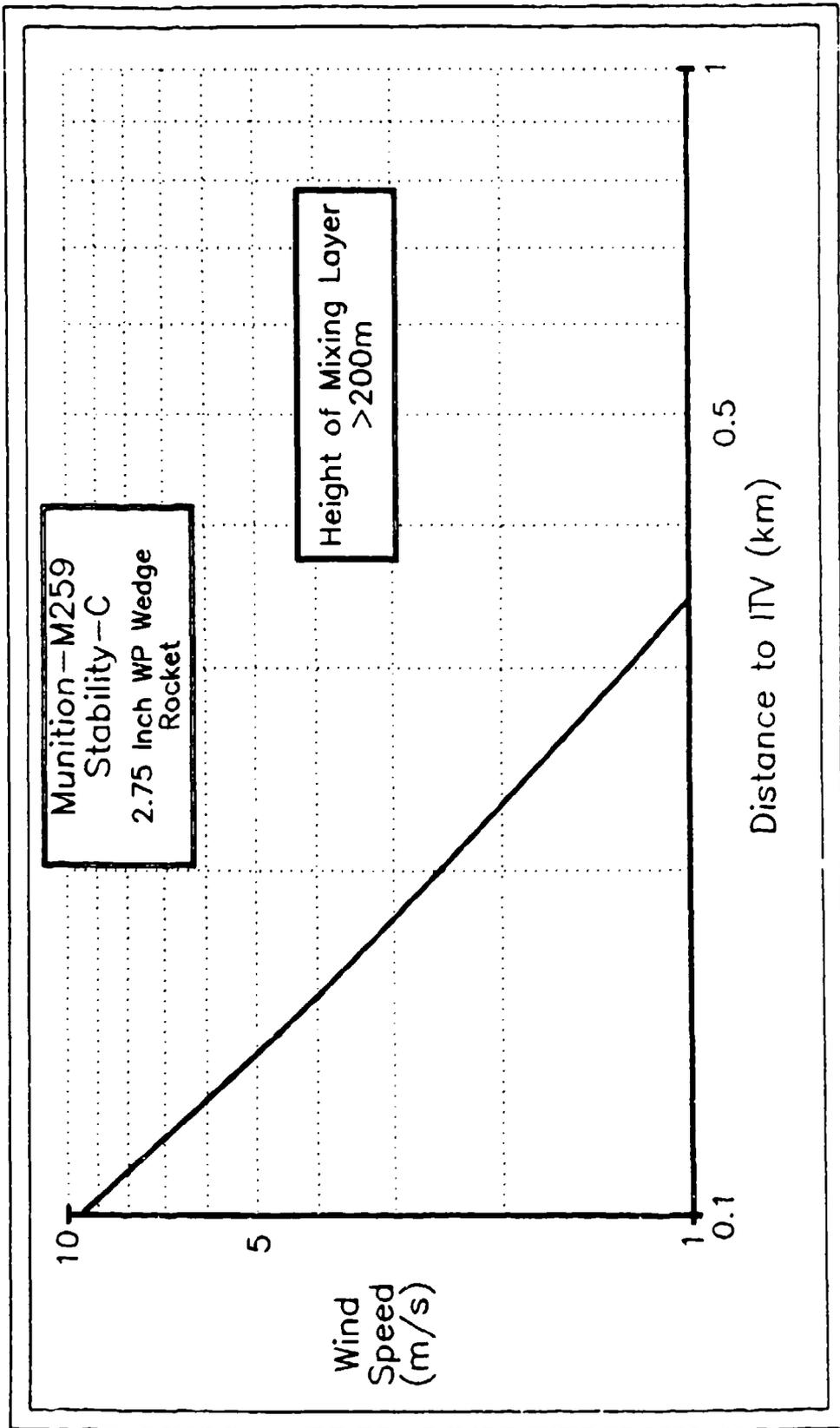


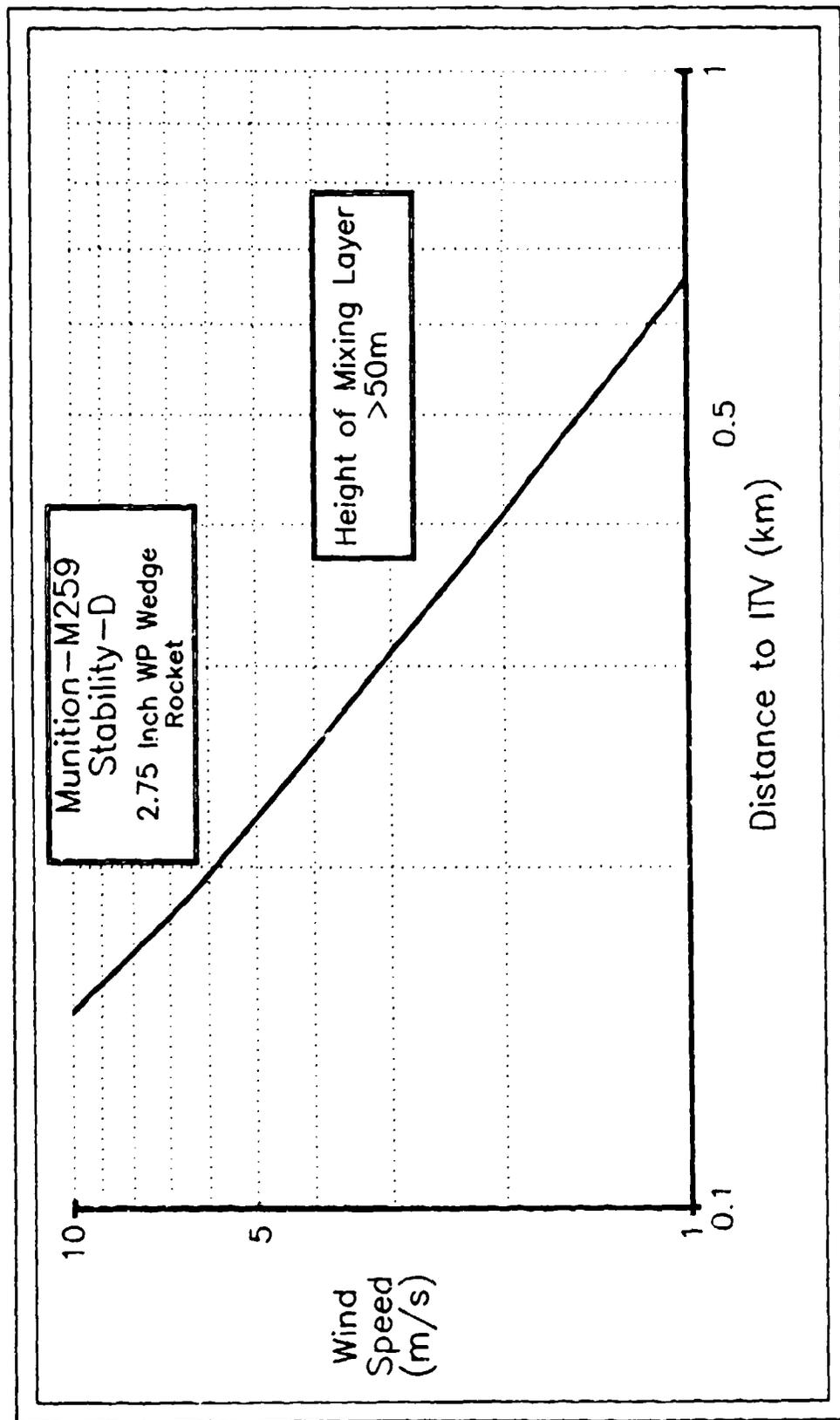


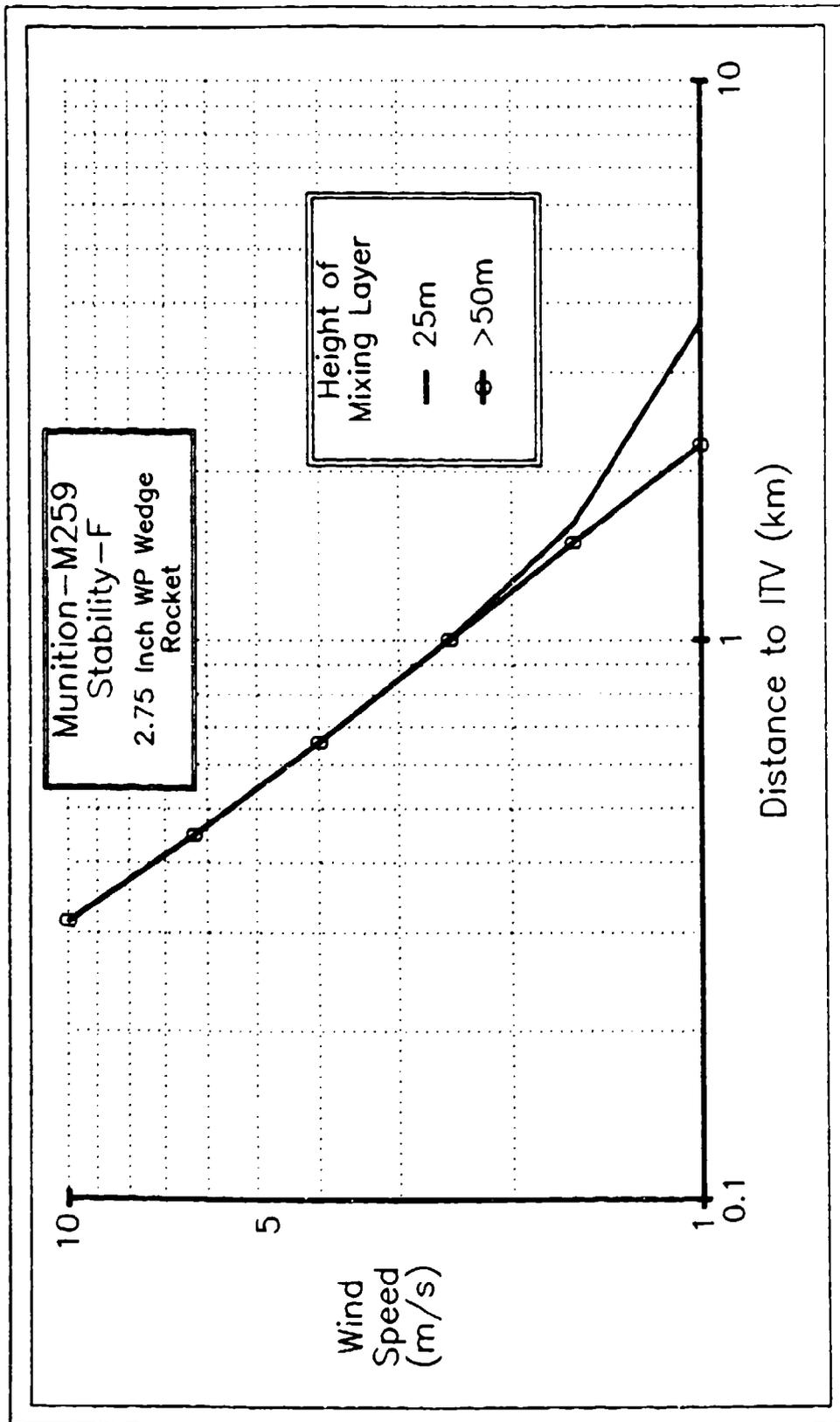


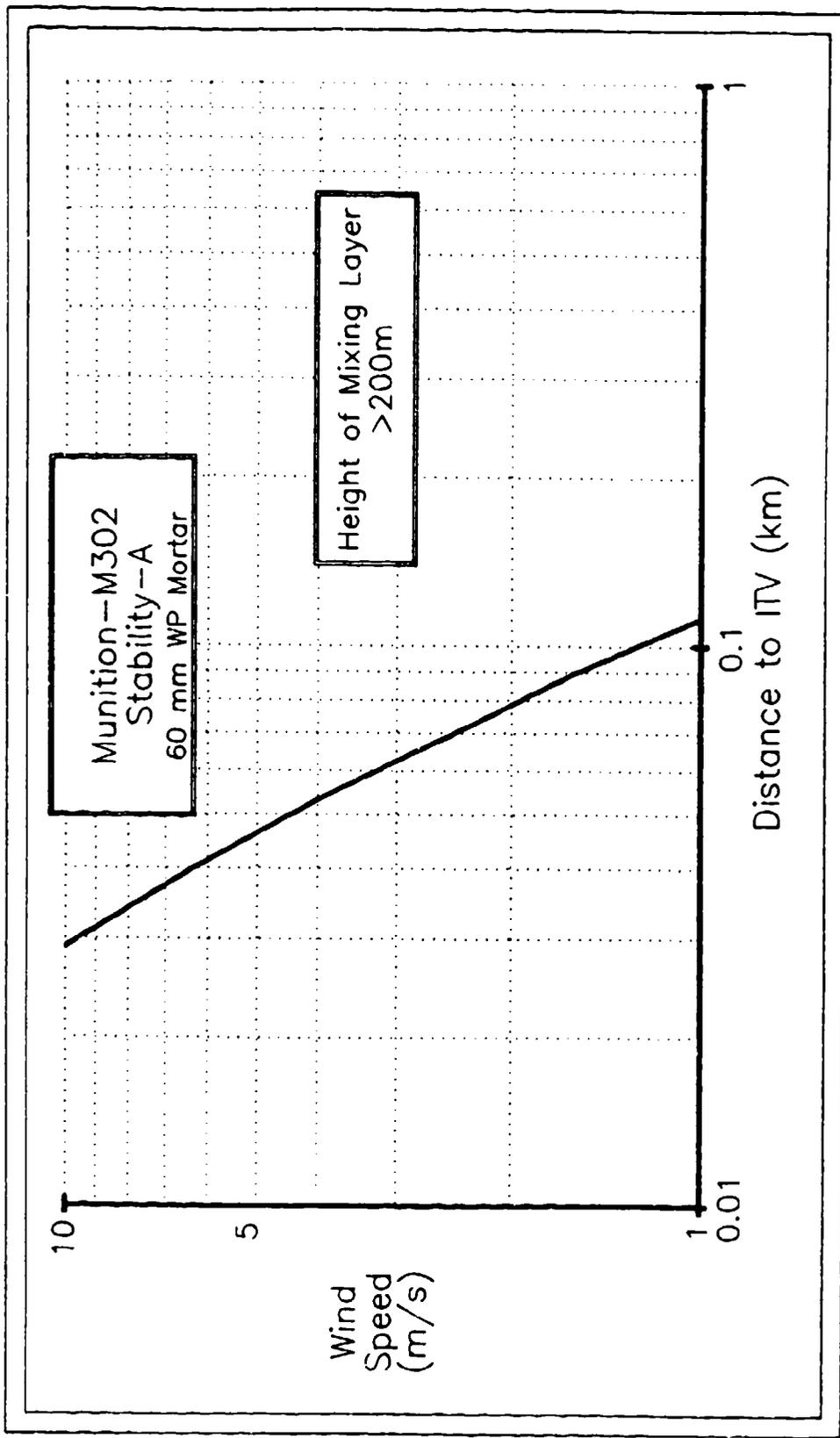


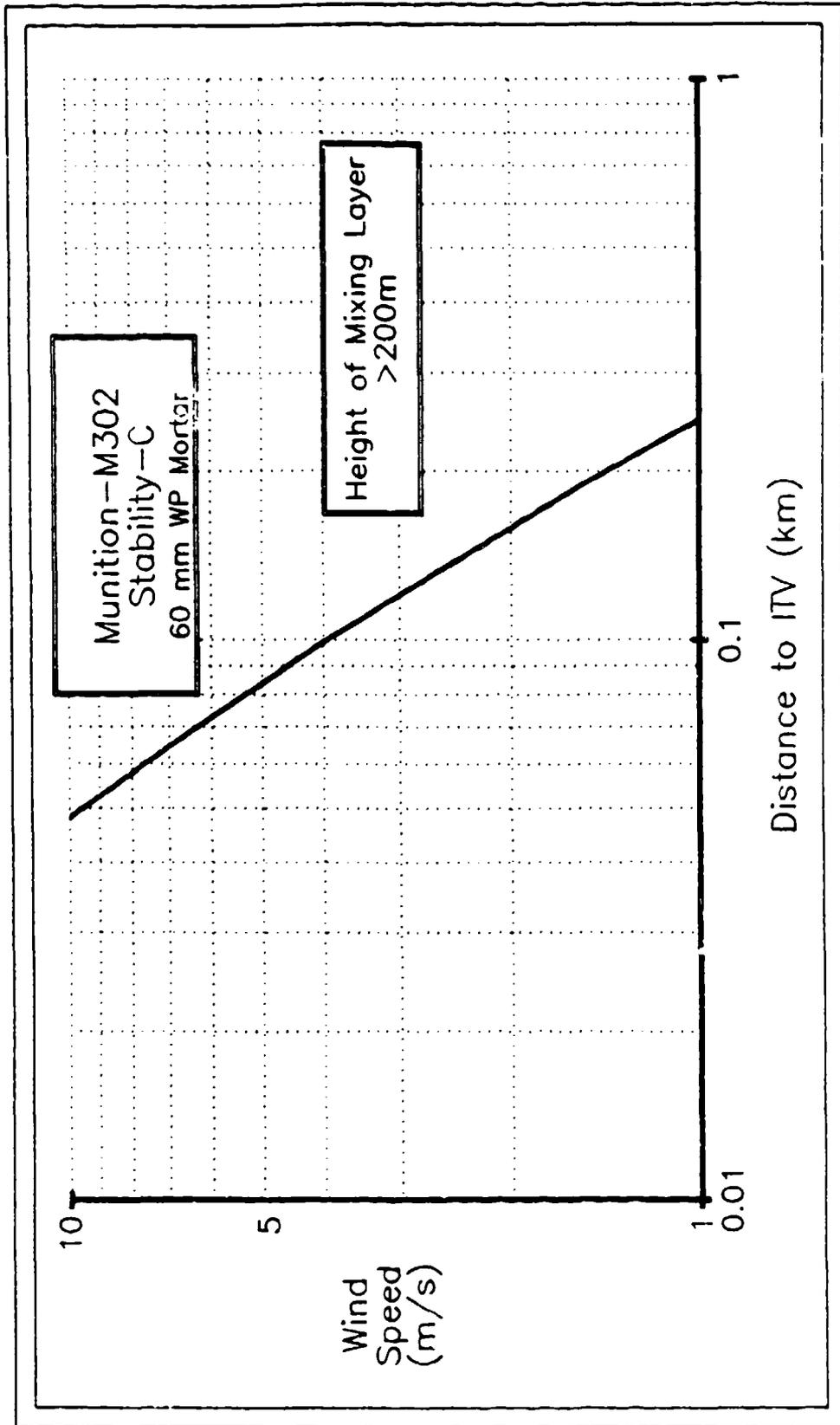


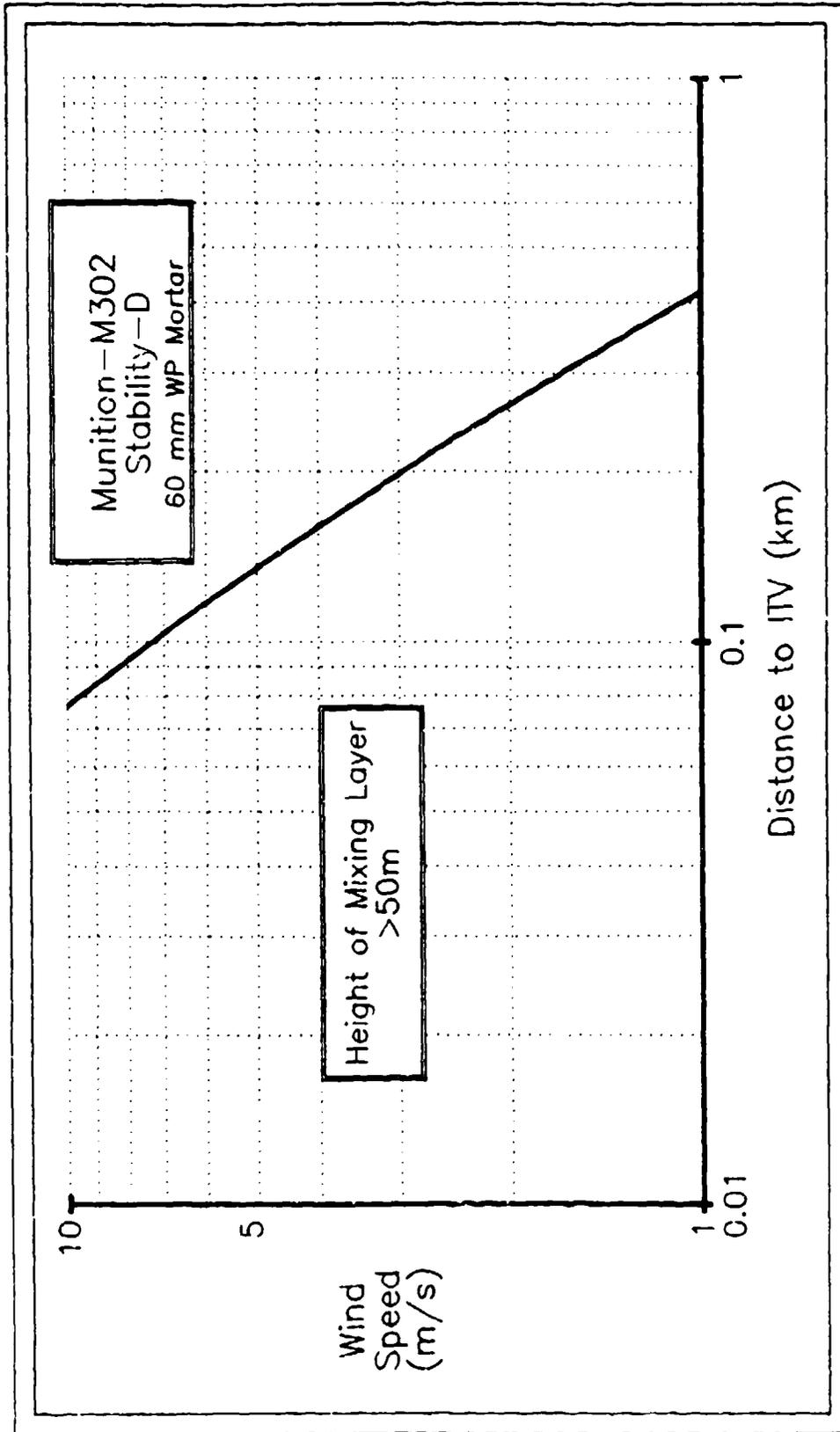


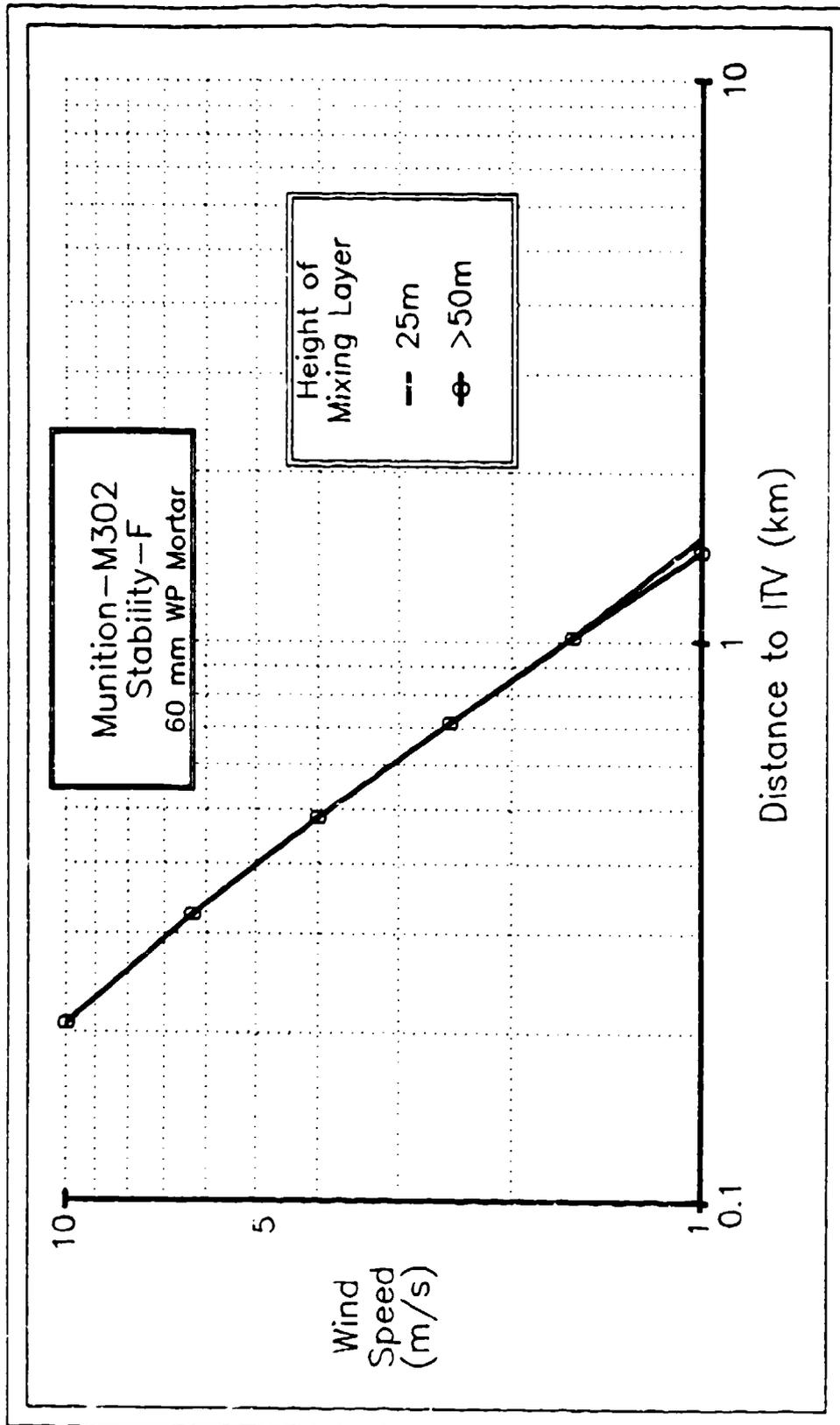


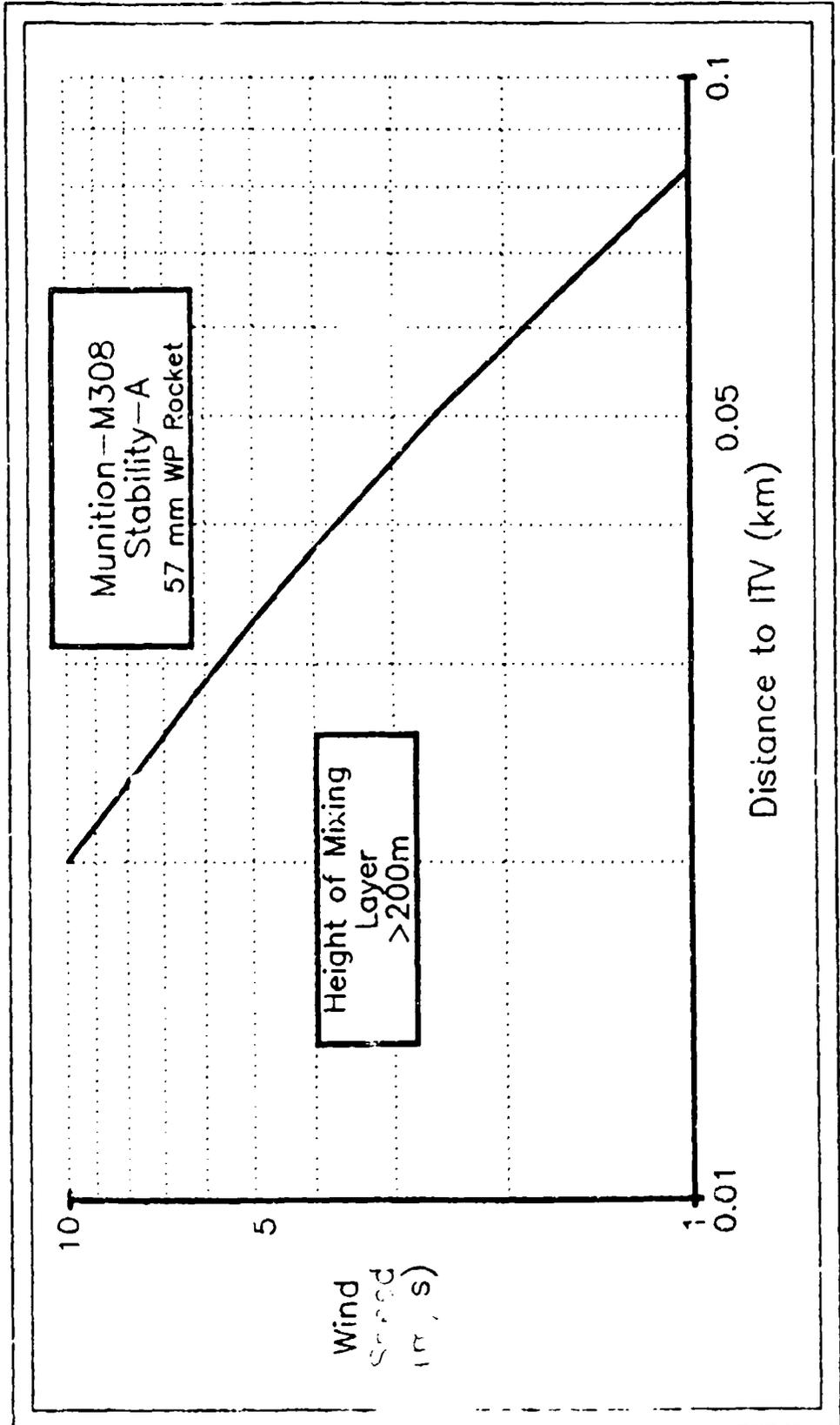


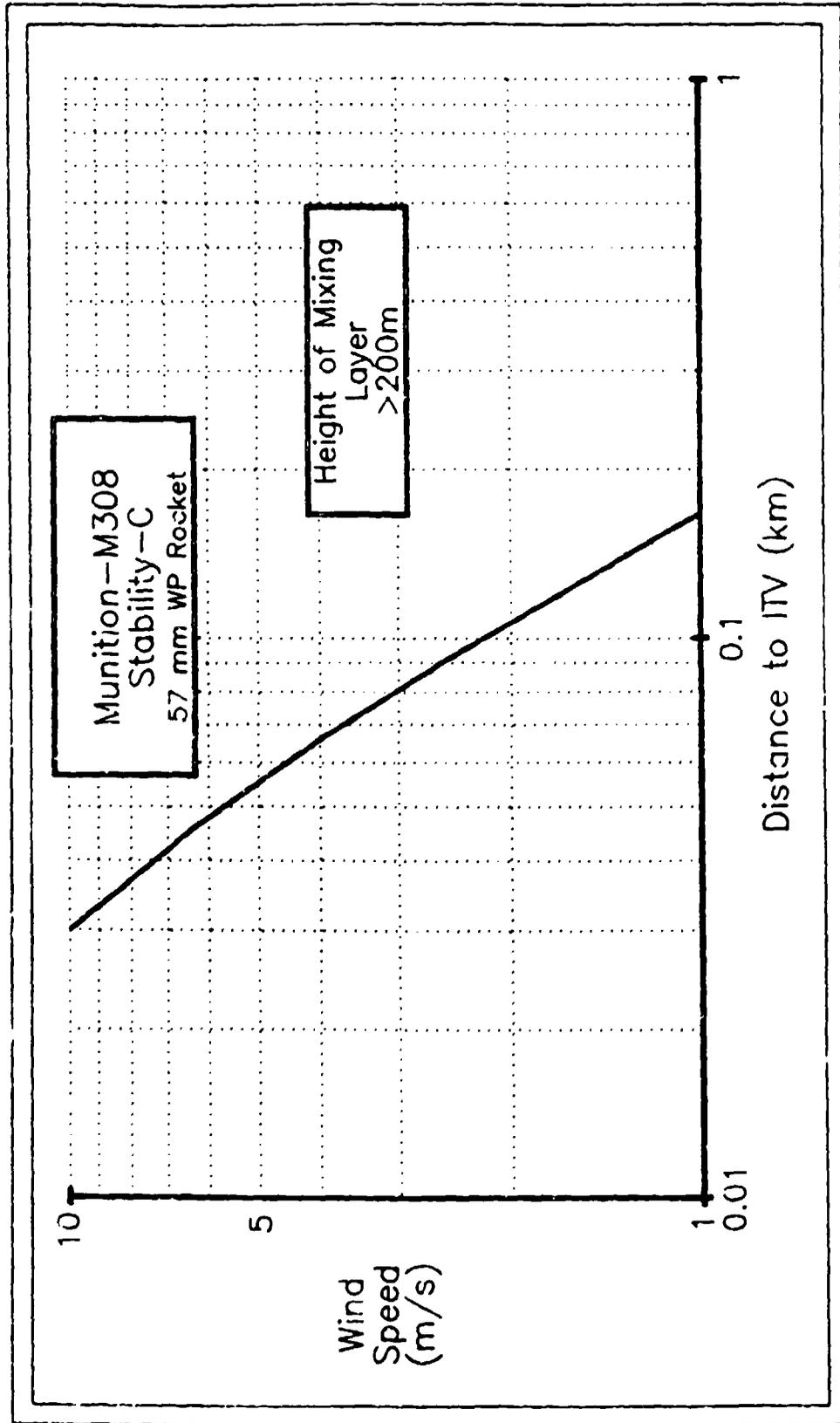


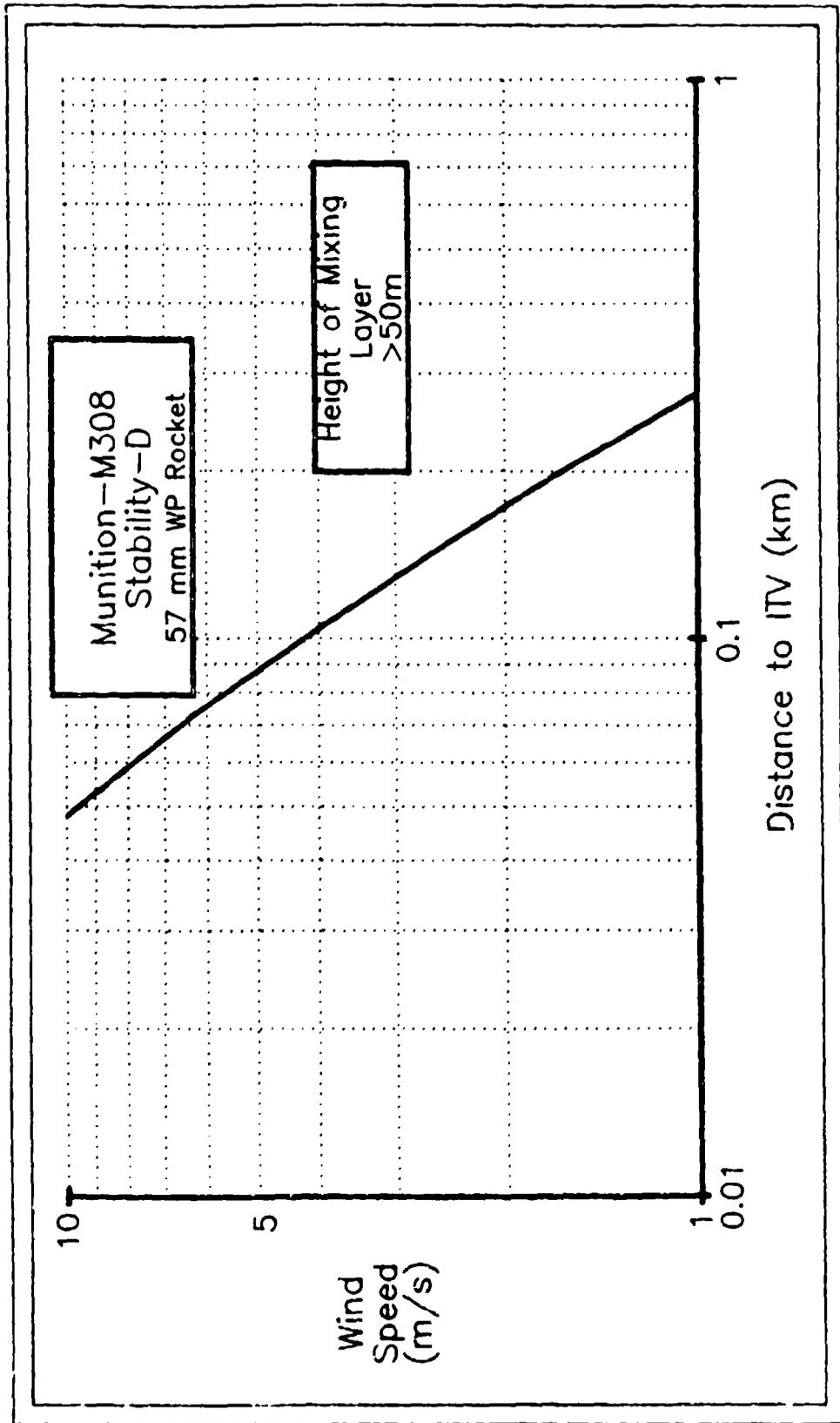


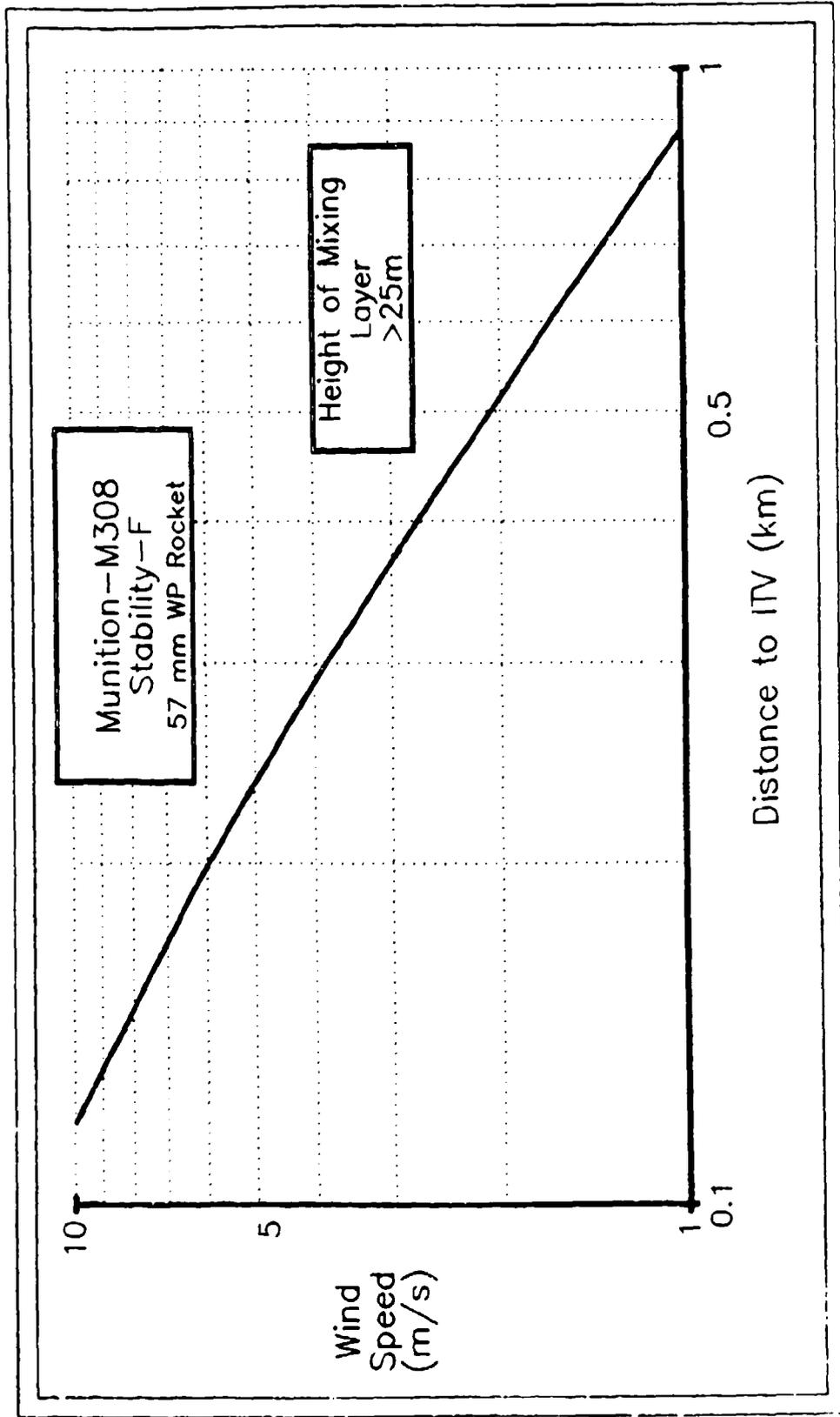


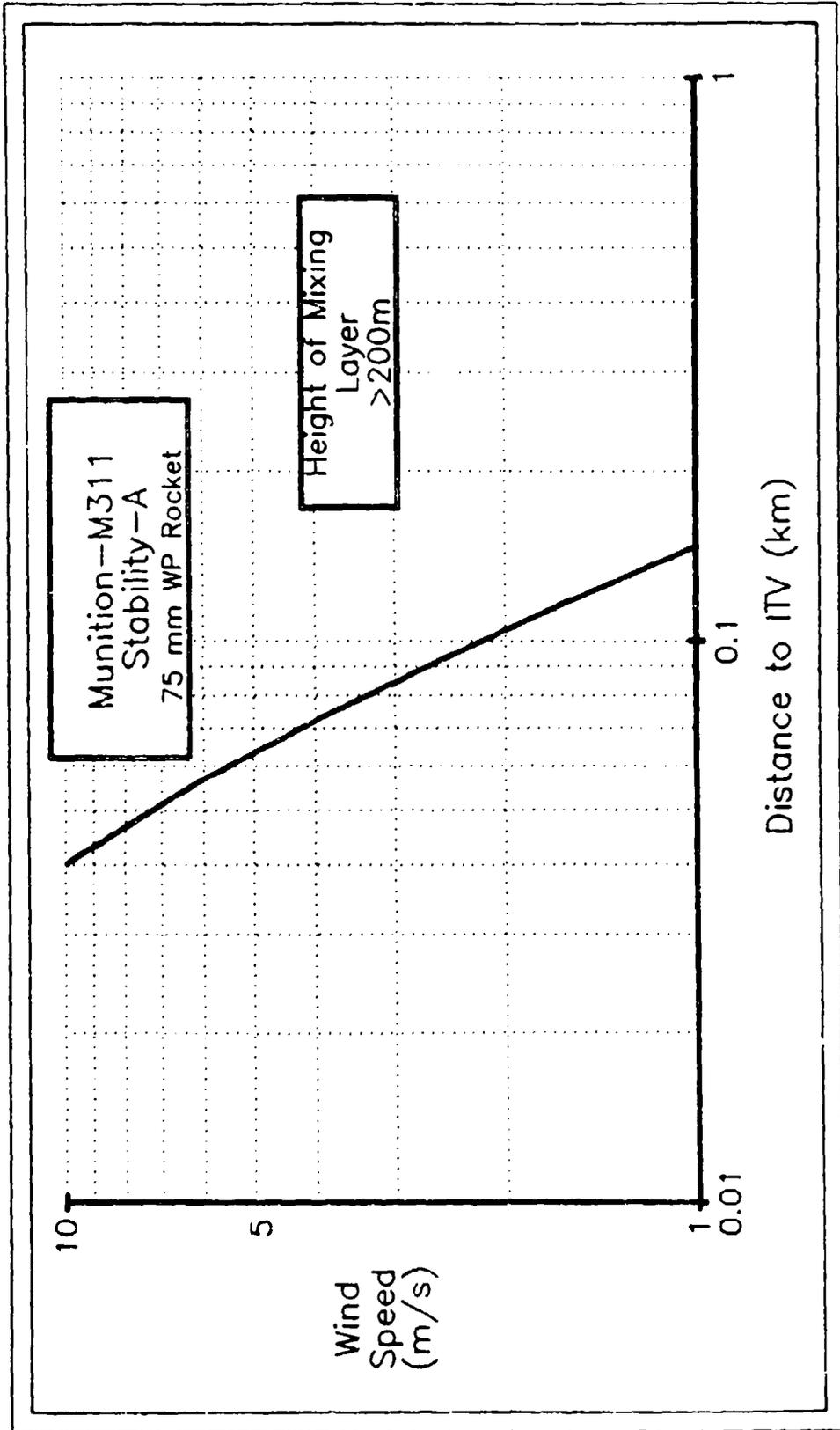


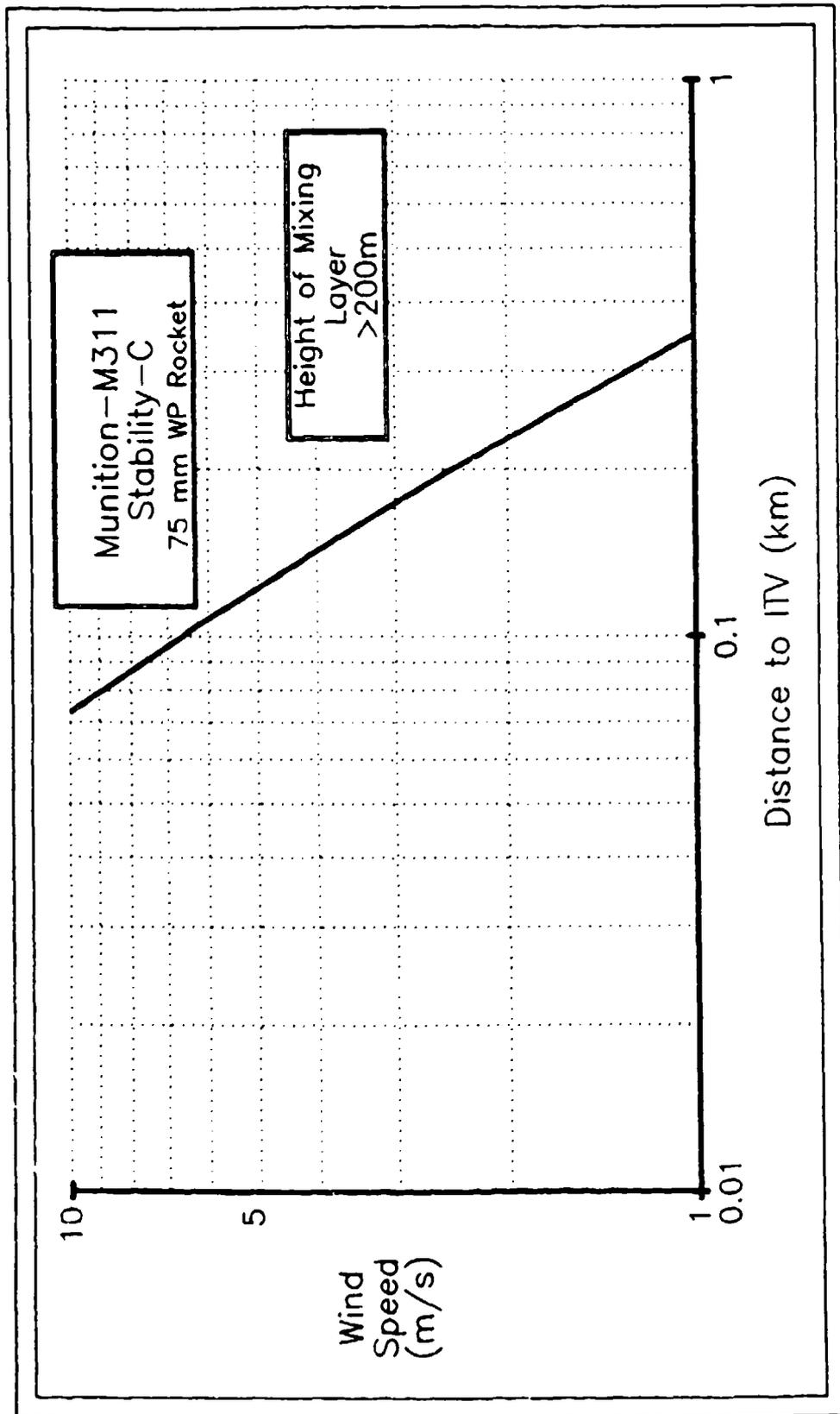


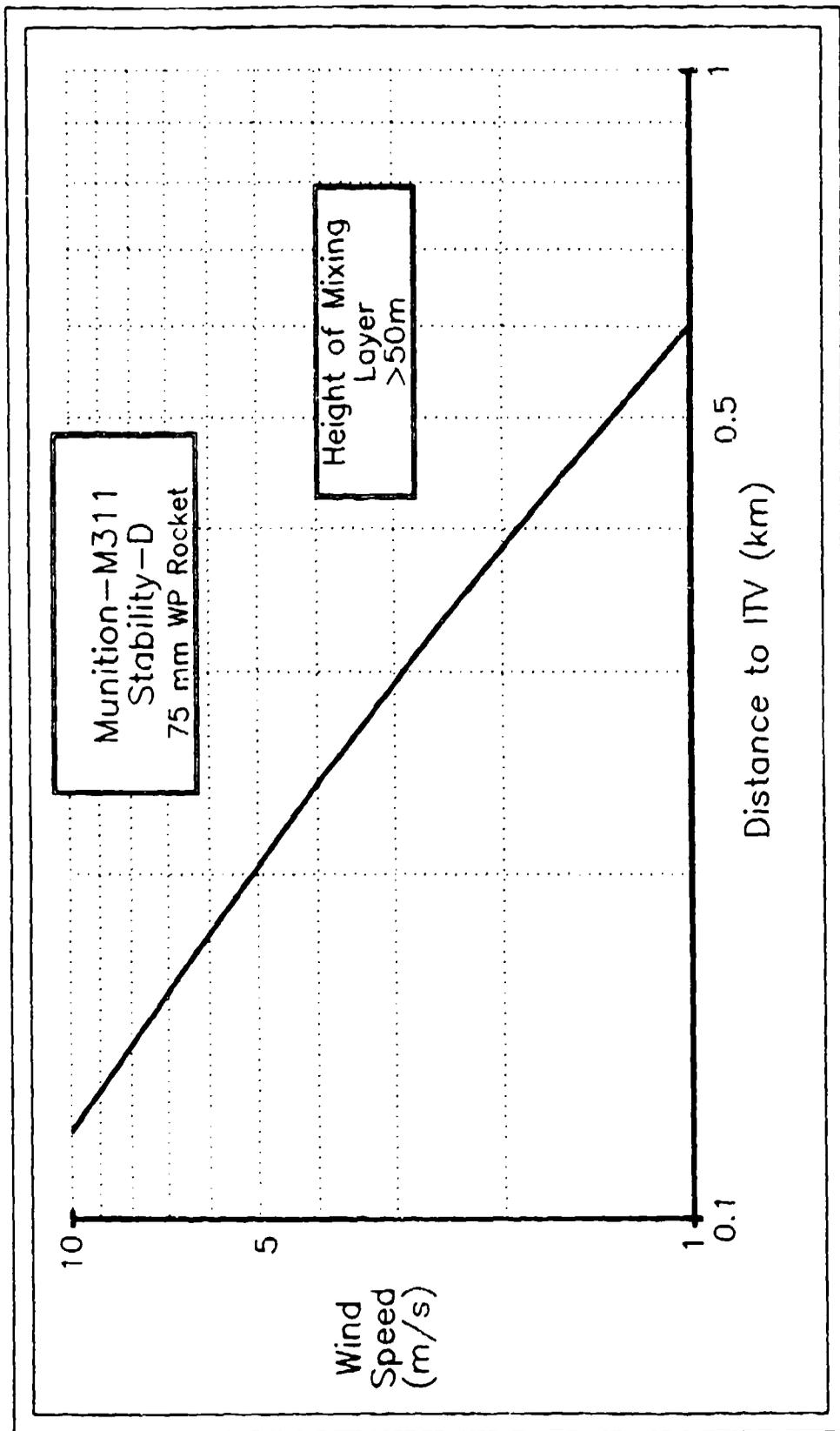


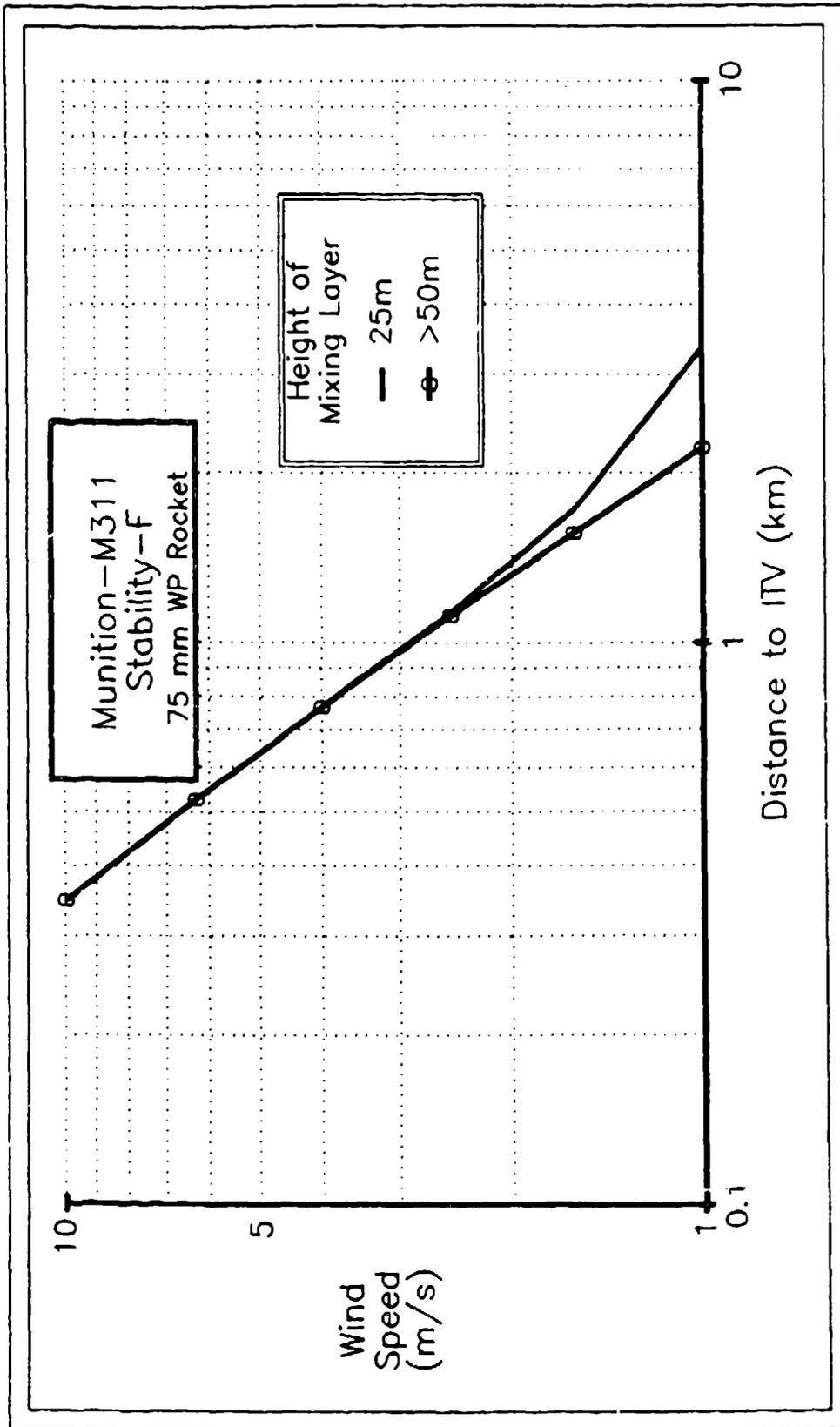


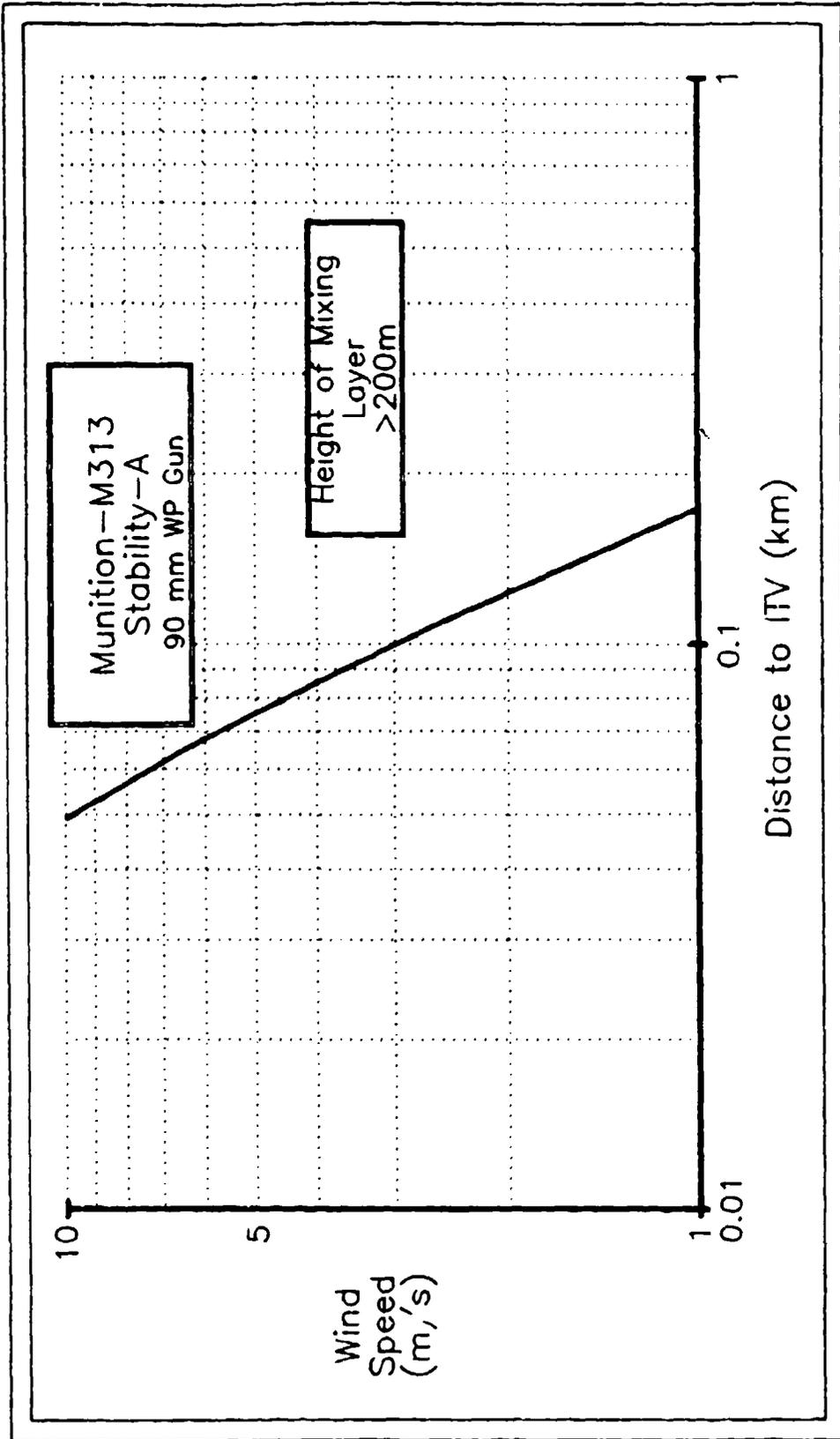


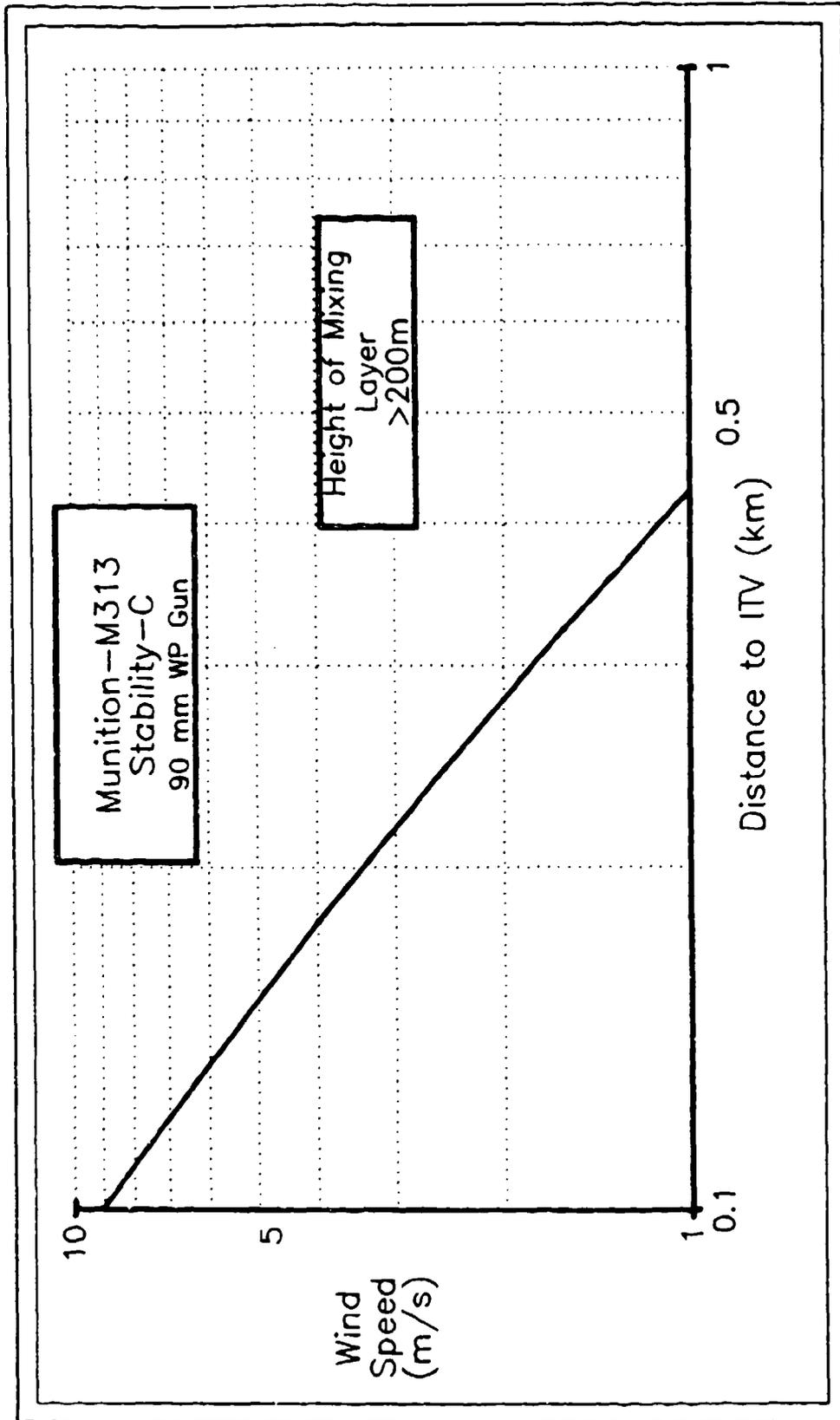


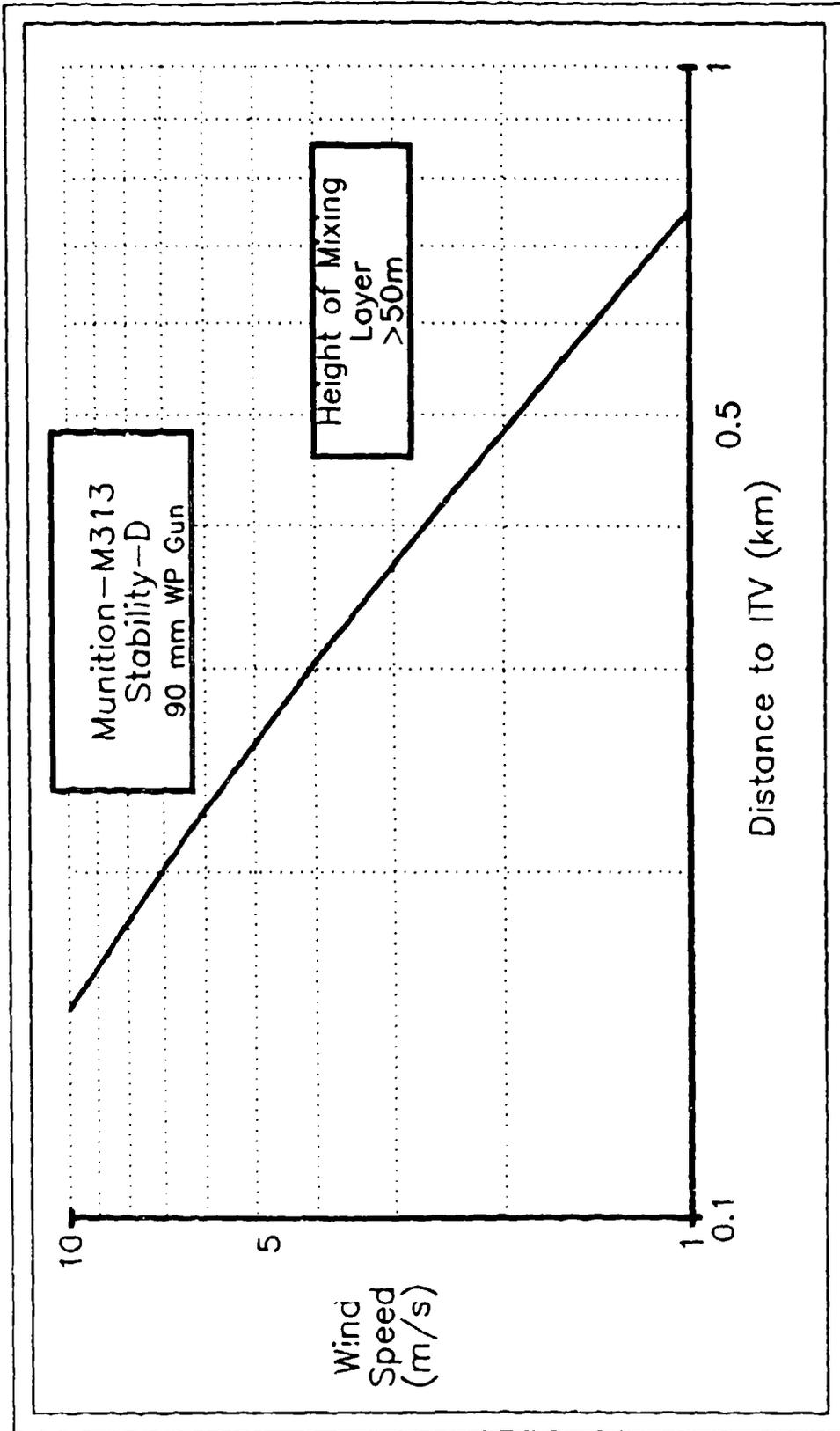


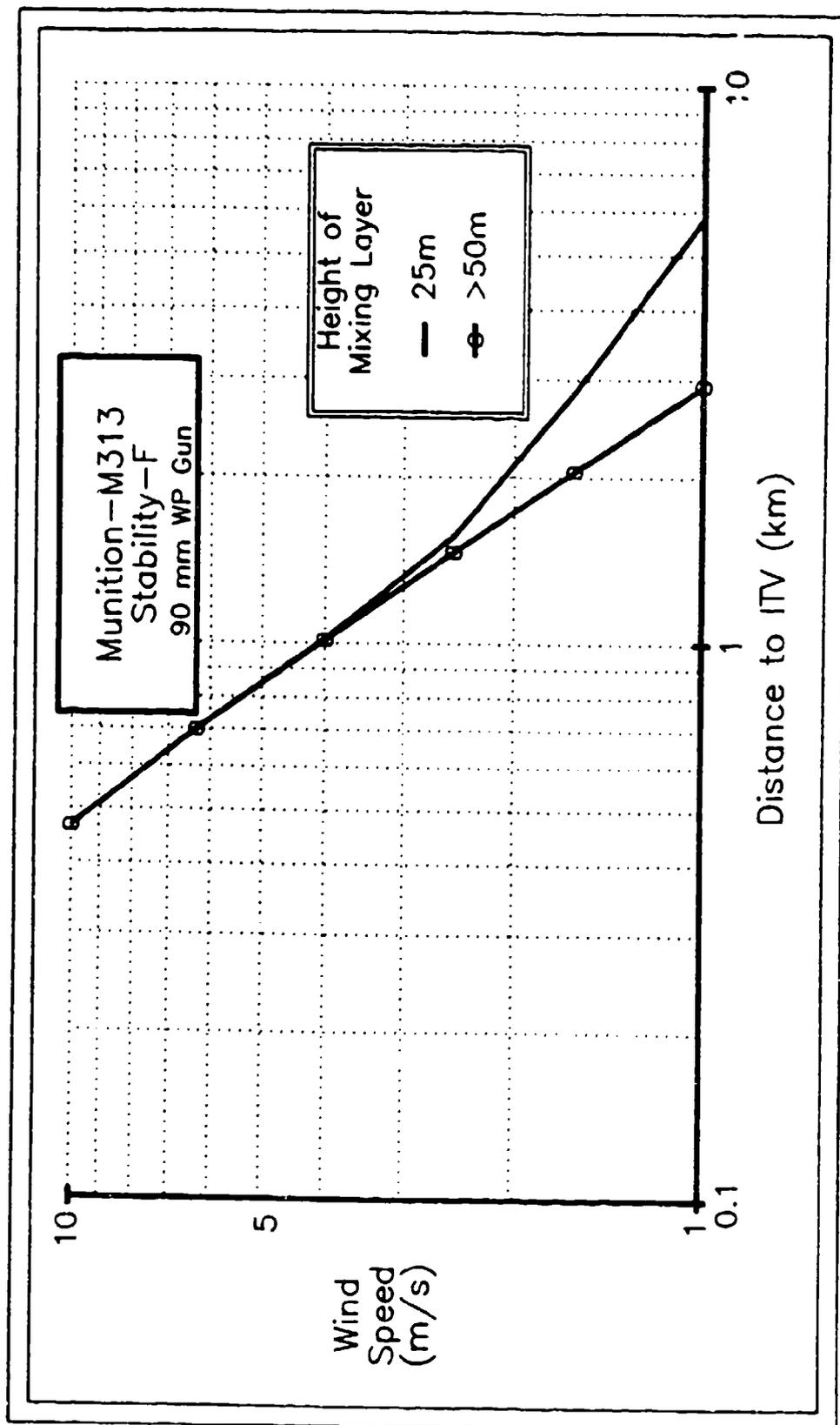


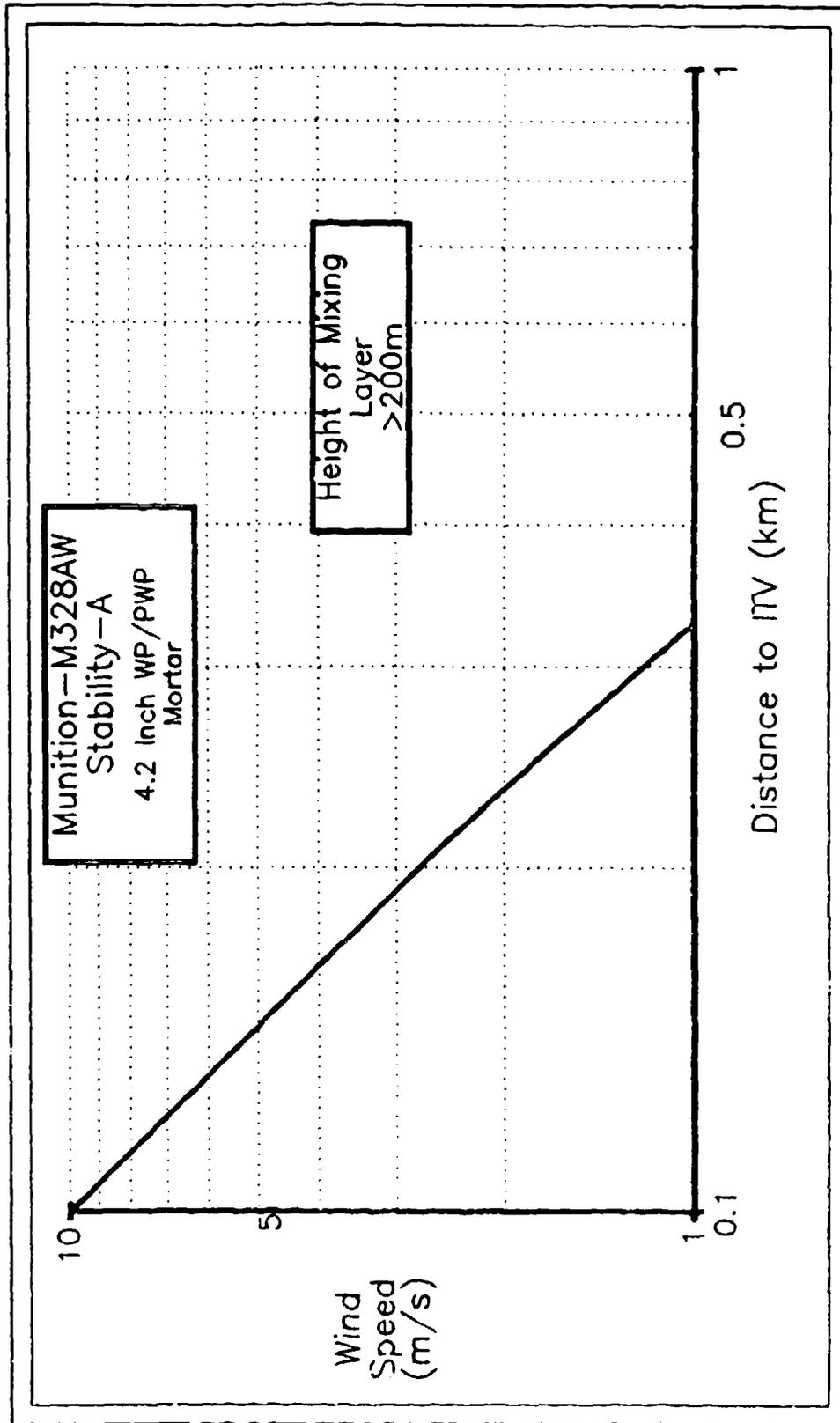


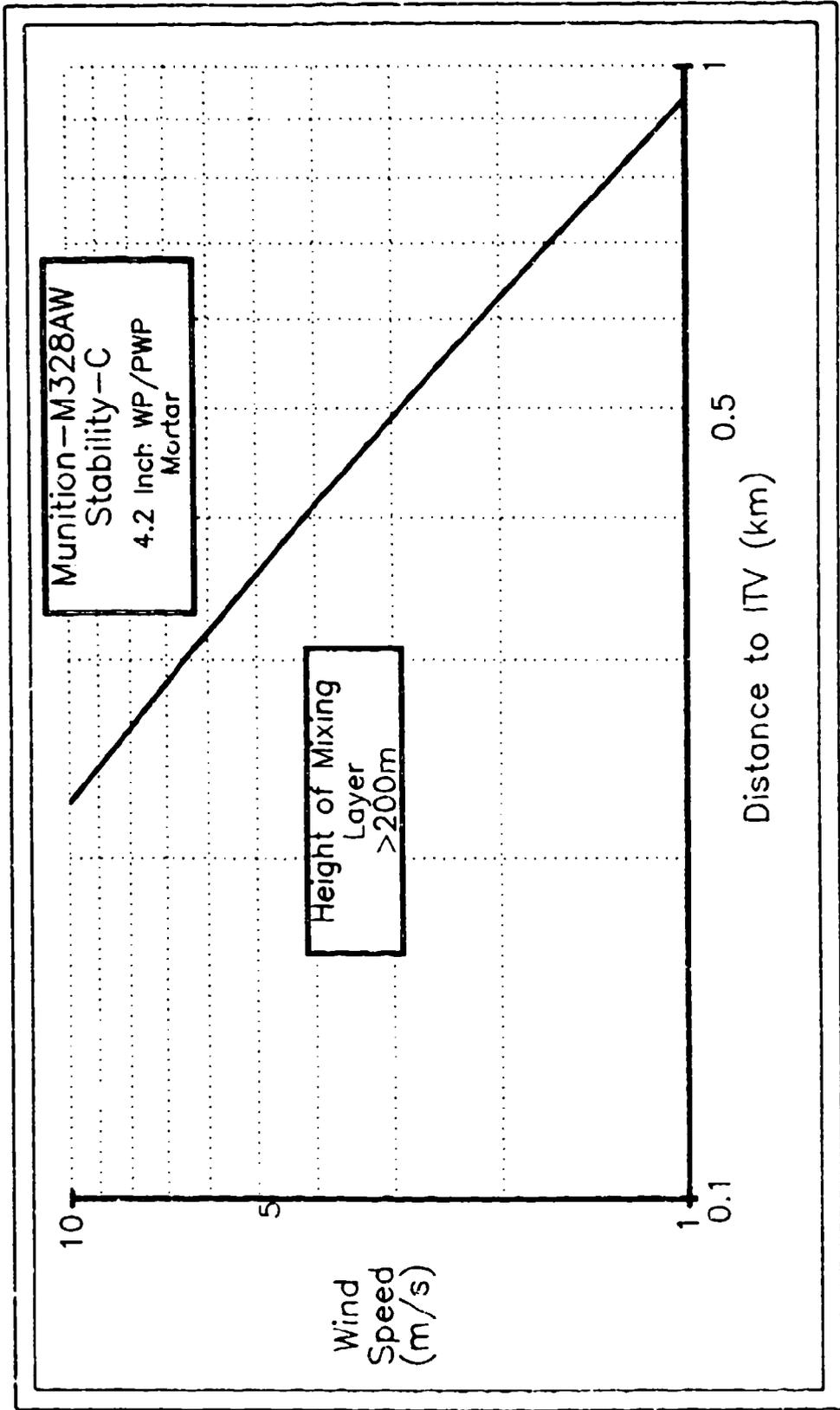


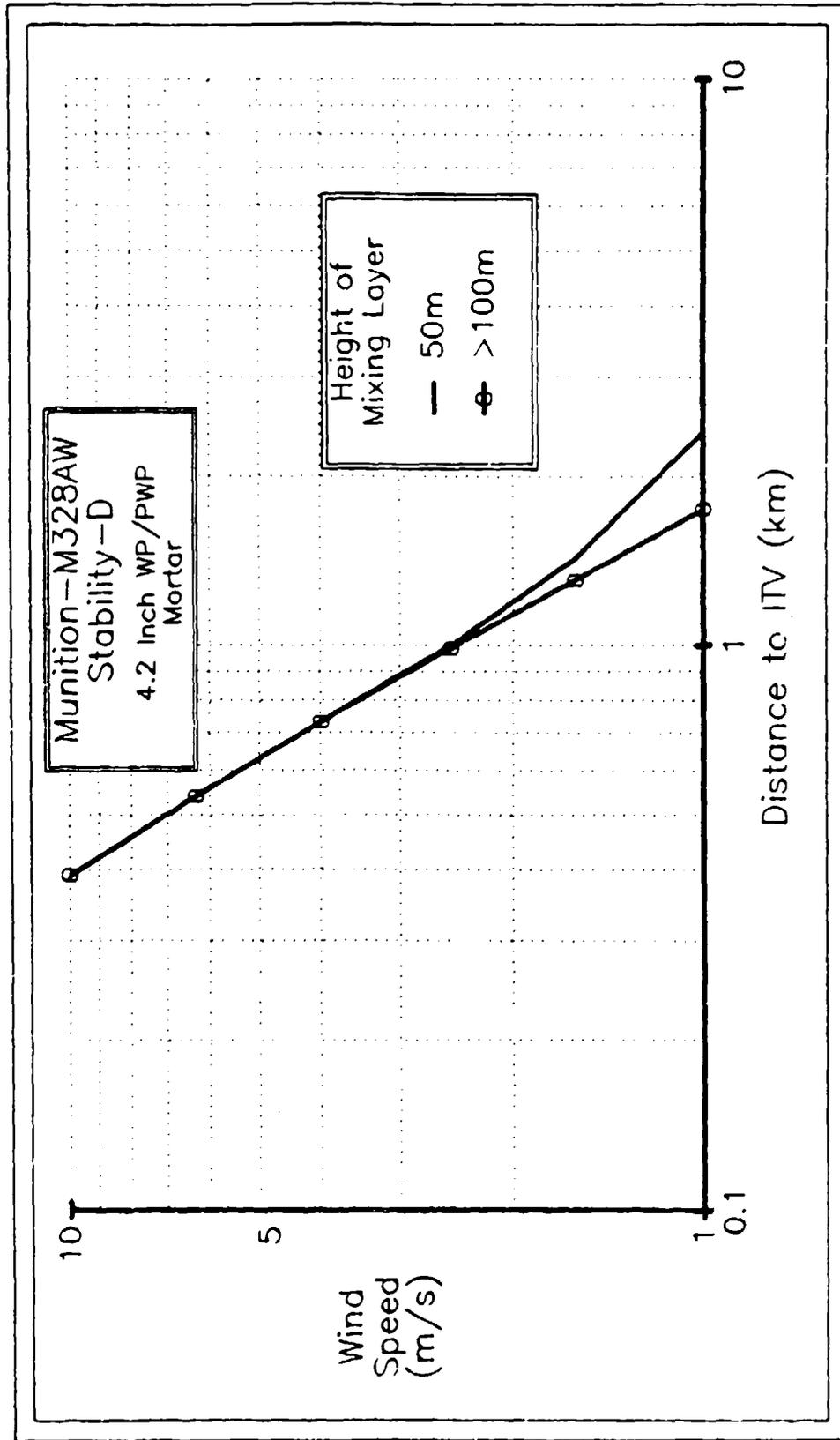


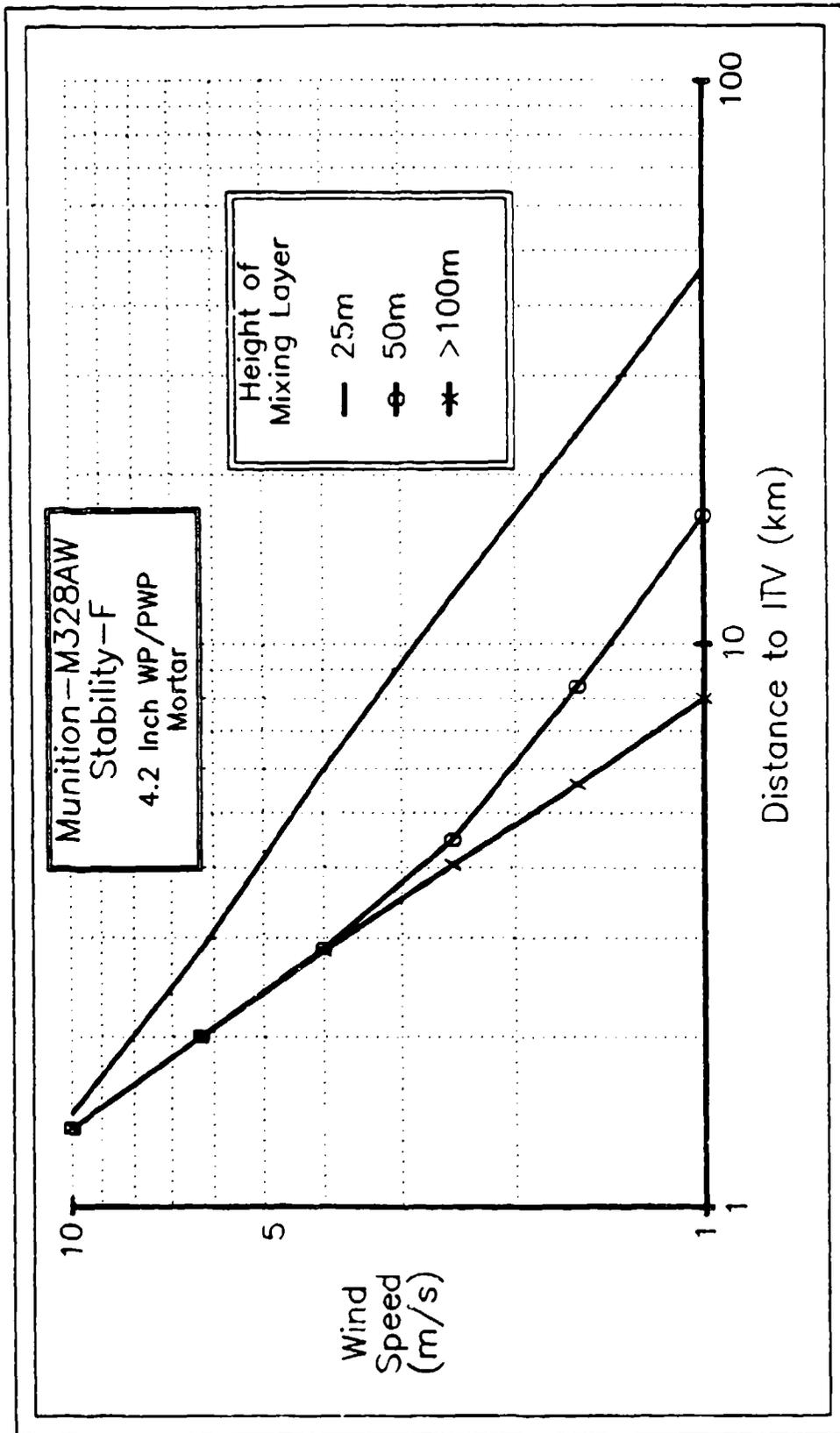


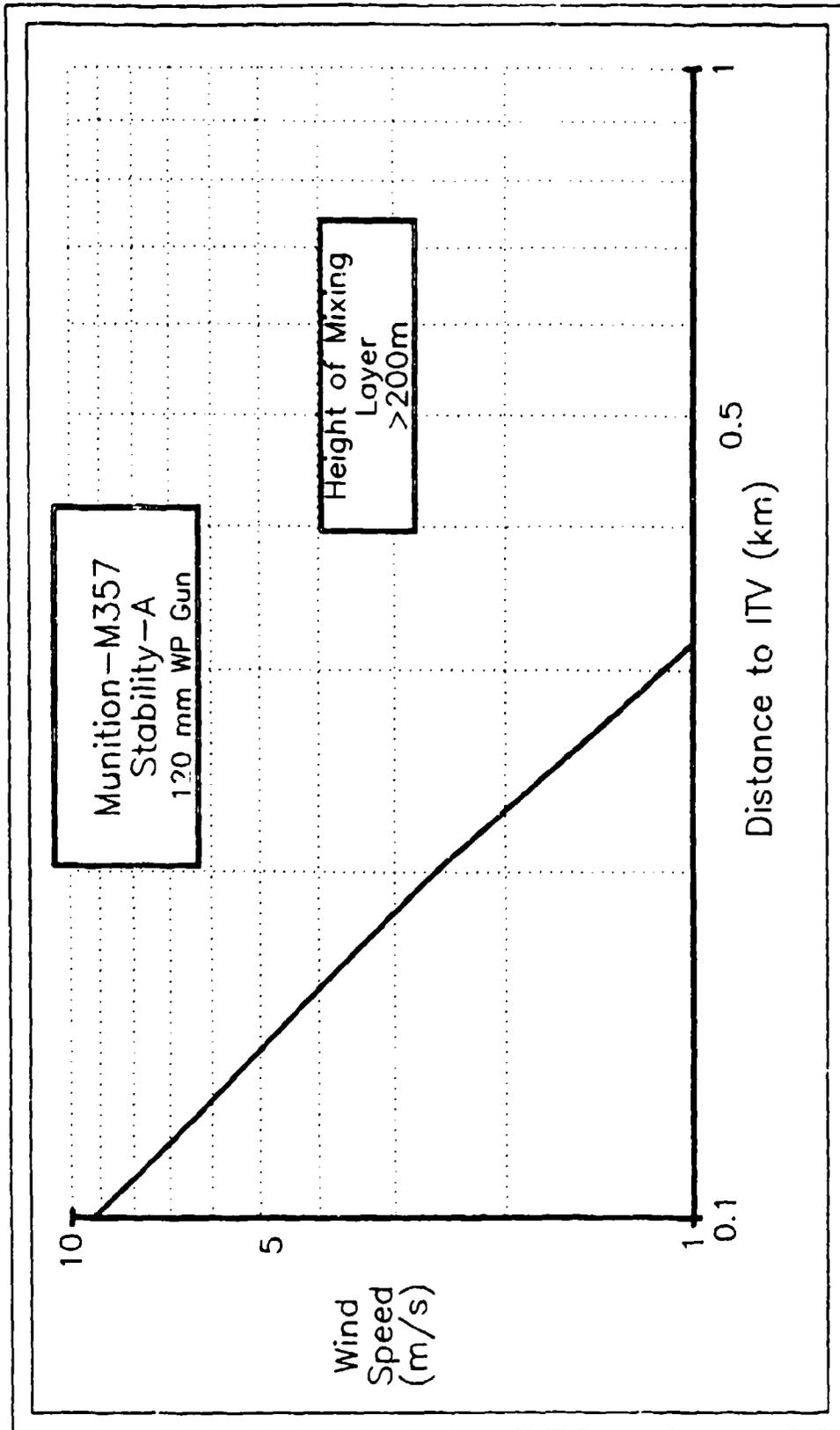


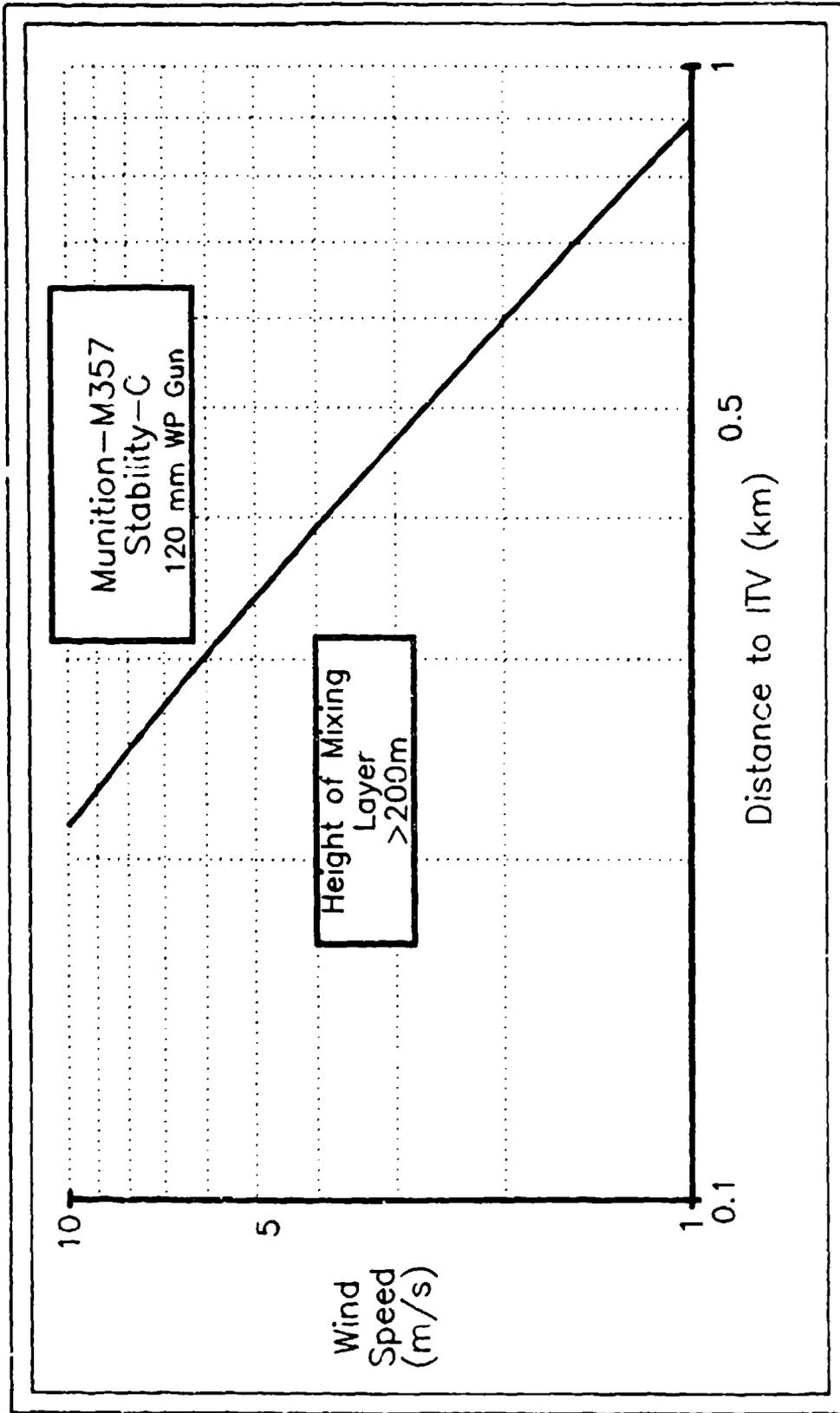


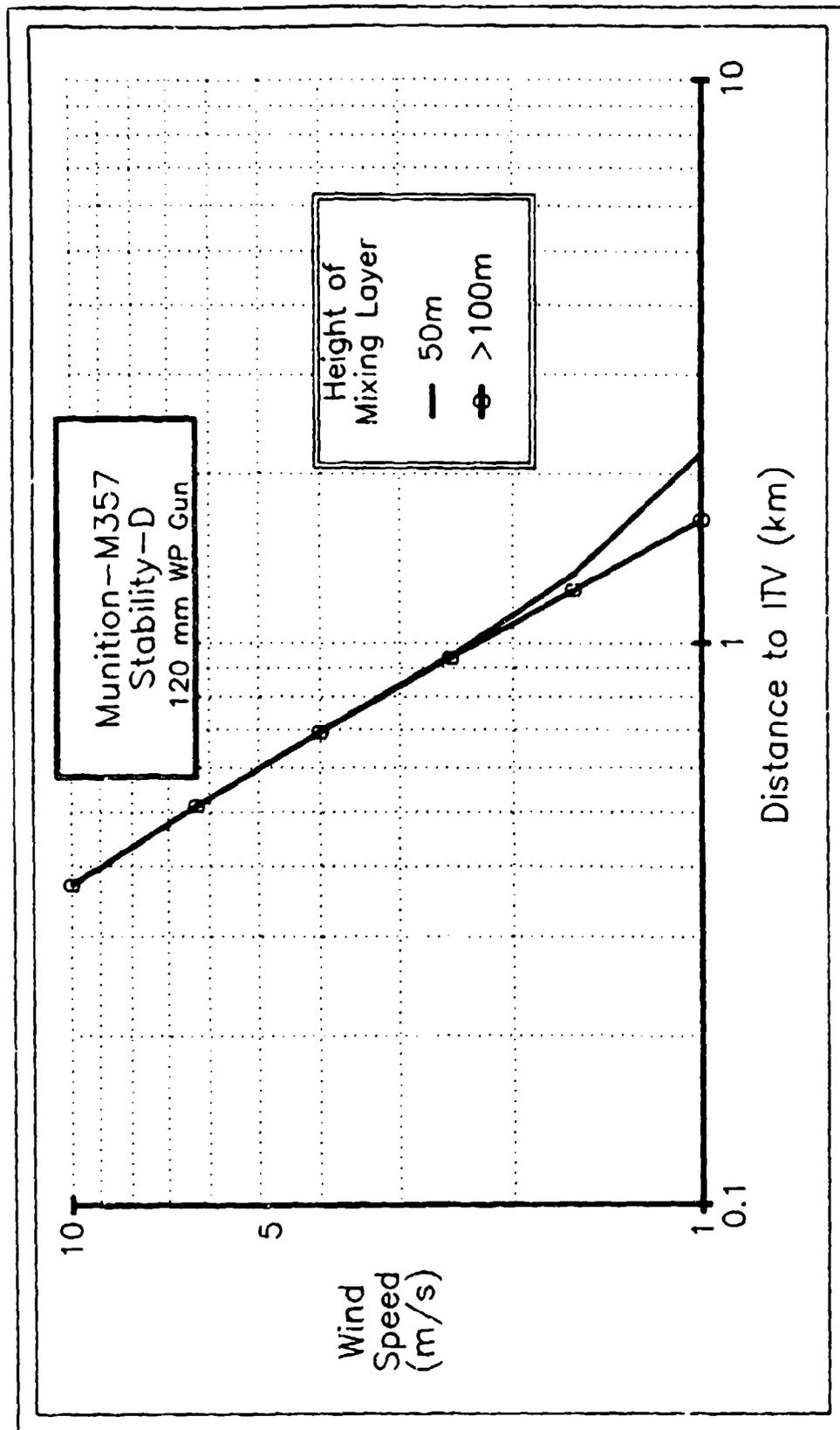


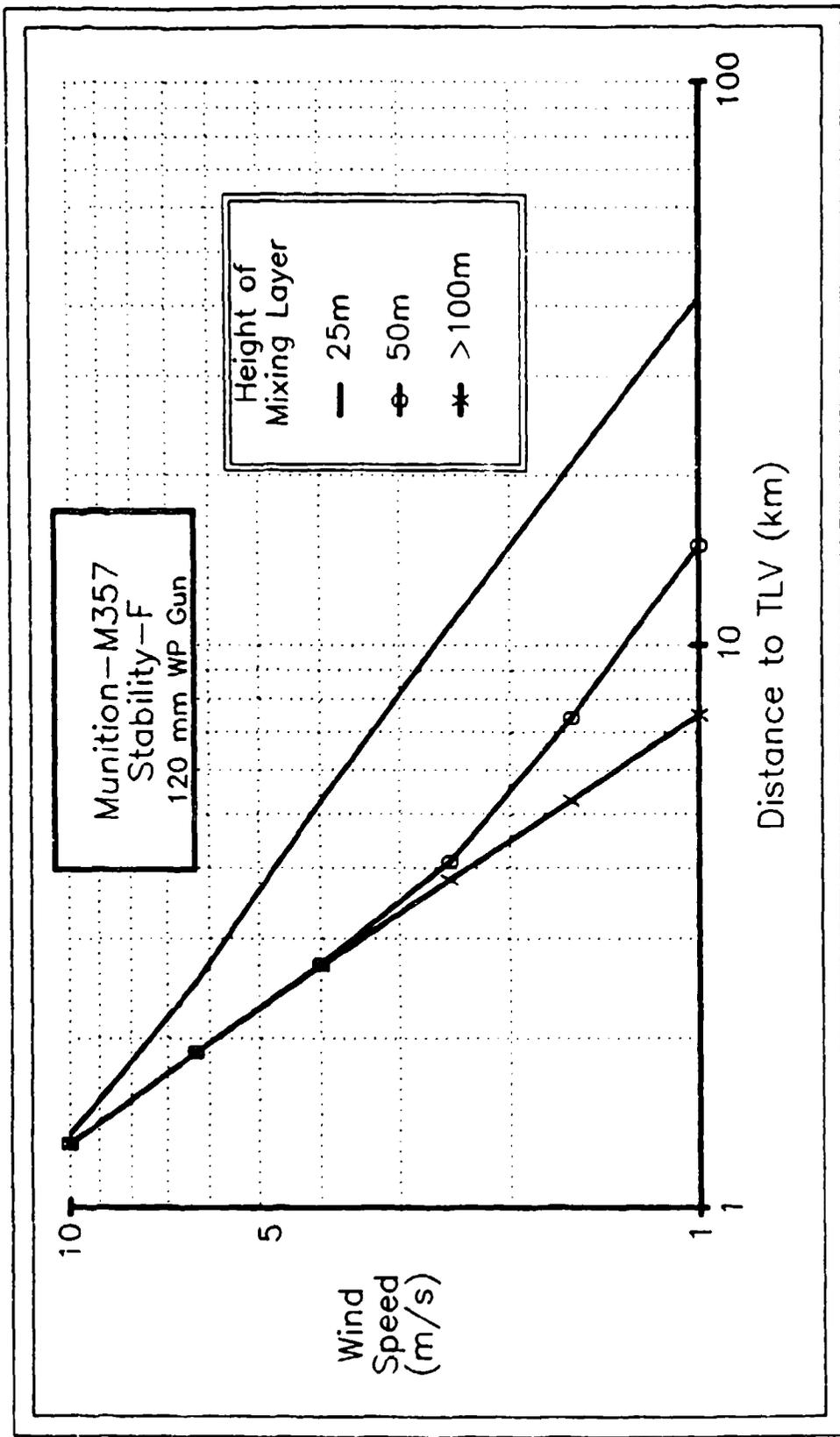


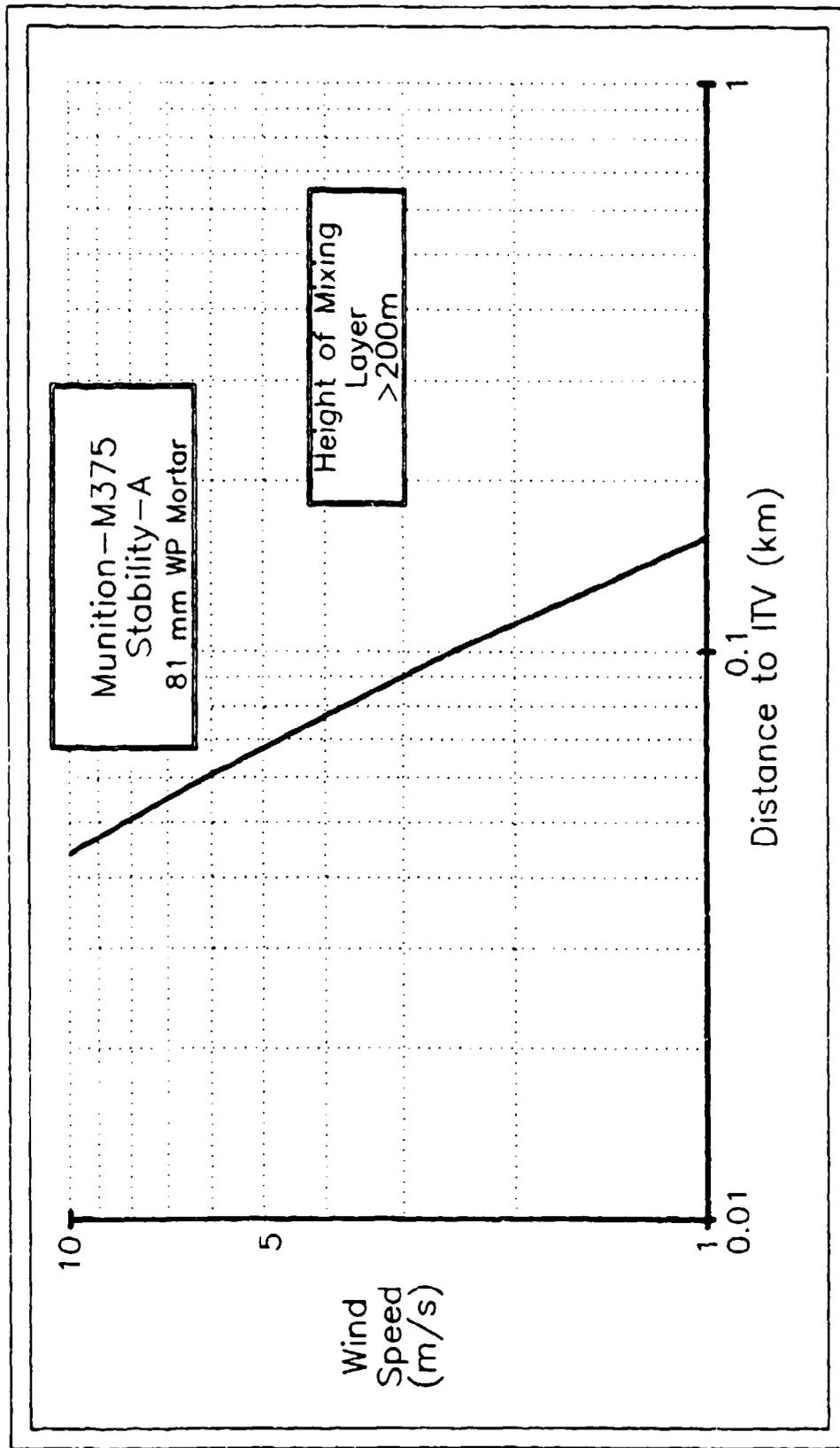


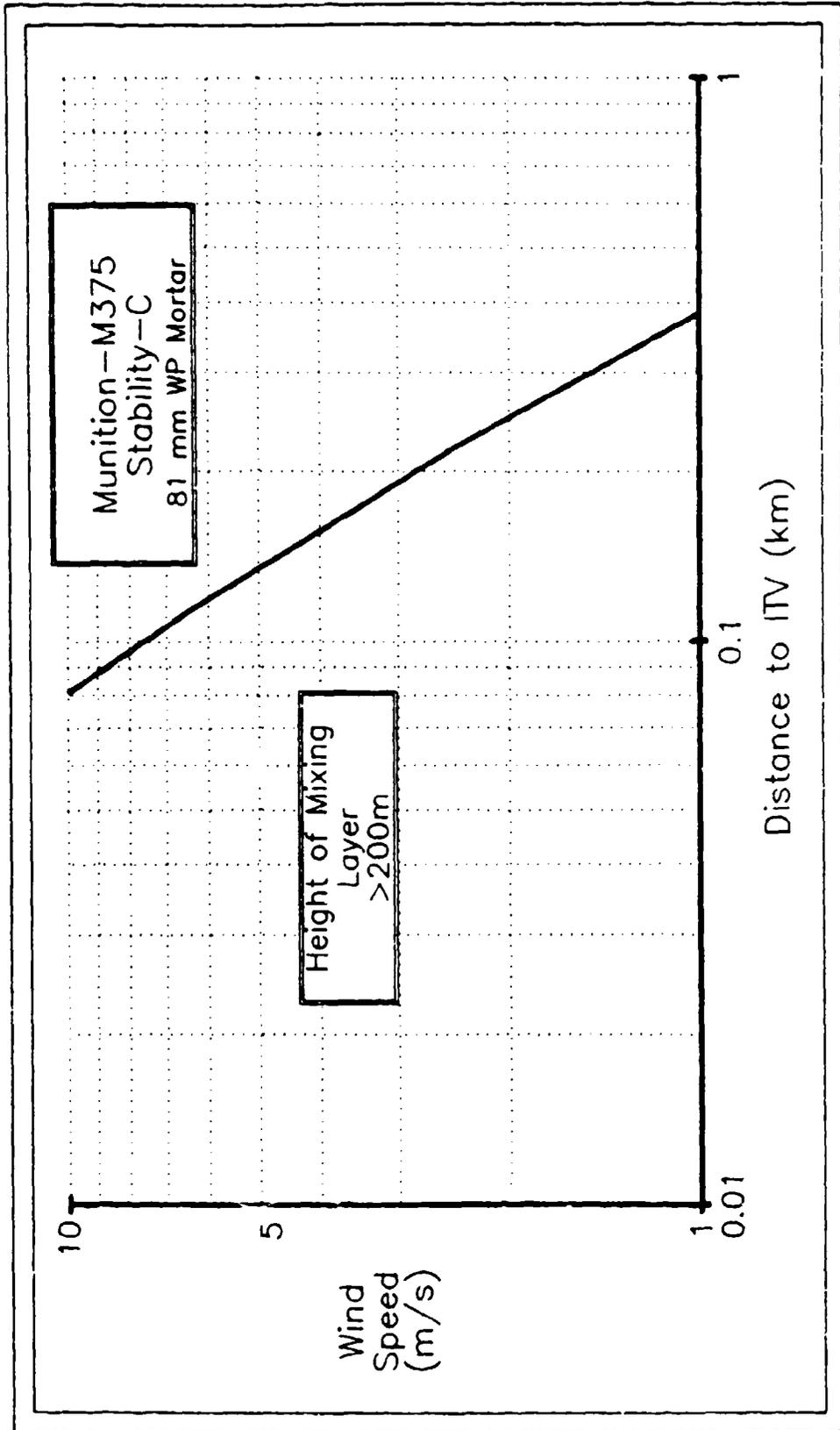


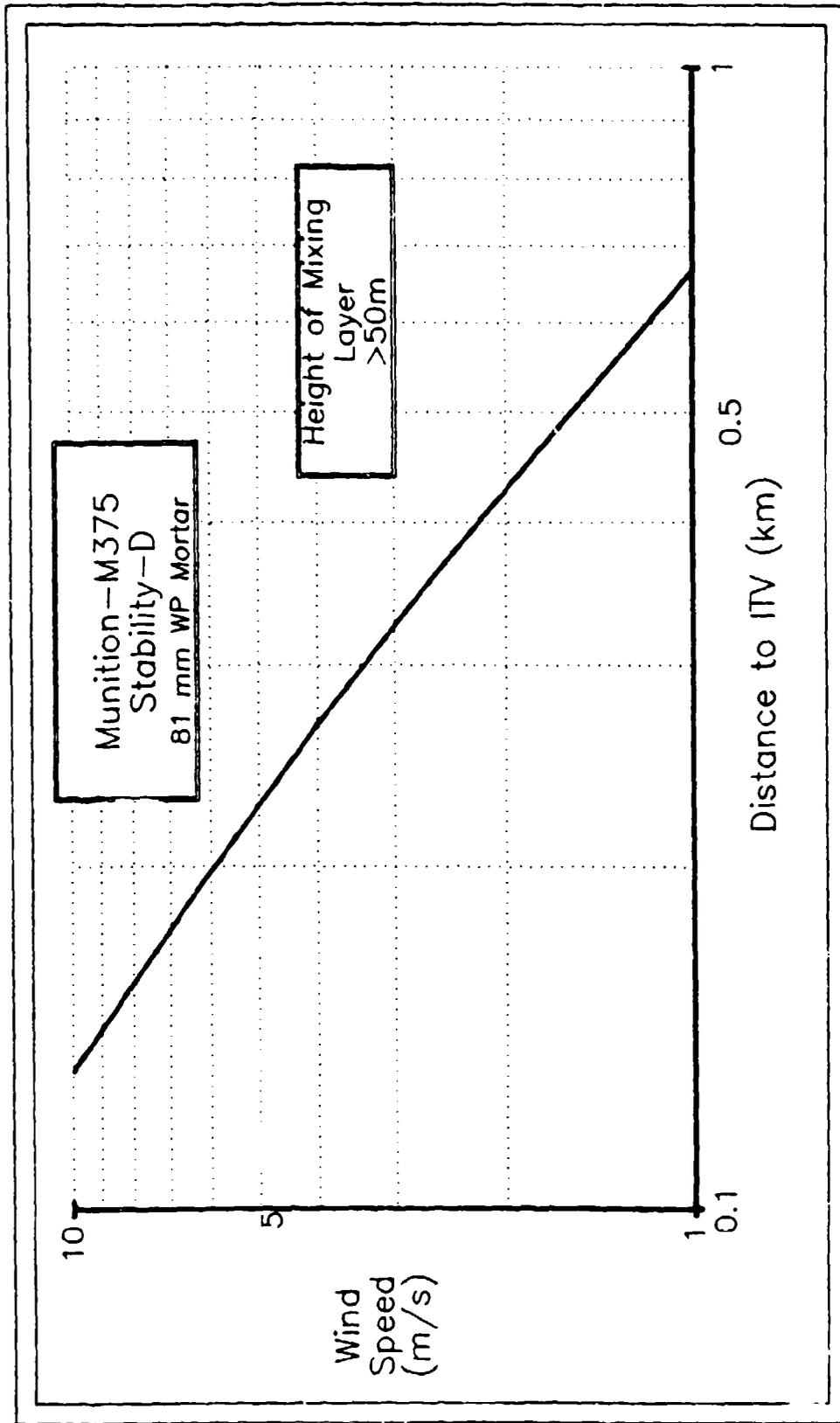


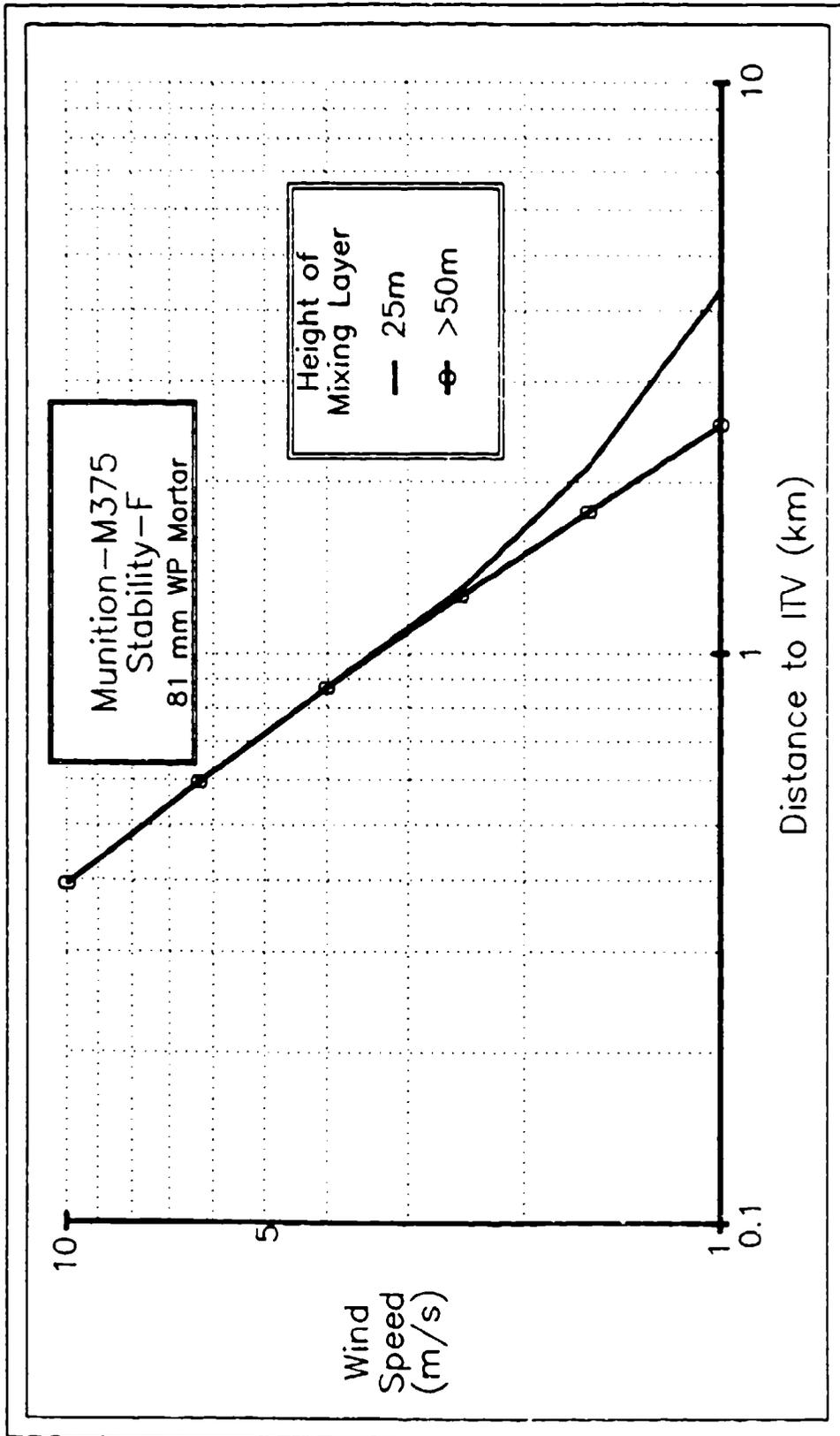


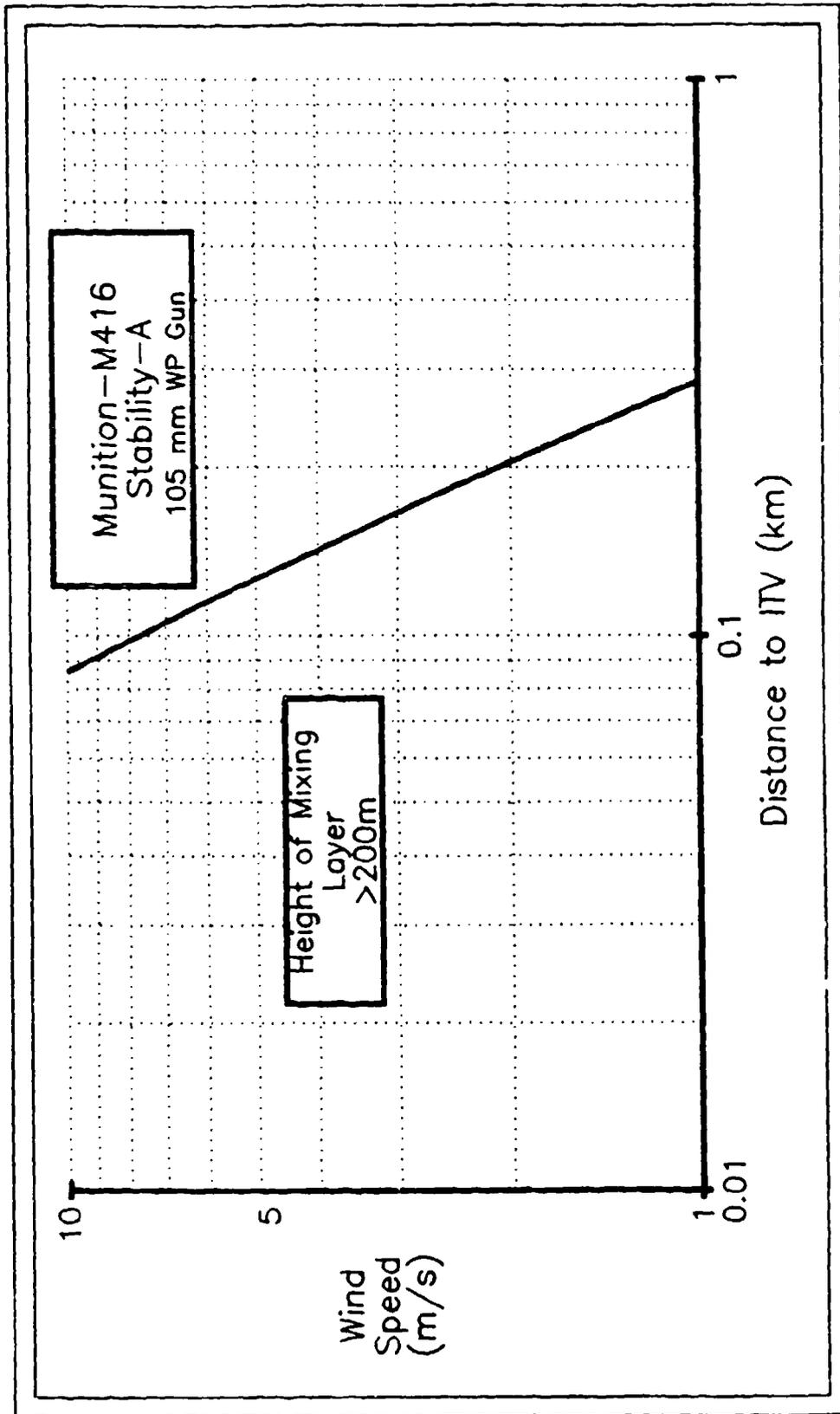


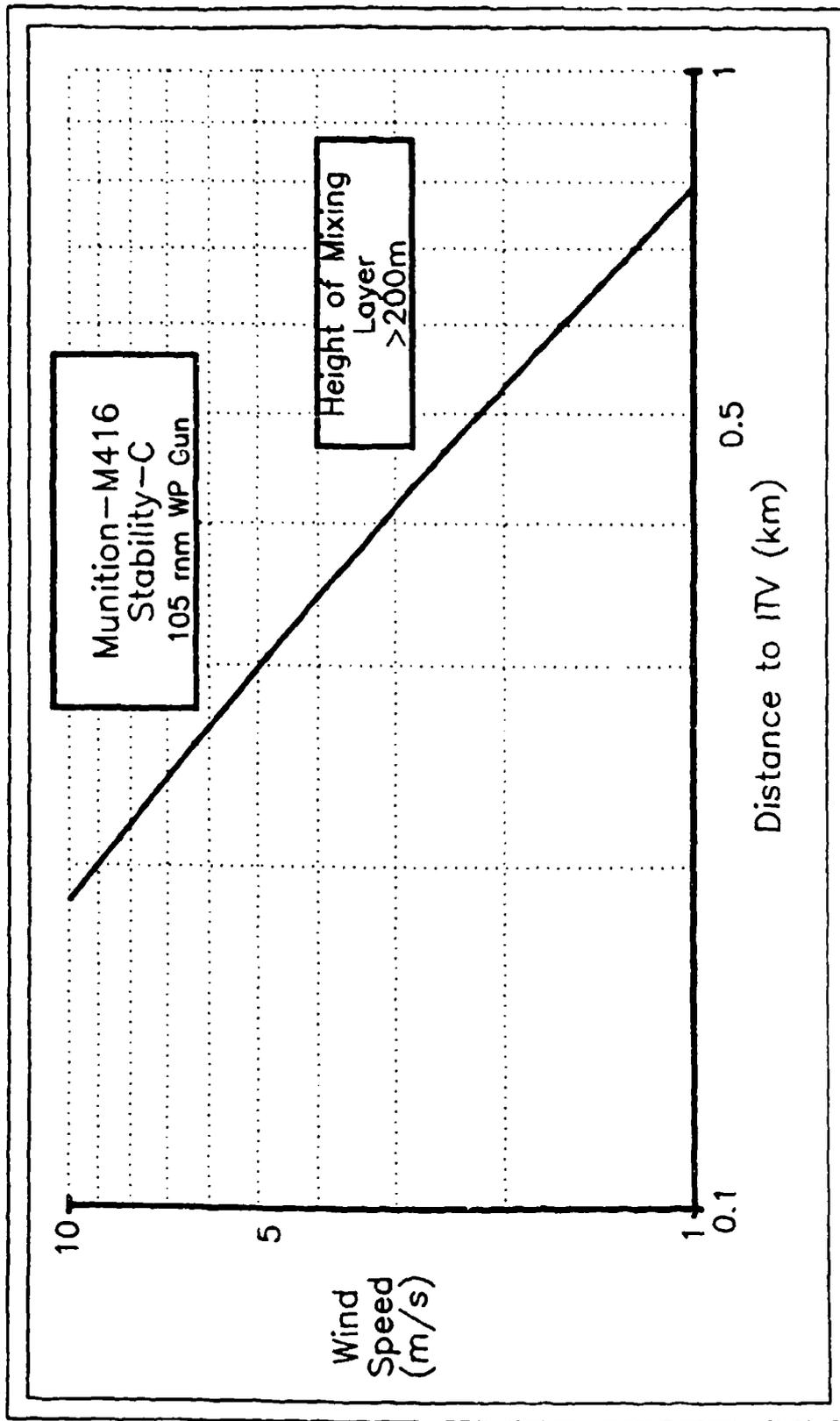


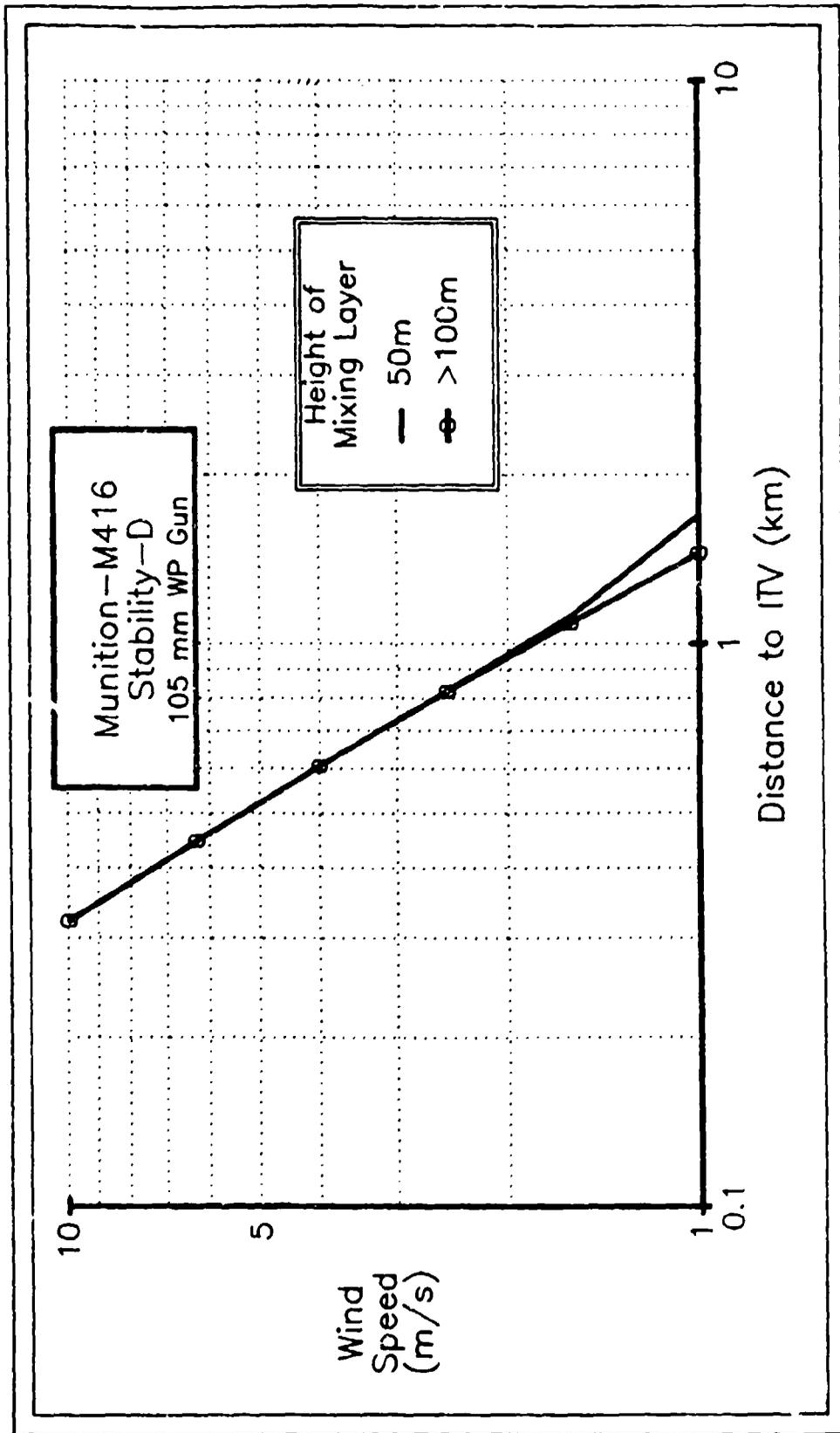


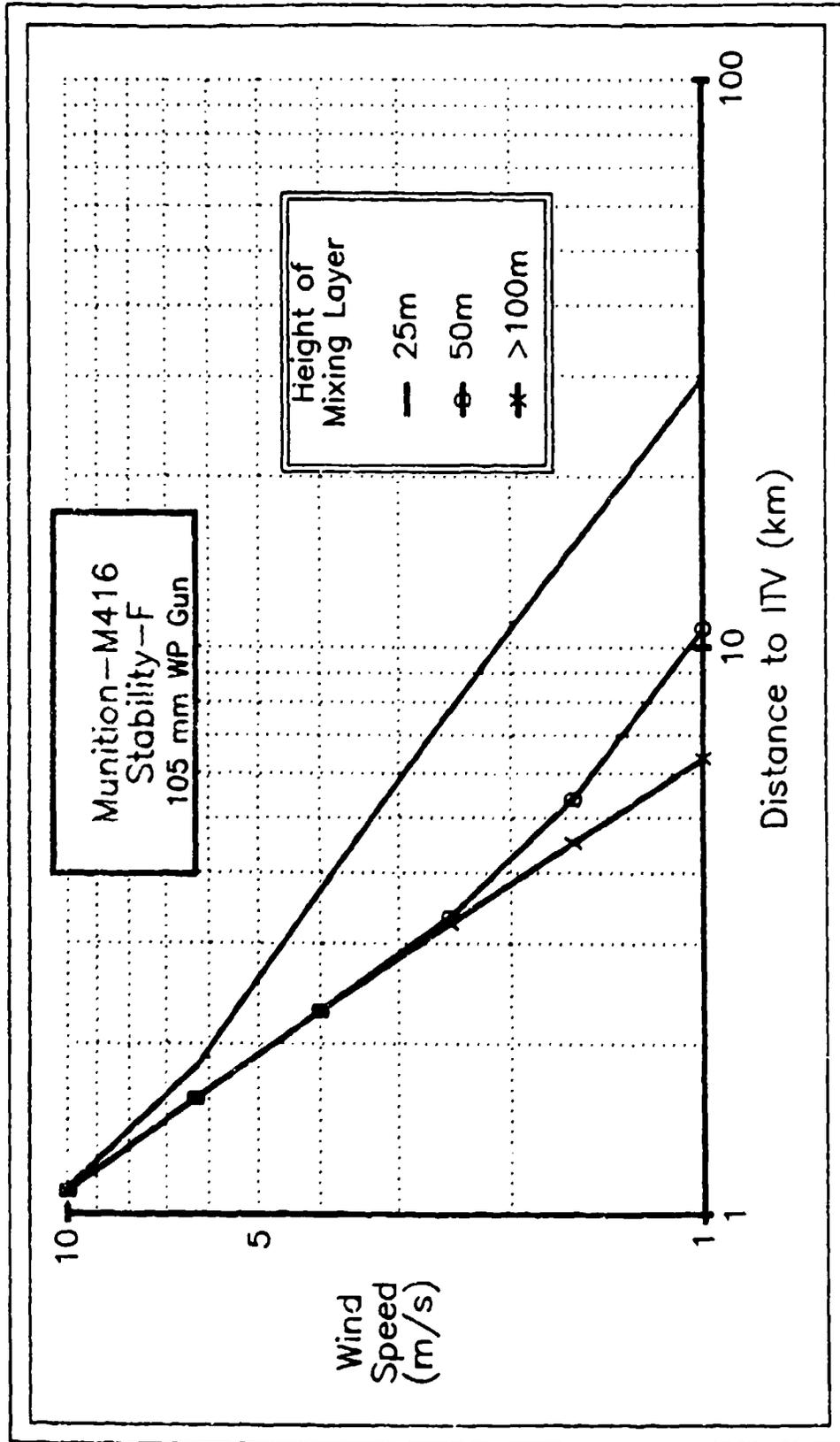


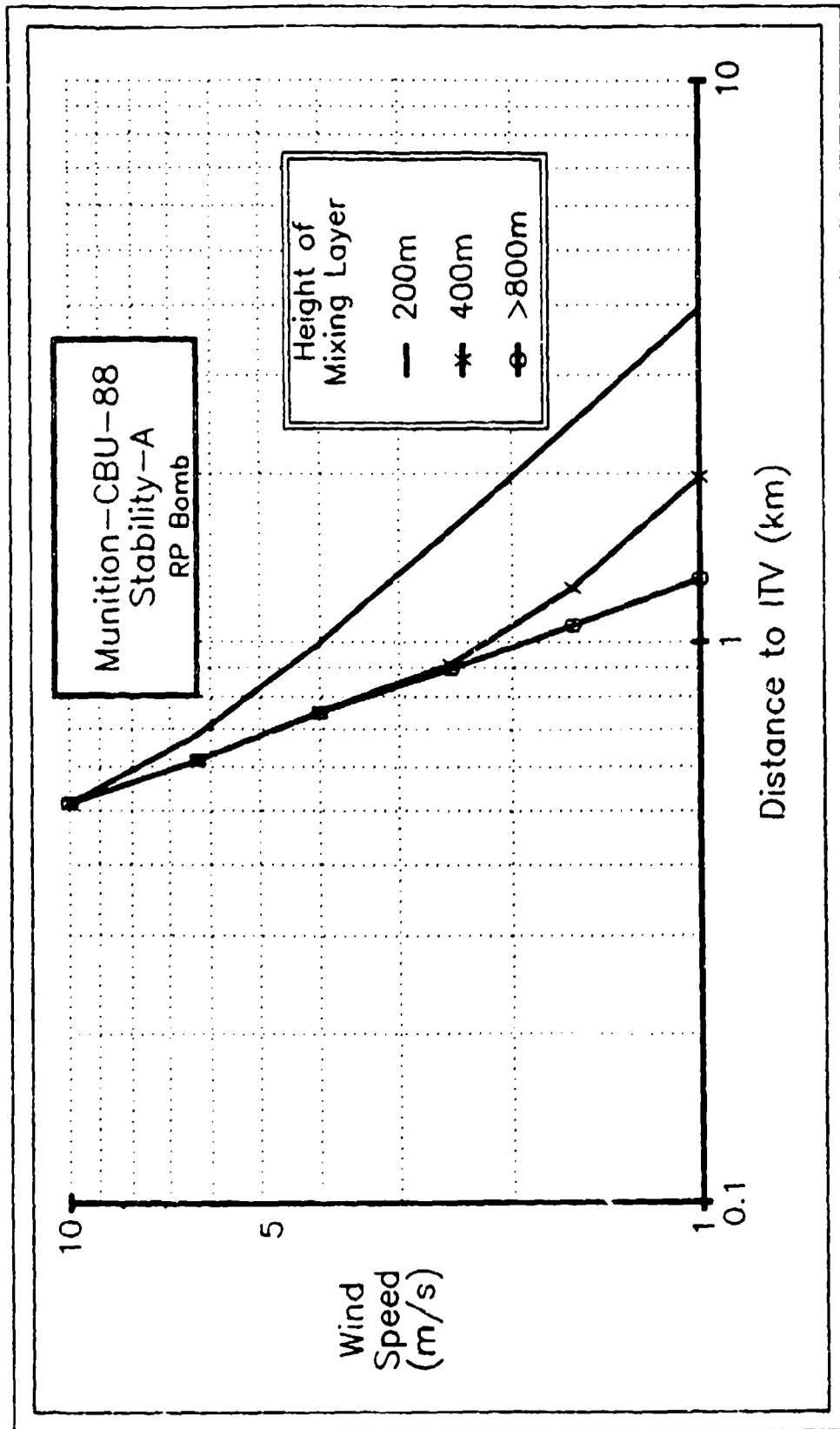


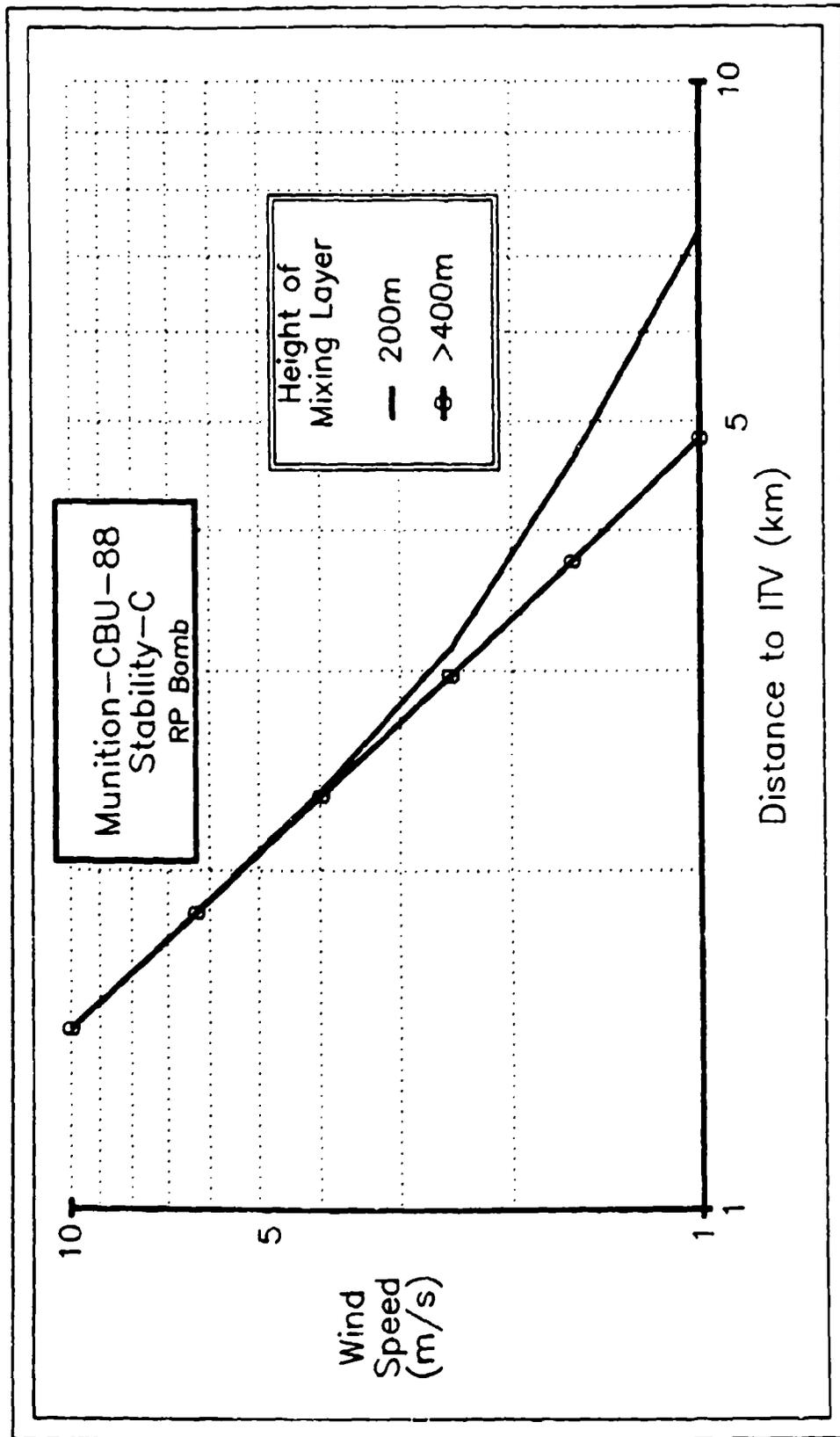


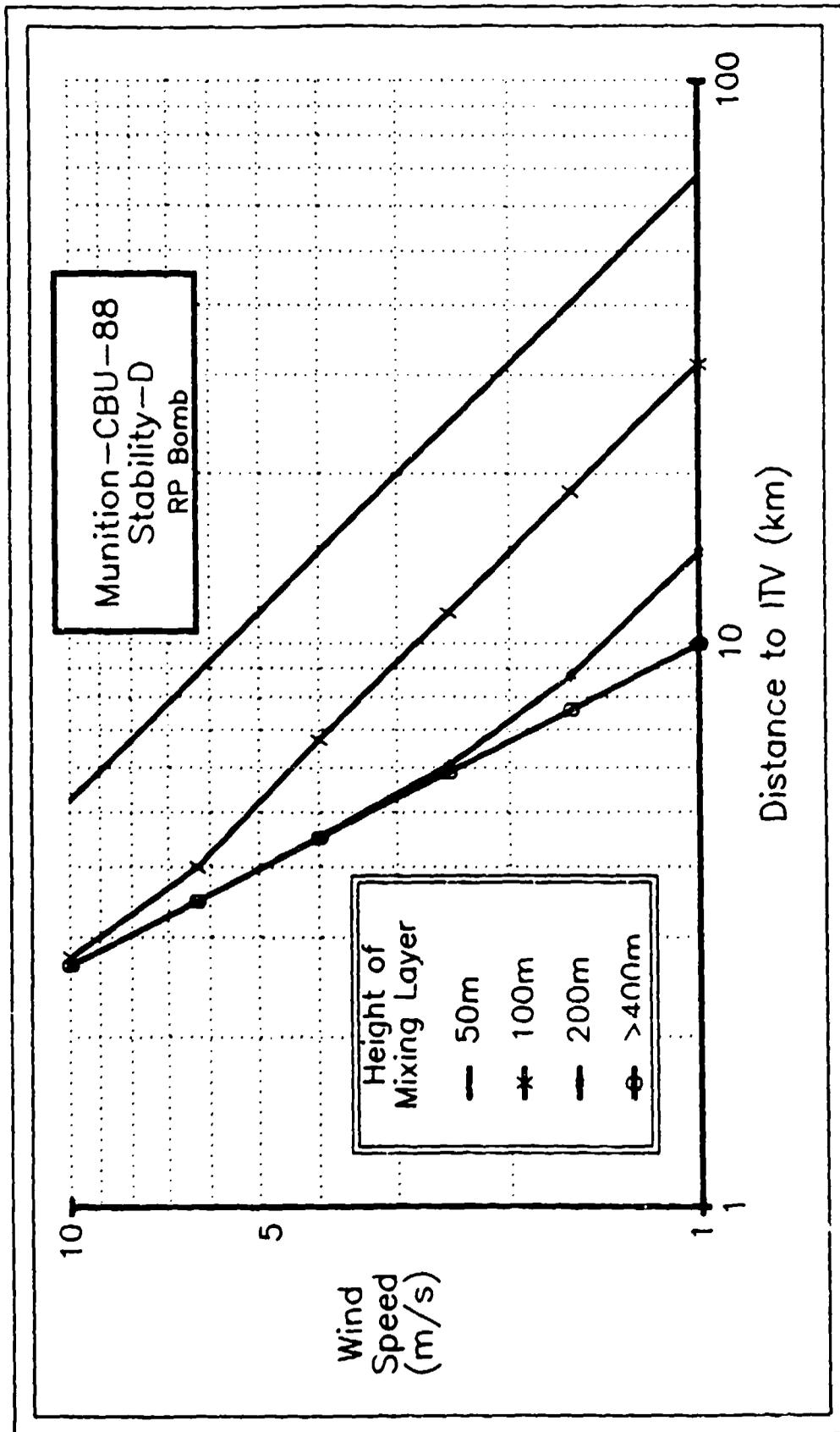


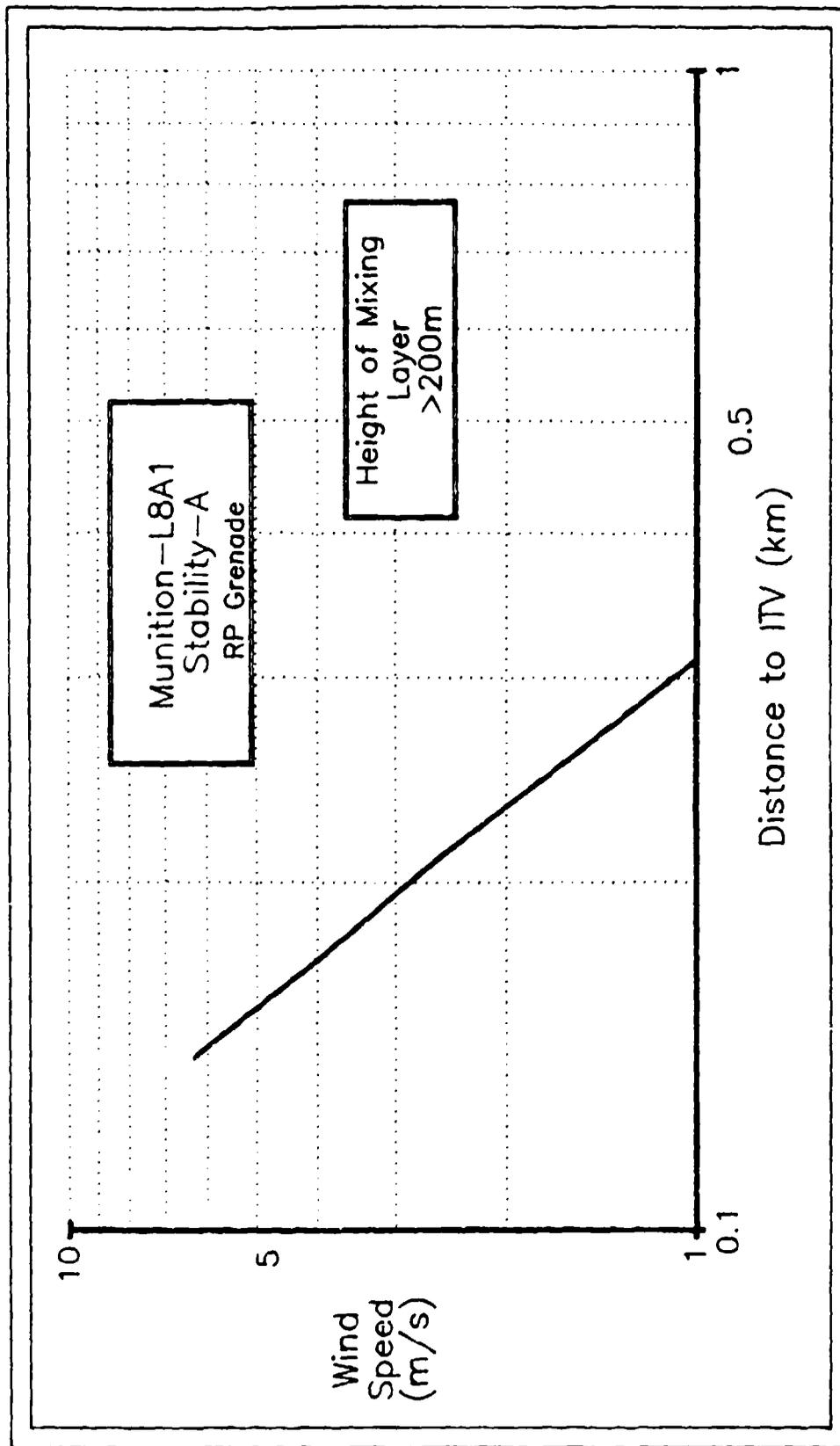


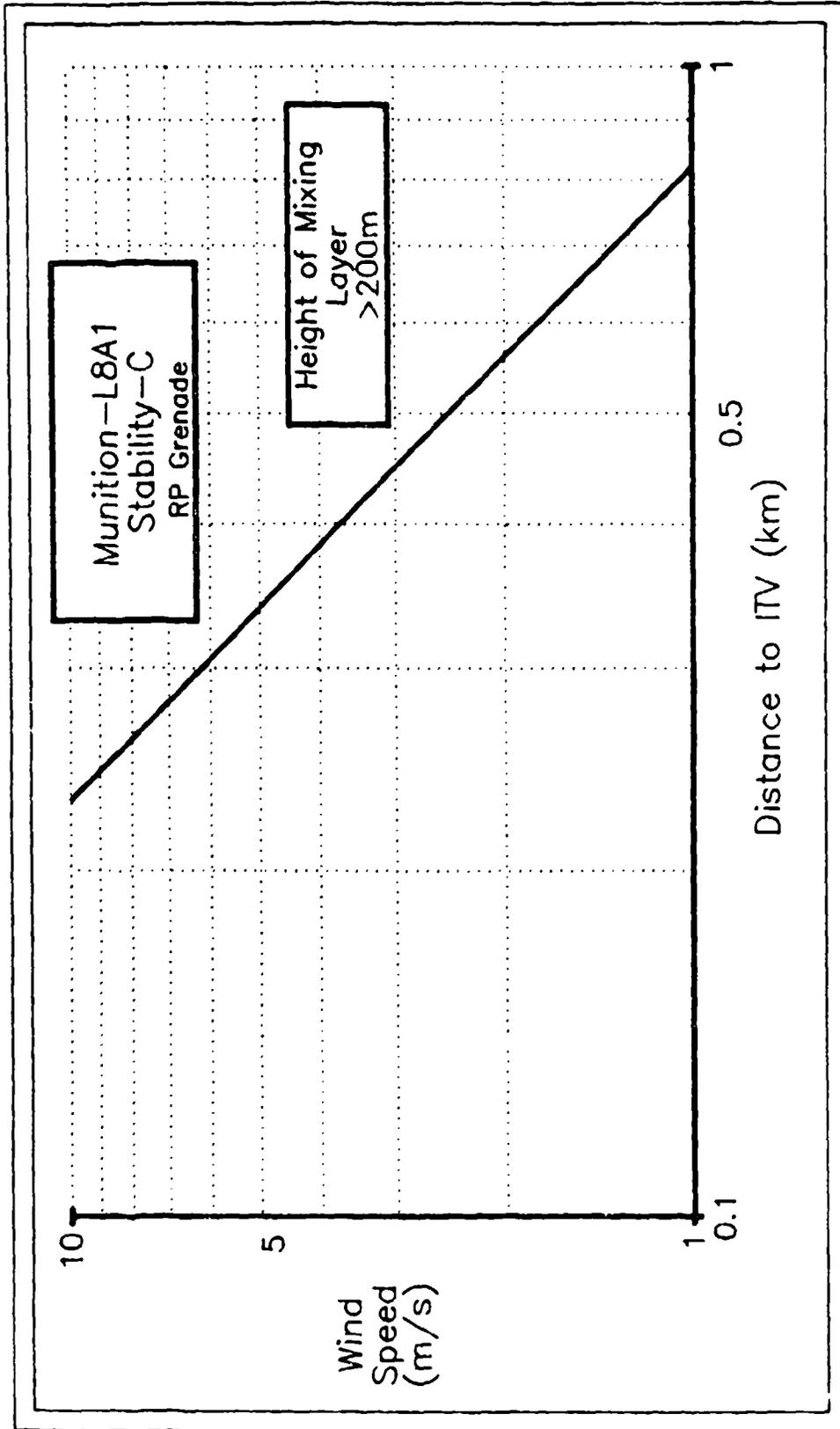


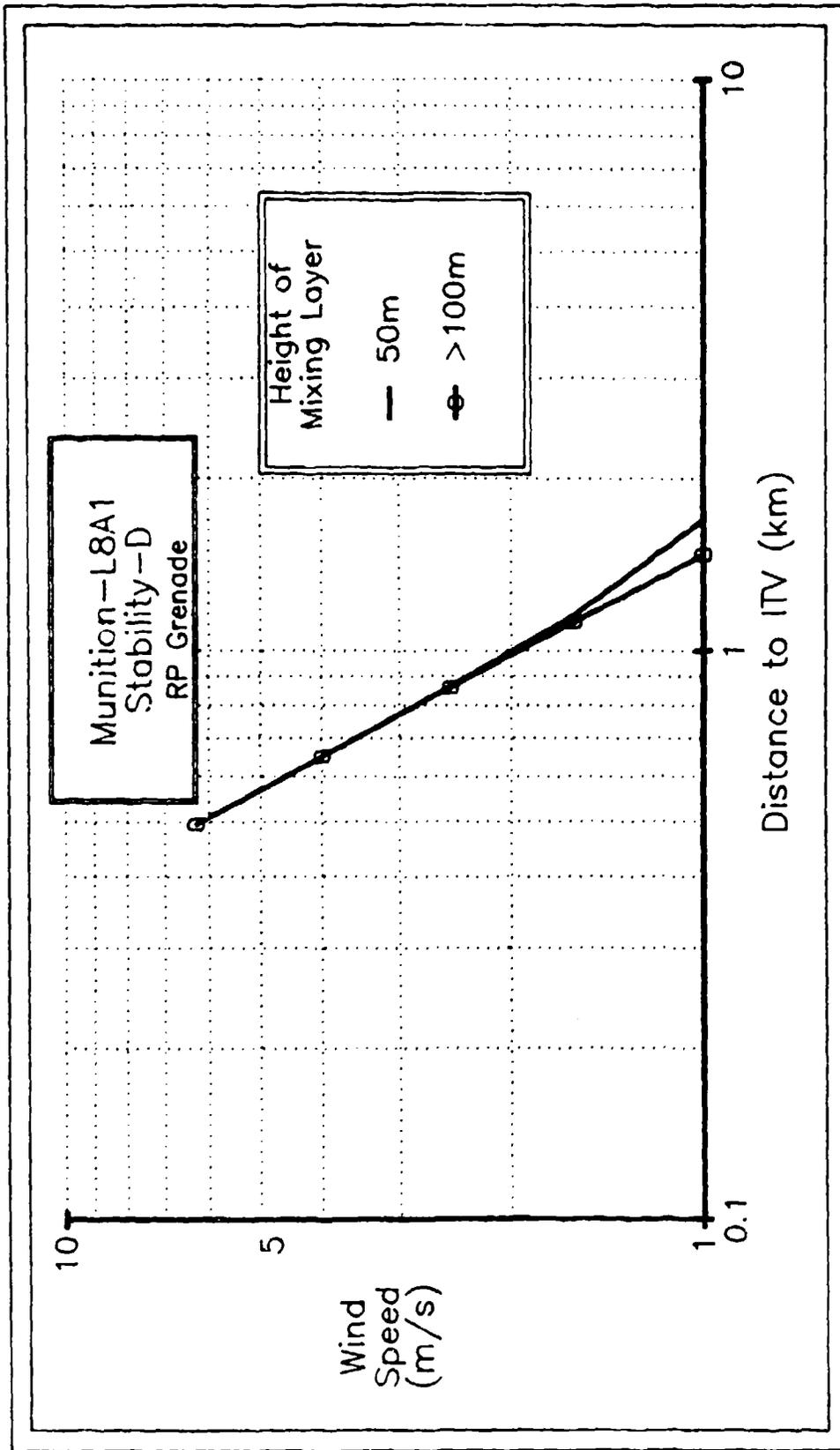


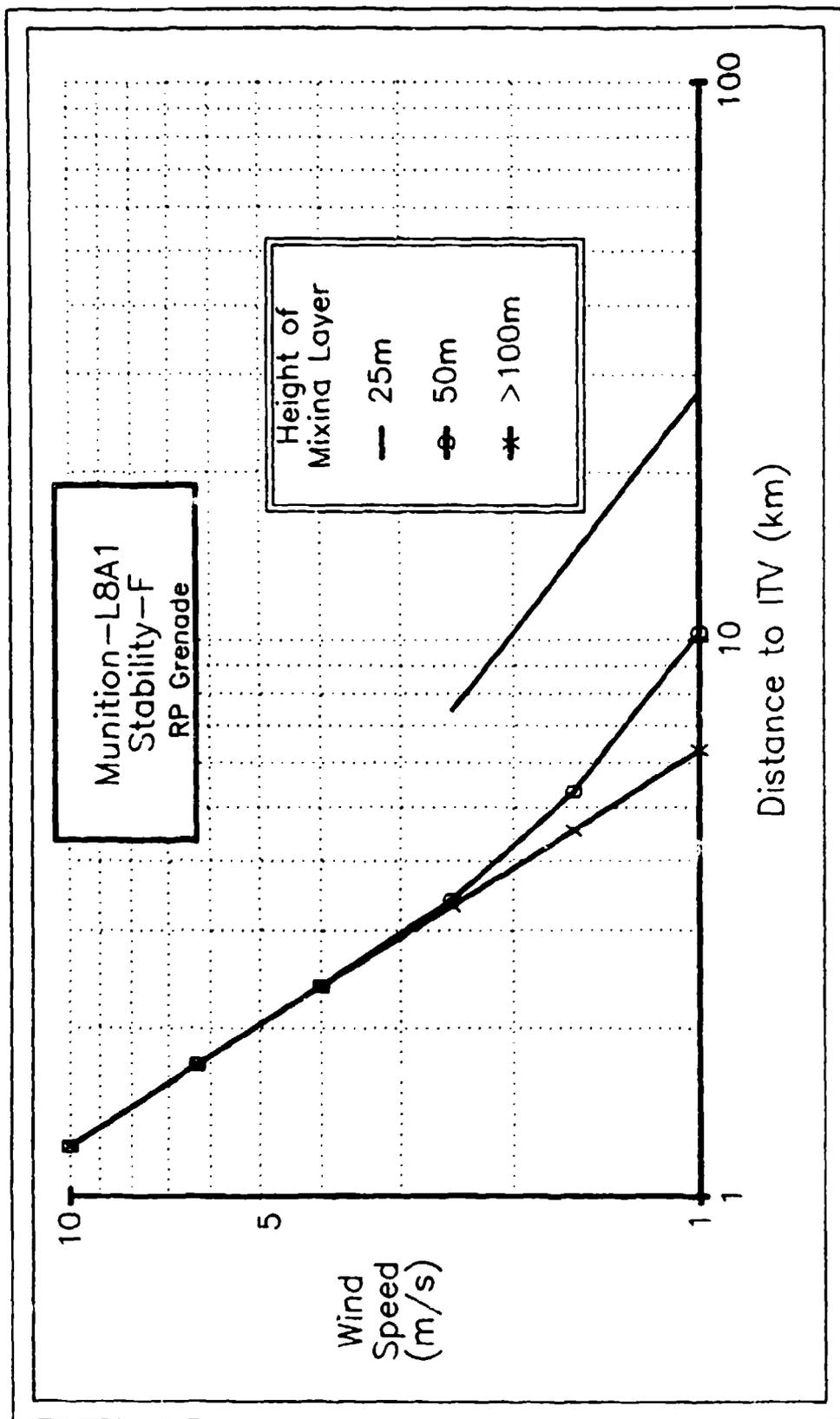


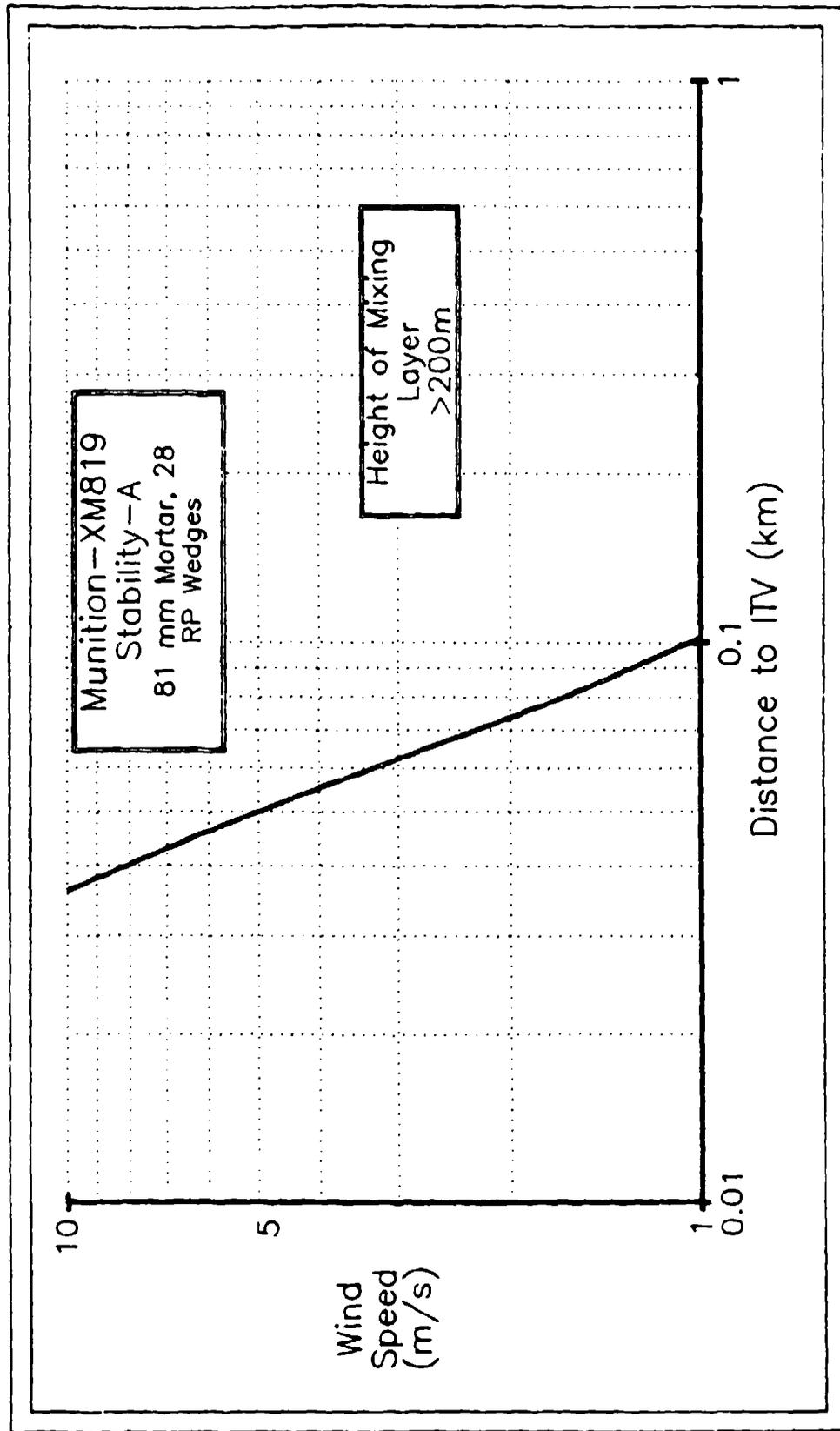


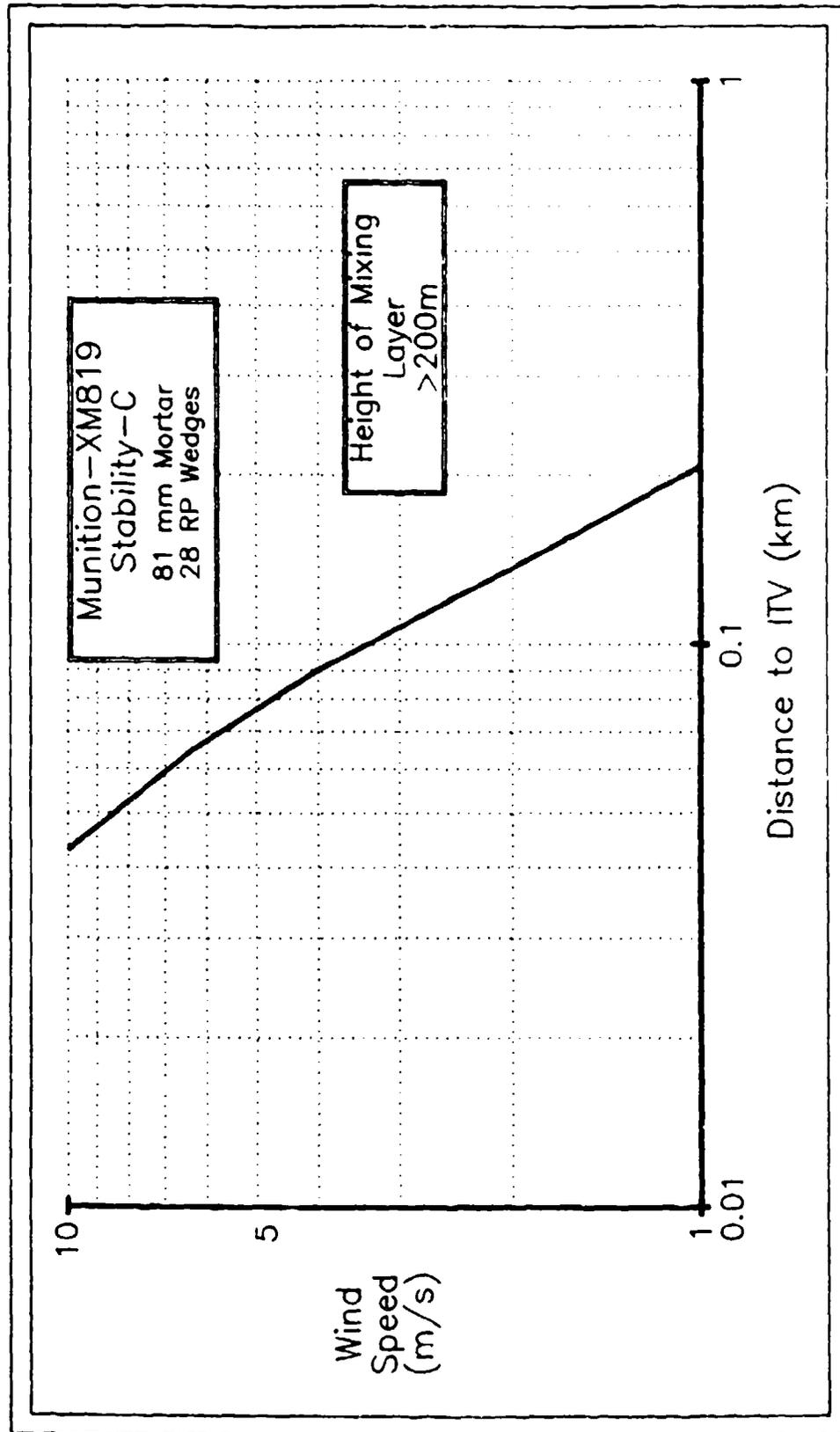


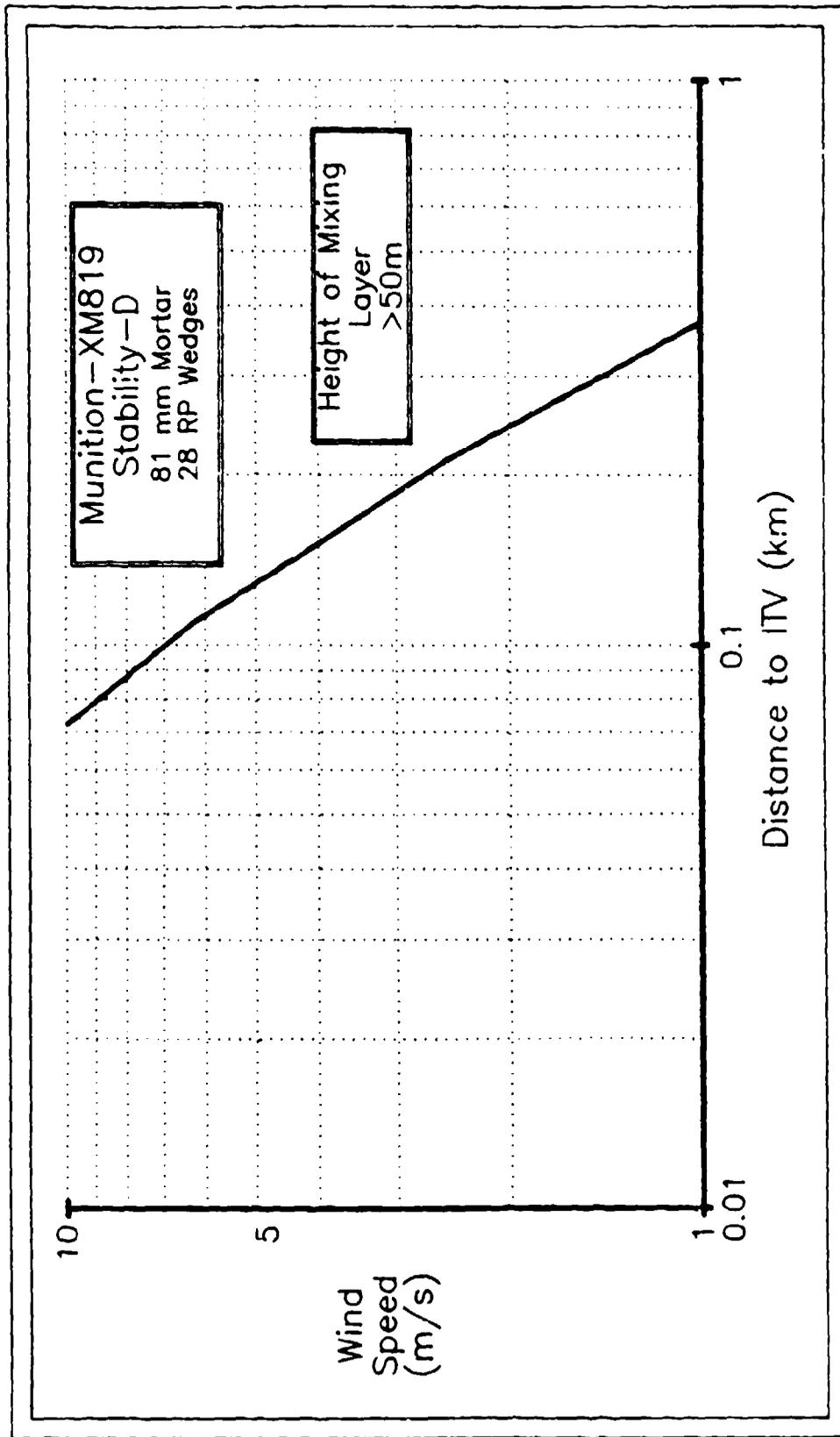


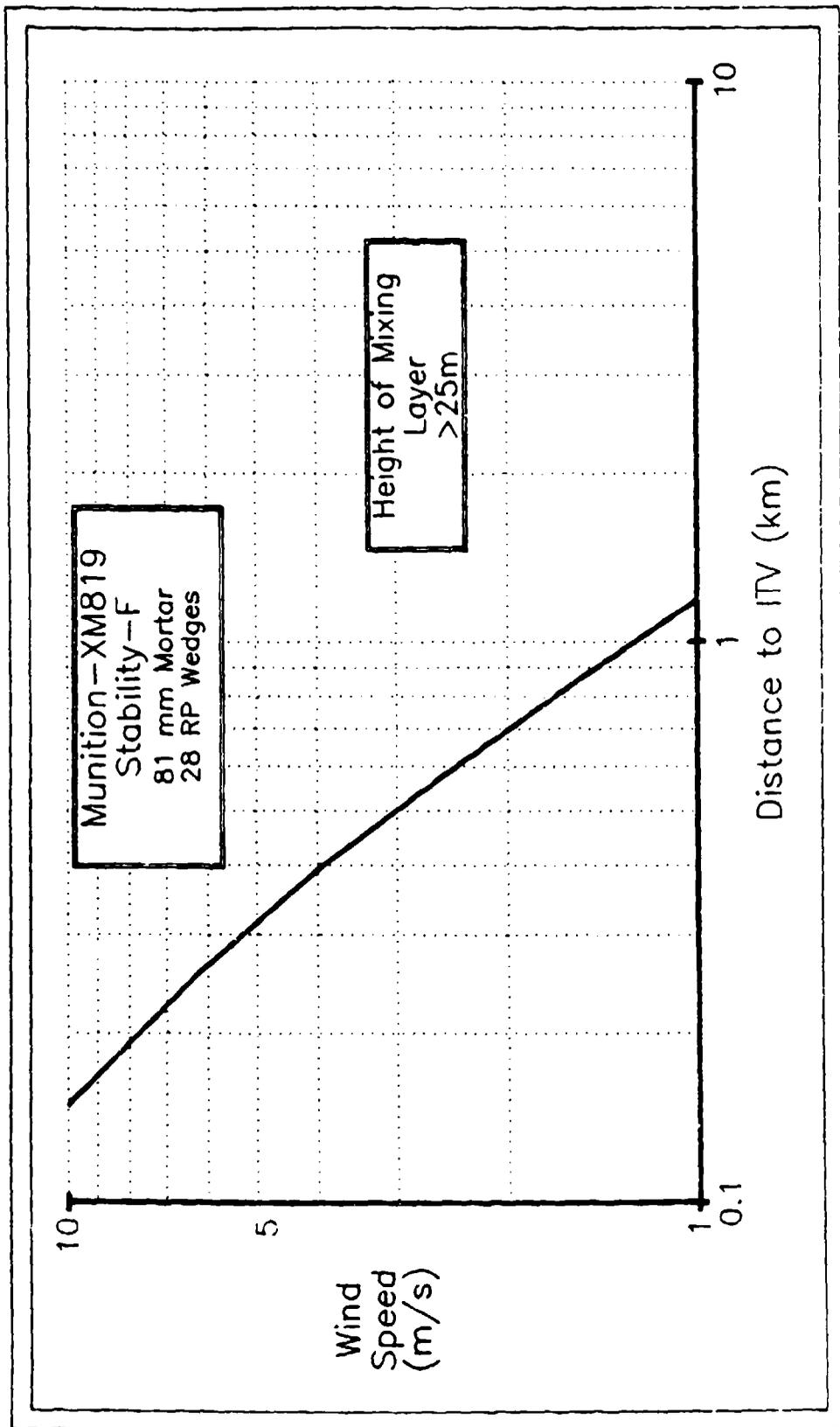


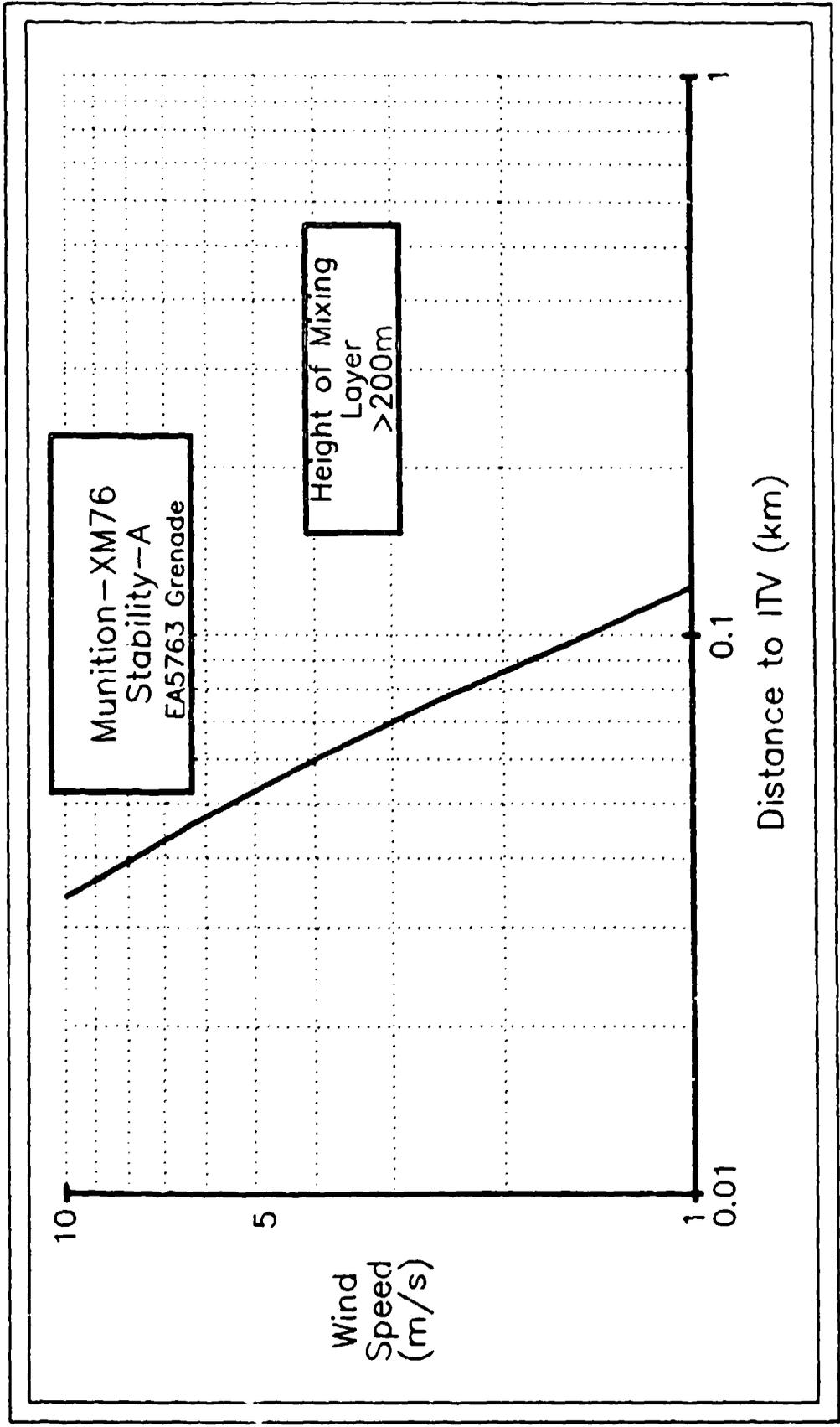


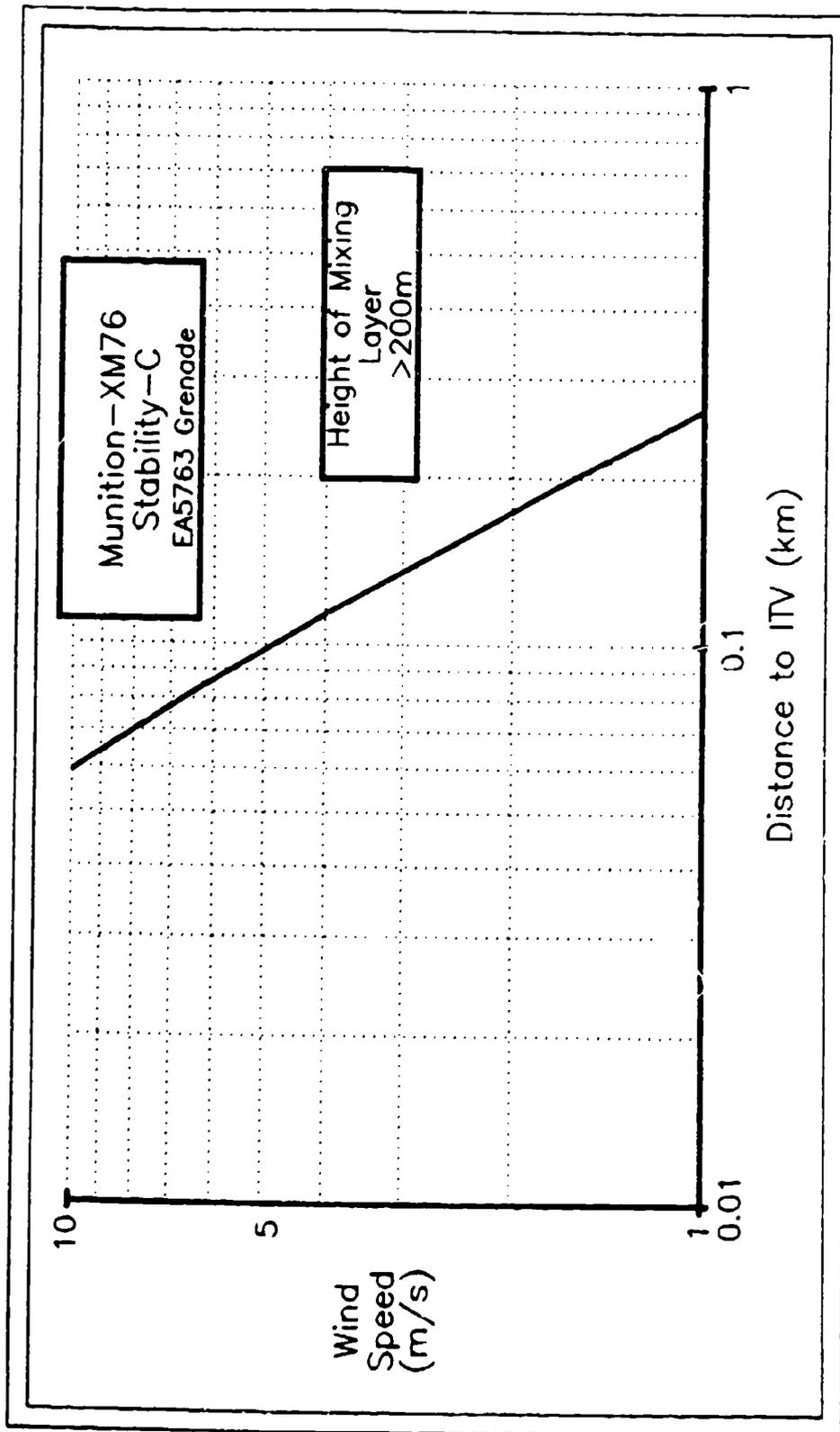


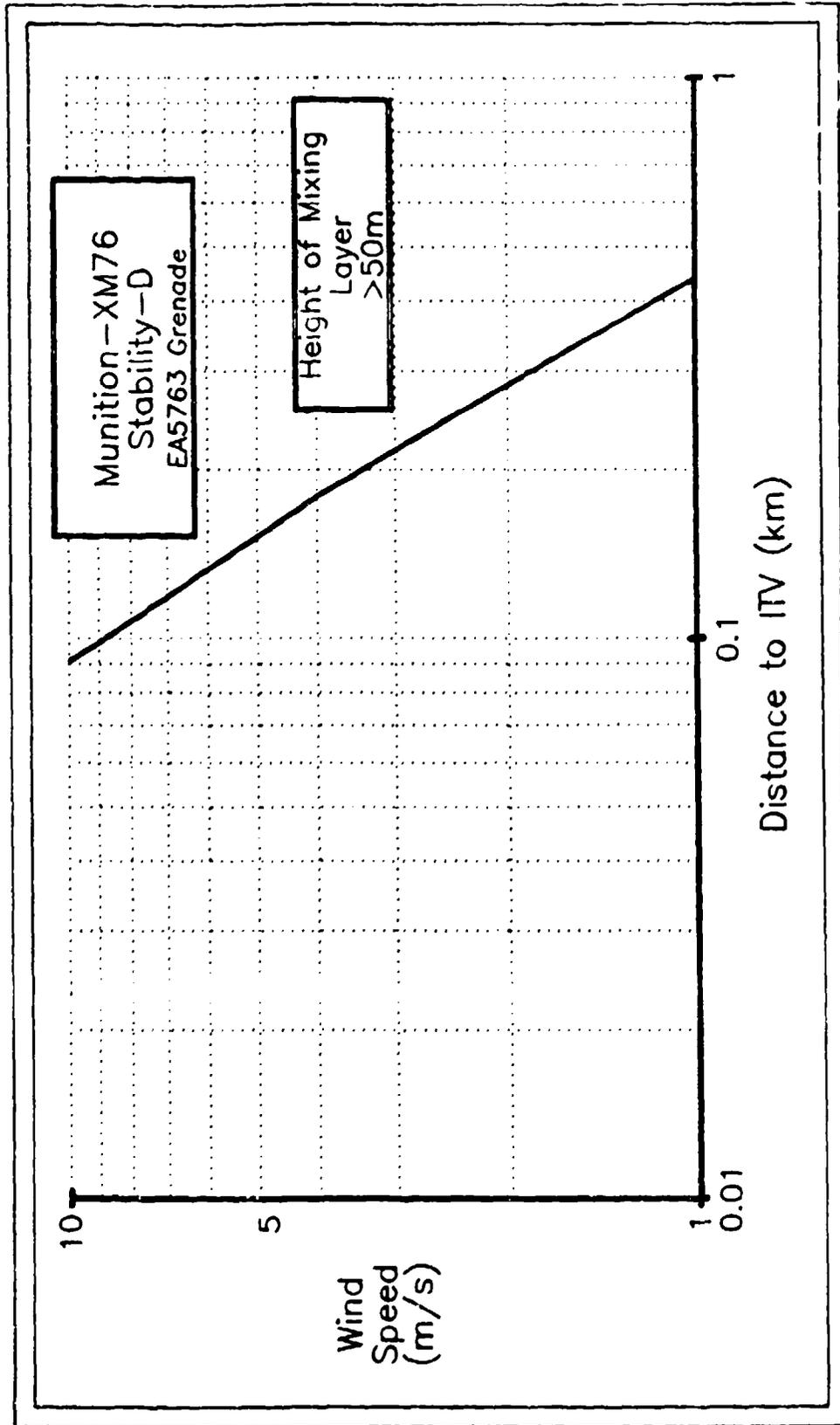


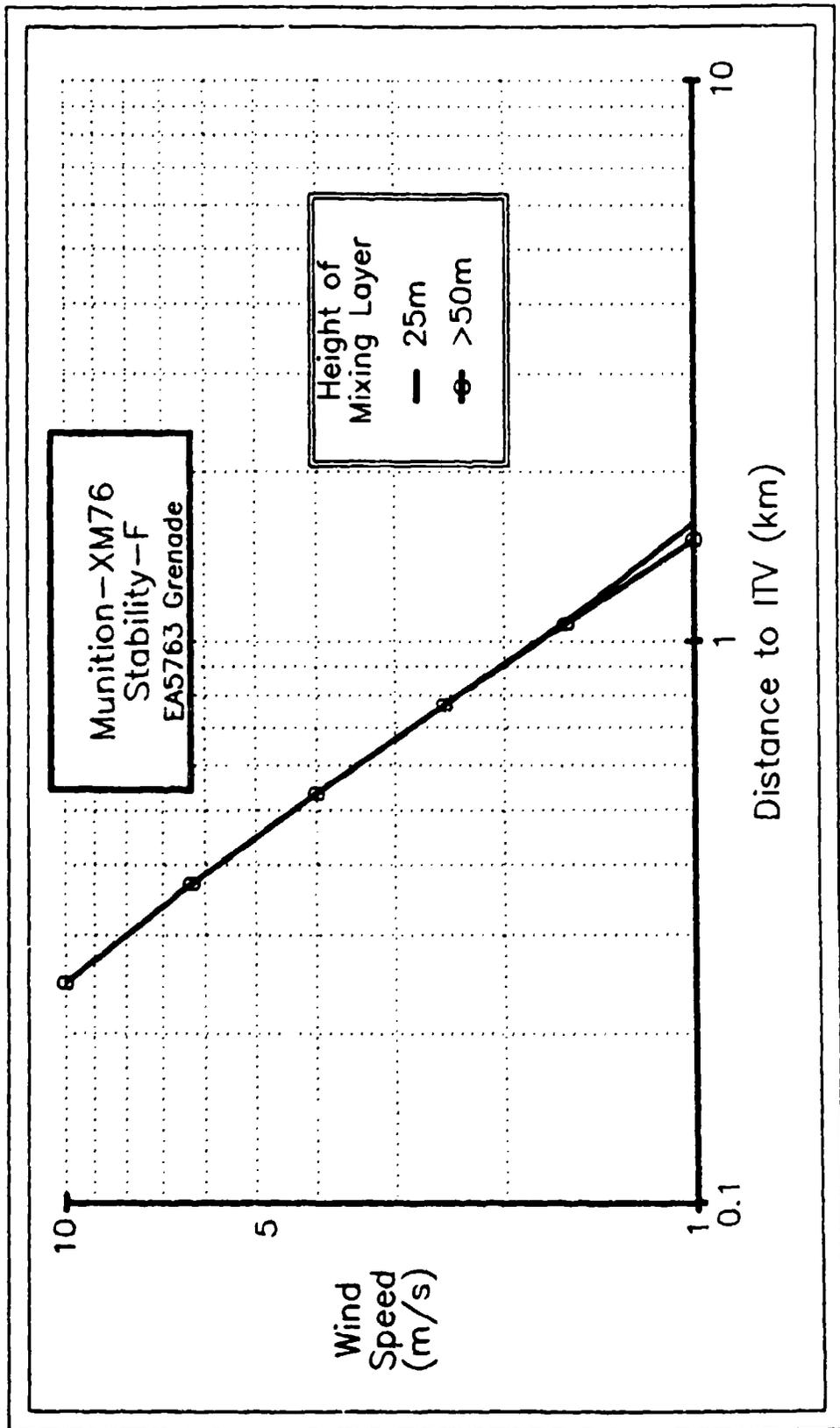


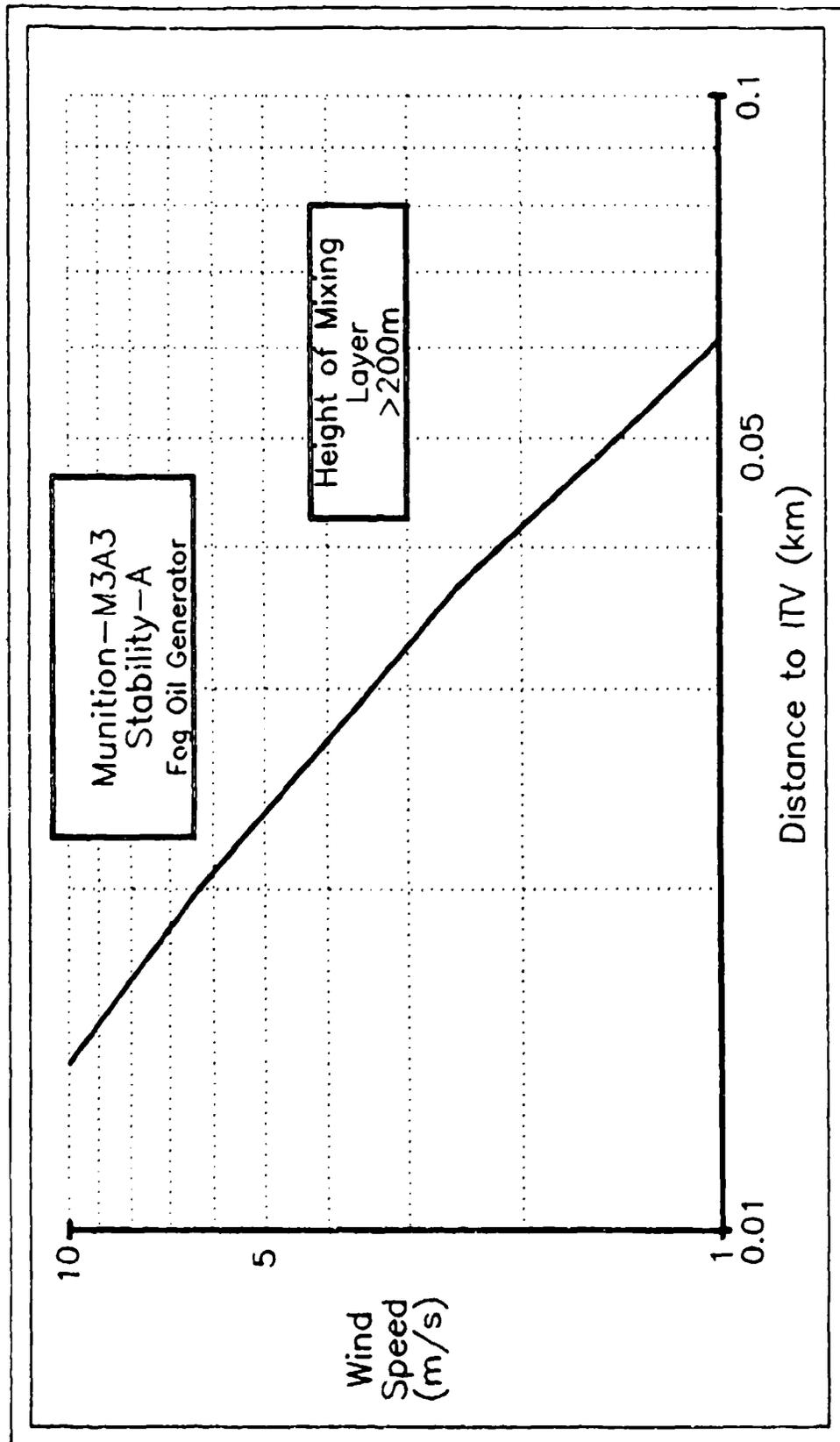


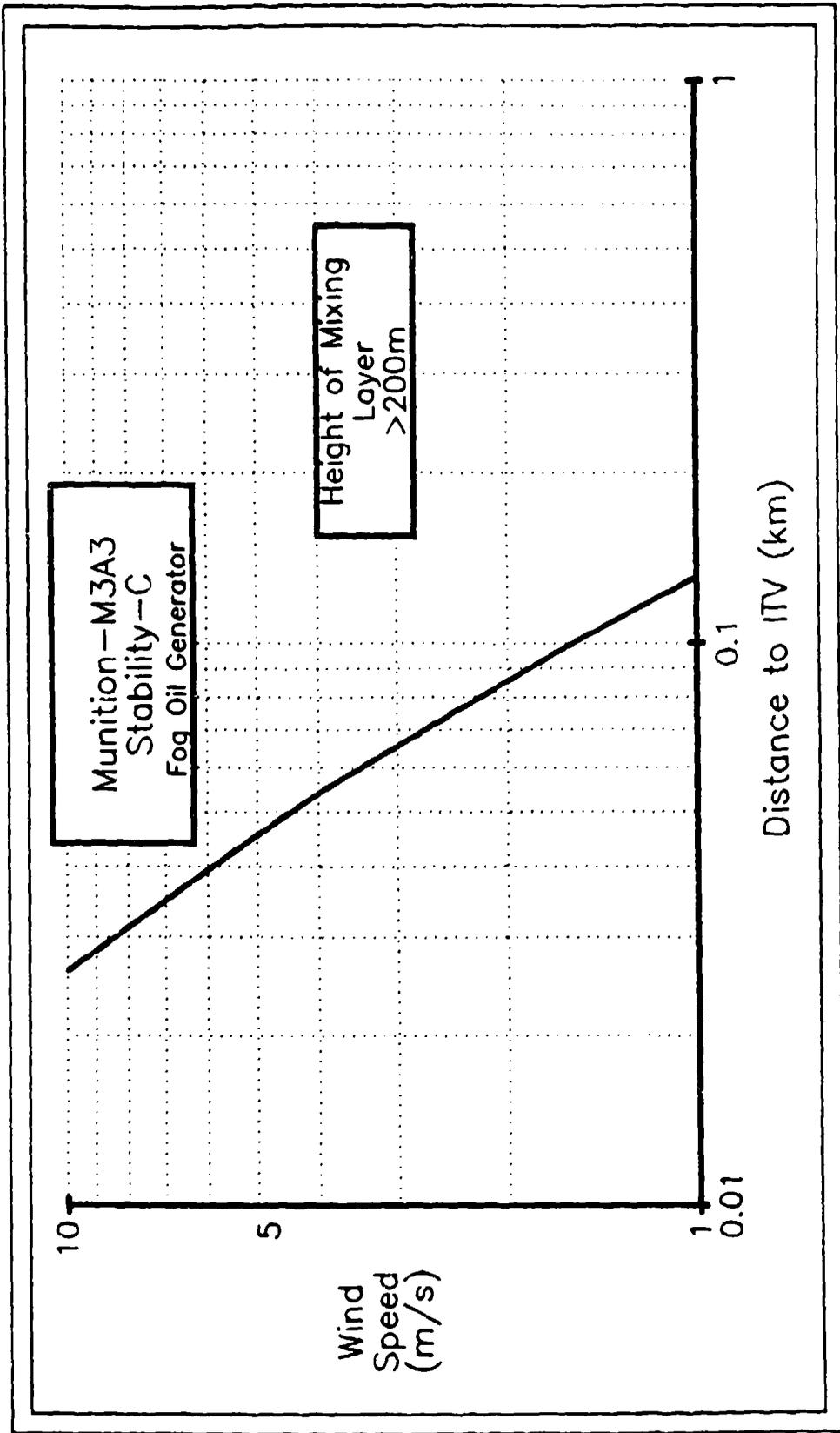


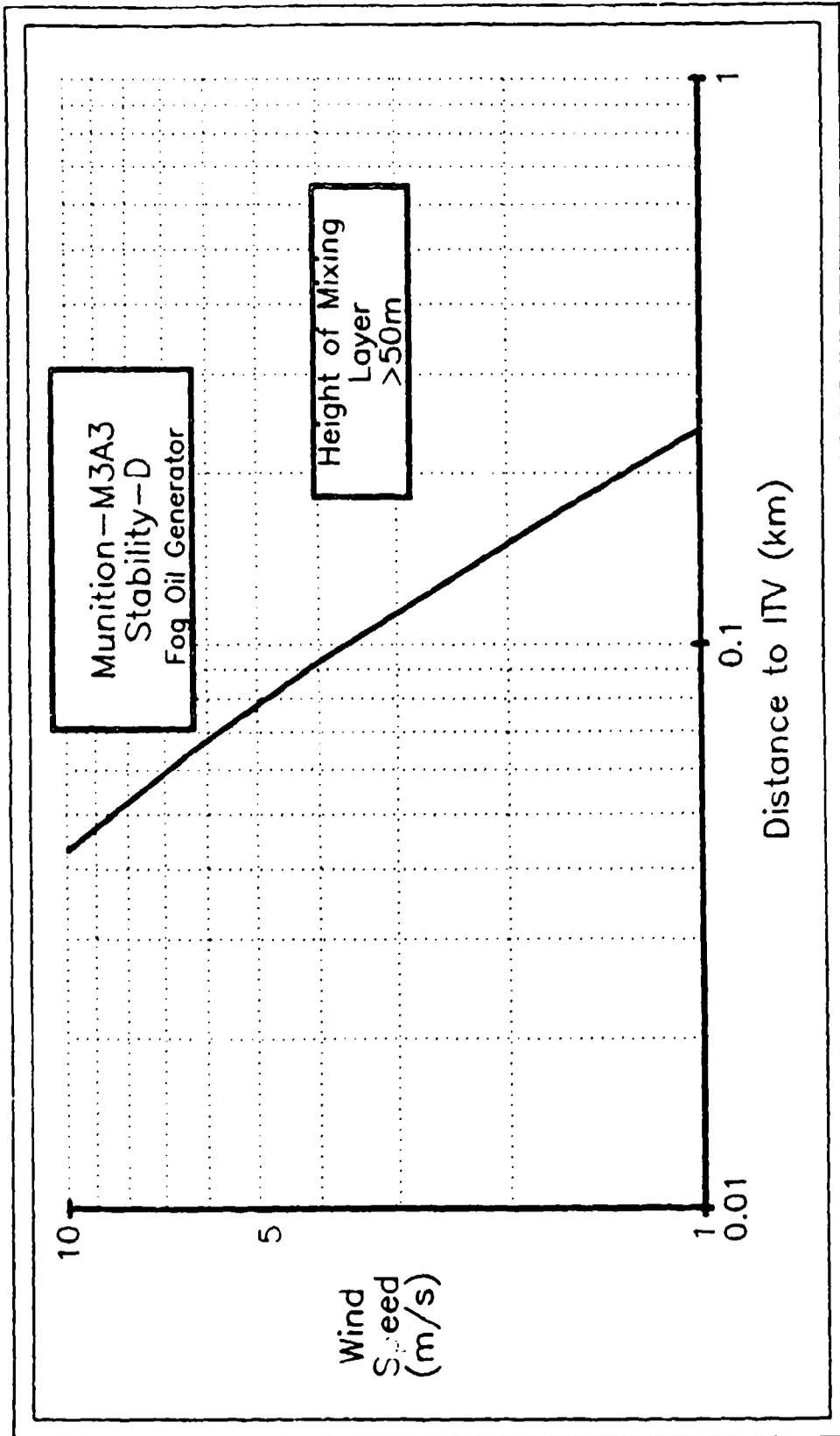


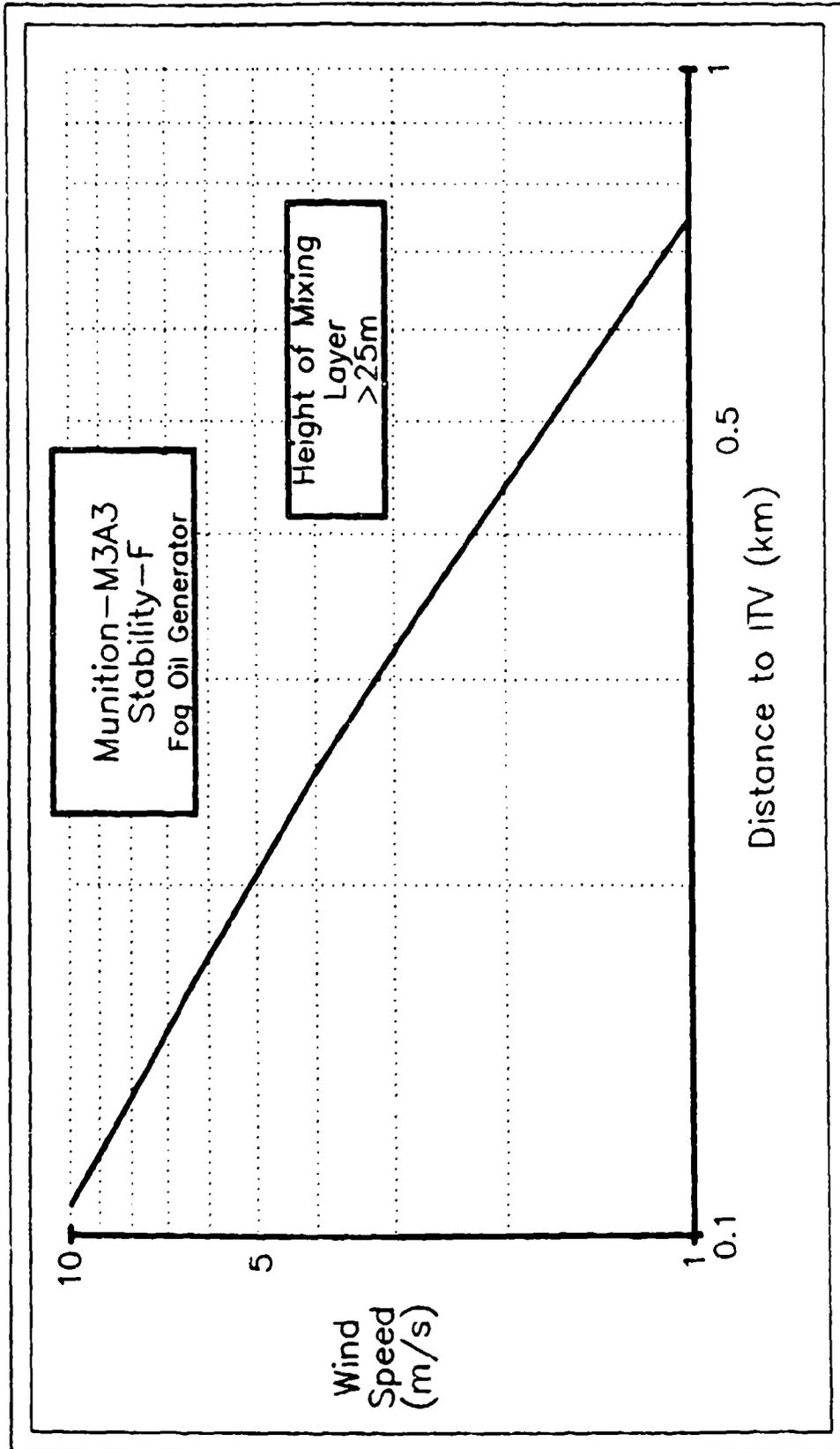












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