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MEMORANDUM
RM-6268-PR
MARCH 1970

FAST-VAL: Relationships Among Casualties, Suppression, and The Performance of Company-Size Units

S. G. Spring and S. H. Miller

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Relationships Among Casualties, Suppression, and The Performance of Company-Size Units

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PREFACE

This Memorandum is part of a Rand study of the influence of air-delivered munitions on ground-combat operations. The purpose of this particular effort has been to define in analytic terms those relationships that describe the performance of a well-led and well-disciplined infantry company during a fire fight. The relationships presented here--among casualties, troop suppression, and combat performance--form a set of inputs to Rand's FAST-VAL II (forward air-strike evaluation) model.

Unlike the primary effects of a combat engagement, i.e., casualties and equipment losses, the secondary effects described by these relationships are very subtle and difficult to quantify. The values we have determined, therefore, must be regarded as tentative and, in many cases, speculative. Because of the lack of available data or relevant reference materials, we have relied heavily on the judgment and experience of Rand's military consultants throughout this study.

Although there exist almost no quantitative data to support our findings in detail, the relationships derived here have appeared to be generally valid in the few cases in which results of simulations of real-life combat actions have been compared with the reported results of those actions. (A comparison of simulation results with actual combat reports of a fire fight at Khe Sanh, South Vietnam, in 1967, will be presented in a forthcoming Rand Memorandum in the FAST-VAL series.)

While it must be emphasized that there is no universal agreement as to the validity of the parameters we have defined, we feel that they serve as a much-needed working starting point. We shall continue to seek new data and evaluate the research results of others in order to either add substance to present judgments or identify needed changes in the functional relationships.

SUMMARY

This Memorandum develops and describes a set of functions that are part of the input to FAST-VAL II simulations to determine the outcome of small-unit combat actions. The FAST-VAL (forward air-strike evaluation) model measures the influence of weapons on ground-combat actions of regimental size or smaller, by dynamic two-sided simulations of engagements. In order for these simulations to reflect the average performance of individual combat troops, it is necessary to include as inputs not only the primary effects of casualties and equipment losses but also the secondary effects of these factors, which are far more subtle and difficult to quantify.

The following basic functions are used to describe in analytical terms the secondary effects of air, artillery, mortar, and small-arms fire on a company's ability to fire and maneuver:

1. The break level--the point at which a unit (offensive or defensive) can no longer perform its mission during a fire fight.
2. The stall level--the point at which an attacking unit ceases its advance and regroups before reinitiating its attack.
3. Company effectiveness--the percentage of an infantry company's initial riflemen that are committed and effective, expressed as a function of the company's policy for committing reserves and its cumulative casualties.
4. Weapon-crew effectiveness--the influence of cumulative casualties within weapon crews on their preplanned rate of fire.
5. Suppression of fire--the degradation of fire by riflemen and weapon crews that occurs as a result of the noise, confusion, and high casualty rate caused by incoming ordnance.
6. Movement rate--the mobility of units as influenced by cumulative casualties and, for mounted units, by damage to personnel carriers.
7. Suppression of mobility--the degradation of a company's movement rate that occurs as a result of the noise, confusion, and high casualty rate caused by incoming ordnance.

8. Hand-to-hand combat performance--the relationship of an attacking unit's effective fire to that of the defending unit during hand-to-hand combat.

Each of these functions represents a complex concept that must be defined in the context in which it is being used. This Memorandum, therefore, discusses the functions and the relationships among them as they are applied in a FAST-VAL simulation. A brief description is given of the FAST-VAL model to indicate the overall framework for the discussion.

The relationships developed in this Memorandum are necessarily based on assumptions in many instances, because neither quantitative data nor reference materials are available on which to base calculations. These assumptions reflect the combat experience and judgment of the military consultants who participated in deriving them; it is not to be implied, however, that there is universal agreement as to the validity of these assumptions. Each assumption is discussed in detail, and the resulting values determined for each of the major combat functions are presented graphically.

Detailed computations used to derive the percentage of a company's surviving riflemen that are effective at various stages of a ground engagement are presented in the Appendix to this Memorandum.

ACKNOWLEDGMENTS

We, the authors, are indebted to Colonel V. J. Croizat, USMC (Ret.), Lieutenant General G. F. Good, USMC (Ret.), the late Colonel W. H. Hastings, USA, Colonel F. Kozaczka, USAF (Ret.), Colonel G. C. Reinhardt, USA (Ret.), Brigadier General L. L. Wheeler, USA (Ret.), and Lieutenant Colonel R. A. Wise, USA (Ret.), for the assistance and expertise they provided in developing the assumptions used in this study. We are also grateful to Kathleen Harris, R. L. Helmbold, M. M. Lavin, and J. R. Lind, of the Rand staff, for their constructive criticism and advice. And finally, our thanks to Janet Murphy, whose editorial efforts, including a considerable amount of rewriting, have greatly enhanced the readability of this Memorandum.

GLOSSARY

Attacking infantry unit: Any infantry (or other) unit assigned an infantry mission of deploying forward on an approach march or of attacking.

Break: Loss of a unit's ability to continue to perform its mission during a fire fight (in FAST-VAL, fire fights are assumed to last less than 24 hr).

Break level: The level, measured in percent casualties, at which a unit can no longer perform its assigned mission.

Casualties: Any persons killed or wounded in action (an example of casualty criteria is the "assault, 5 min" standard of Ballistic Research Laboratories, as defined in Ref. 5).

Company effectiveness: The percentage of a company's initial riflemen that are committed and effective at a given time.

Defending infantry unit: Any infantry (or other) unit assigned to hold hasty or prepared defensive positions or to fight a delaying action.

FAST-VAL: A system of computer models developed at Rand for forward air-strike evaluation, designed to ascertain the influence of air-delivered weapons on ground combat actions. FAST-VAL can also be used to examine the damage-producing capabilities of artillery, mortars, and small arms, as well as the interactions of opposing forces in the presence of combined enemy fires.

FAST-VAL II: A computer program designed to simulate dynamic two-sided regimental or smaller-size combat engagements. FAST-VAL II supersedes FAST-VAL I (see Ref. 10). A detailed description of FAST-VAL II will be published in a forthcoming Rand Memorandum.

Final coordination line: A line close to the enemy position at which the lifting and shifting of supporting fires are coordinated, along with the final deployment of maneuver elements prior to an assault.

Ineffective individual: Any person who is not a casualty but is engaged in activities other than his primary function, or is in some other status that prevents him from accomplishing his mission (firing his own weapon, acting as a weapon crewman, or other support function).

Percent casualties: The ratio (expressed as a percentage) of the number of casualties to the initial number of personnel.

Small arms: Rifles and machine guns.

Stall: The cessation of an attacking infantry unit's advance toward the enemy for some time interval, during which the unit regroups before reinitiating its attack.

Stall level: The level, measured in percent casualties, at which a unit stalls. (The stall level does not apply in FAST-VAL simulations to any unit that crosses the final coordination line.)

Suppressed individuals: All persons who, due to noise, concussion, or other effects of near misses, take cover or move quickly out of an impact area and consequently momentarily abandon their missions.

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I. INTRODUCTION

Providing air support for ground forces in combat is a major responsibility of the Air Force; therefore, there is a continuing need to improve the bases for developing and evaluating tactics, techniques, delivery methods, and munitions used for this purpose. One of the tools that has been developed at Rand to assist the Air Force in planning for and executing its tactical support mission is FAST-VAL, a mathematical model for forward air-strike evaluation, which measures the influence of air-delivered weapons on the outcome of small-unit ground-combat engagements.

In a FAST-VAL simulation, two deployed forces may exchange artillery fire, mortar fire, and air strikes. At the same time, attacking rifle companies may advance and exchange rifle and machine-gun fire with defending rifle companies. As simulated time advances, the first, or primary, effect of the exchange of fire is the production of personnel casualties and equipment losses. These casualties and losses not only directly reduce a unit's strength, they also have secondary effects; i.e., they cause survivors to be diverted, leave them without leaders, and reduce the cohesion of the unit, thus degrading the unit's ability to advance and to deliver fire. In addition, incoming ordnance can cause surviving personnel to be suppressed, that is, to seek cover or to take evasive action and thereby further reduce their ability to perform their mission.

The FAST-VAL II model is structured to allow the user to express these secondary effects of fire upon a unit's performance. Secondary effects, however, are far more subtle and difficult to quantify than are the primary effects (the expected numbers of casualties and equipment losses).* Therefore, we have developed a set of relationships

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*The FAST-VAL method[1] of computing expected or average target damage inflicted by single or multiple weapons, considering delivery conditions such as ballistic errors, aiming errors, and weapon pattern, and target characteristics such as distribution, size, and shape, has become one of the basic techniques used by the Tri-Service Joint Munitions Effectiveness Manual (JMEM) Group.

among casualties, suppression, and unit performance, which are used as inputs in FAST-VAL II and which permit the secondary effects to be expressed in analytical terms.

Because there are no commonly accepted data on which to base these relationships, we have had to make numerous assumptions. These assumptions reflect the experience and judgment of Rand's military consultants, and the values we have calculated using the assumptions appear reasonable. However, it must be emphasized that these assumptions and relationships are subjective and will undoubtedly undergo modification as empirical data become available.

Section II describes the ground-combat engagement as it is simulated by FAST-VAL II, showing how the relationships presented here are employed in the model. Section III describes the relationships between a company's rate of fire and its break level, stall level, commitment of reserves, cumulative casualties, and suppression during periods when incoming ordnance causes noise, confusion, and a high casualty rate. Section IV presents the relationships between a unit's ground mobility during the battle and its cumulative casualties, suppression, and loss of personnel carriers. Section V describes the relationship of an attacking unit's fire to that of the defender during hand-to-hand combat. The Appendix gives the computations used to derive the percentage of surviving riflemen that are committed and effective at various stages of ground combat.

II. FAST-VAL SIMULATION OF A GROUND ENGAGEMENT: THE EFFECTS OF CASUALTIES AND SUPPRESSION ON PERFORMANCE

GENERAL OPERATIONAL FUNCTIONS

During an attack against a defending rifle company, the production of small-arms (rifle and machine-gun) fire by the attacker depends on both command action and the number of riflemen that are effective--that is, neither incapacitated nor diverted from their jobs--at any given point in the engagement. Prior to reaching the point at which the opposing forces are fully engaged, commonly called the "final coordination line," an advancing company may be hit with any combination of air, artillery, mortar, and small-arms fire. If it sustains sufficient damage, measured as the percentage of troops who become casualties, the attacking company may stop to reorganize before proceeding with the attack. The level of casualties at which such a halt occurs we shall call the "stall level."

If the fraction casualties exceeds some critical level, the company may be forced or ordered to abandon the attack; at this point, the company is said to "break." Should the attacking company pass the final coordination line without stalling or breaking, it starts its final charge into the enemy position and continues to fight until either the position is taken or the attack loses its momentum and the attacker is forced to withdraw. In the latter case, the attacking company breaks: It ceases to operate as a cohesive unit, and the troops withdraw in small, uncoordinated groups.

A defending rifle company's small-arms fire production is influenced by casualties and suppression in a manner similar to that of the attacking company. The defending company is subject to attack by air, artillery, mortars, and small arms, and accrues casualties and equipment losses. Since the defender is not in motion, there is no stall point, but if hit hard enough (again measured in fraction casualties), the defending company will break, being forced to make an uncoordinated withdrawal.

In a FAST-VAL simulation, the engagement is allowed to continue until either the attacker stalls or breaks or the defender breaks;* thus the ultimate victor is determined.

FAST-VAL SIMULATION

In a FAST-VAL simulation, a deployed unit is defined by gridding the battlefield into squares 100 ft on a side. Then, employing a rectangular coordinate system, the numbers of riflemen, support personnel, and pieces of equipment contained in each occupied square are associated with the coordinates of the center of the square. The name of a rifle company or battery to which the men and equipment in the square belong is also specified.

Two distinct postures or vulnerability levels may be defined for the riflemen and two for the support personnel. The first posture is the upper, more exposed stance; the second, lower posture represents the effect of suppression. The model user associates a fractional efficiency with each of the postures. Examples of postures typically used in simulations are the prone position, standing in foxholes, crouching in foxholes, or in log bunkers.

Simulated time is advanced in steps of a user-defined time interval.** During each interval, the model computes the casualty rate (fraction casualties per minute) that the riflemen and support personnel in each square would have sustained had they been in their first posture. This casualty rate is a function of the air-delivered weapons, artillery, and mortars but not of rifle and machine-gun fire. If during a time interval, the casualty rate within a square exceeds some user-defined rate, the men in the square will seek their second (suppressed) posture and remain there during the succeeding time interval. Should the casualty

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*A simulation may contain several distinct engagements, each of which may contain several attacking companies and several defending companies. An engagement continues until all the defending companies break or until all the attacking companies break or stall.

**A time interval of 4 min has generally been specified by Rand users.

rate drop below that specified rate during the succeeding time interval, the men in the square will return to their first posture. The effectiveness of suppressed troops is equal to whatever fractional effectiveness the user has associated with the second posture. For each time interval, the model also records the fraction of the men in each rifle company currently in their second posture.

To incorporate the effect of cumulative casualties on the efficiency of artillery, mortar, and machine-gun crews, the cumulative casualty fraction of the support personnel in the square containing a particular weapon is assumed to represent that of the entire crew. The model also continually records the expected percent of casualties suffered by each rifle company. In addition, if an attacking company is specified to advance initially in personnel carriers, the model records the expected percent of carrier losses for each company.

Suppression and cumulative casualties are assumed to disrupt the battle plans of the two opposing units independently. These effects are measured at and applied to individual artillery and mortar tubes rather than to the battery as a unit. The battle plans for these weapons consist of (1) a preplanned rate-of-fire table defining rates as a function of time and (2) a preplanned targeting table defining area targets and the time intervals during which to fire upon the targets. During a simulation time interval, the actual rate of fire that a weapon will achieve against a target is the product of (1) the preplanned rate, (2) the fractional effectiveness associated with the current posture of the weapon-crew members colocated with the weapon, and (3) an input function expressing crew efficiency as a function of the fraction casualties suffered by the support personnel colocated with the weapon.

For rifle companies, battle plans consist of assigning attacking rifle companies to objectives--sets of defending rifle companies--defining the time each attacking company is to begin to advance, setting rates of fire for rifles and machine guns as functions of the distance separating the opposing companies, and defining basic advance rates.

Attacking companies pass through three distinct phases as they advance toward their objectives, and a distinct basic rate of advance is defined for each phase. In the first phase, the opposing companies are

said to be unengaged; they neither deliver nor receive rifle and machine-gun fire. However, both forces are subject to artillery and mortar fire and air strikes. The model user may specify that attacking companies advance in personnel carriers during this phase.

The second phase begins when and if the attacking rifle company reaches the "line of departure," an imaginary line located at a user-defined distance from the defending companies. During the second phase the opposing companies are said to be semiengaged and may deliver and receive rifle and machine-gun fire as well as artillery and mortar fire and air strikes. The region within which companies are semiengaged is normally too deep for a single definition of rifle and machine-gun rates of fire, so it may be divided into as many as four smaller regions.

The third phase begins when and if the attacking companies reach the final coordination line, again an imaginary line located at a user-defined distance from the defending companies. During the third phase the forces are said to be fully engaged. The defender's machine guns may continue to fire during this phase, but those of the attacker may not. (If a machine gun is carried forward of the final coordination line and fired from the "hip" or other rifle-like position, it is treated like a rifle for this phase of the fire fight.) Both forces continue to deliver rifle fire. Normally, air strikes, artillery, and mortar fire will have shifted to alternate targets when the forces enter this phase.

When and if attacking companies reach the objective, they are said to be in the hand-to-hand phase. In this phase only the rifles are presumed to fire. No attempt is made to simulate all the complexities of hand-to-hand combat. The input parameters for the rifles (rates of fire and expected casualties per burst) are employed to approximate the results of this phase.

As stated earlier, the battle plans of the rifle companies may be disrupted by the effects of both suppression and cumulative casualties. First, the user defines for each company the fraction casualties at which the company will break. In a simulation, a company that reaches its break level will cease to advance and will neither deliver nor receive rifle and machine-gun fire. However, it may continue to suffer casualties from artillery, mortars, and air strikes. The break level defined for defending companies is normally higher than that for attacking companies.

Prior to the time that an attacking rifle company reaches its break level, its advance rate may also be degraded by suppression and cumulative casualties. The actual rate of advance achieved by an attacking company during a time interval is the product of the preplanned basic advance rate for the current phase of the attack and two input functions. The first function expresses the fraction of the basic advance rate the company may maintain, as a function of the fraction of the men in the company currently suppressed, i.e., in their second posture. The second function expresses the fraction of the basic advance rate the company may maintain, as a function of the fraction casualties suffered by the company. During the fully engaged phase of an attack, the preplanned advance rate is not degraded. If the user specifies that the company is to advance in personnel carriers during its unengaged phase, he must also define a basic rate of advance for the carrier and a function expressing the fraction of this advance rate that the company can maintain, as a function of the fraction carrier losses. When the company advances in personnel carriers, its men are assumed to be only as vulnerable as the carrier itself, and the suppressive effect of incoming ordnance is ignored.

Should the input function expressing mobility as a function of cumulative casualties drop to zero at some fraction casualties less than the break level for an attacking company, the company stalls, ceasing to deliver or receive rifle and machine-gun fire. The user may define the time interval required by the company to reorganize prior to resuming its attack. When the company resumes its forward movement, its ability to move is degraded as a function of the casualties it has suffered since the time it stalled.

The exchange of rifle and machine-gun fire is also influenced by suppression and cumulative casualties. The actual rate of fire achieved by the machine guns of both sides during a time interval is the product of (1) the preplanned rate for the current phase of the attack, (2) the fractional effectiveness associated with the current posture of the weapon crews colocated with the weapon, and (3) the input function expressing crew efficiency as a function of the fractional casualties suffered by the support personnel colocated with the weapon. The latter

function is the same as that applied to the artillery and mortar crews and is assumed to be identical for the attacker and the defender.

The actual rate of fire achieved by riflemen during a time interval is the product of (1) the preplanned rate for the current phase of the attack, (2) the fractional effectiveness associated with the current posture of the rifleman, and (3) an input function expressing the fraction of the surviving riflemen currently effective as a function of the fraction casualties suffered by the company. The latter function, which may be different for the attacker than for the defender, implicitly reflects the user's assumptions about the commitment of reserve riflemen during an attack. During the fully engaged and hand-to-hand phases of an attack, all surviving riflemen are assumed to have been committed, and the disruptive effect of cumulative casualties is ignored.

Engagements of regimental (brigade) and battalion size usually resolve into several smaller, independent but correlated fire fights, each of which may have different objectives. In a regimental battle, for example, fire fights may be initiated on one flank and at the center to hold the enemy in position while an end run is made at the other flank. Or, at the other extreme, the enemy position may be attacked by only one company of a battalion.

In a FAST-VAL engagement, the fire fights are simulated simultaneously but independently. As mentioned before, a FAST-VAL engagement ends only when all the units committed on one side either break or stall. Since fire fights are of short duration (usually less than 24 hr), it is assumed that all the survivors of a company that breaks are ineffective for the remainder of the fire fight.

The capability of FAST-VAL to examine regimental, battalion, company, and, on occasion, platoon-size fights has spotlighted the need for developing criteria appropriate to the smallest operational unit to be considered. From the character of the fights that have been examined with FAST-VAL to date, it appears that the company should be considered as the basic operational unit. Much of the war-gaming and analysis effort of other studies has used the division, regiment, or battalion as the base unit. These earlier efforts can now be used as a point of departure for estimates at the company level.

III. SECONDARY EFFECTS OF CASUALTIES AND SUPPRESSION ON RATES OF FIRE

Under combat conditions, surviving troops--i.e., those that have not become casualties--are often diverted from their primary missions, or they become separated from their leaders and cannot contribute effectively to their unit's mission. For example, if a platoon leader's radio operator becomes a casualty, the cohesion of that platoon may be seriously disrupted and not be restored until a new operator takes over and regains contact with squads and supporting weapons. No clear guide exists as to the degree of ineffectiveness among survivors that occurs at different casualty levels prior to the time that a unit accomplishes its objective, breaks, or stalls. As indicated in Section II, the preplanned rate of fire of riflemen and weapon crews must be adjusted to provide for the fact that only a fraction of the surviving riflemen and weapon crews fire during a fire fight. Therefore, in this section we shall examine the relationships among company survivors and the factors that influence their rate of fire in terms of the unit's break level, stall level, cumulative casualties, commitment policy, and suppression caused by incoming ordnance.

THE ATTACKING RIFLE COMPANY

It has been suggested in earlier studies that most attacking battalions (more than 90 percent) will break before the battalion sustains 20 percent casualties.[2] This is illustrated in Fig. 1 (the battalion curve is taken directly from Ref. 2). We have derived the company curve by analyzing the battalion components--rifle companies and battalion headquarters and headquarters company--and allocating the fraction of the casualties that each component might reasonably be expected to receive. Each of the three rifle companies was allocated an equal number of casualties. Then at selected break-level points, the portion of casualties allocated to one rifle company was divided by the initial

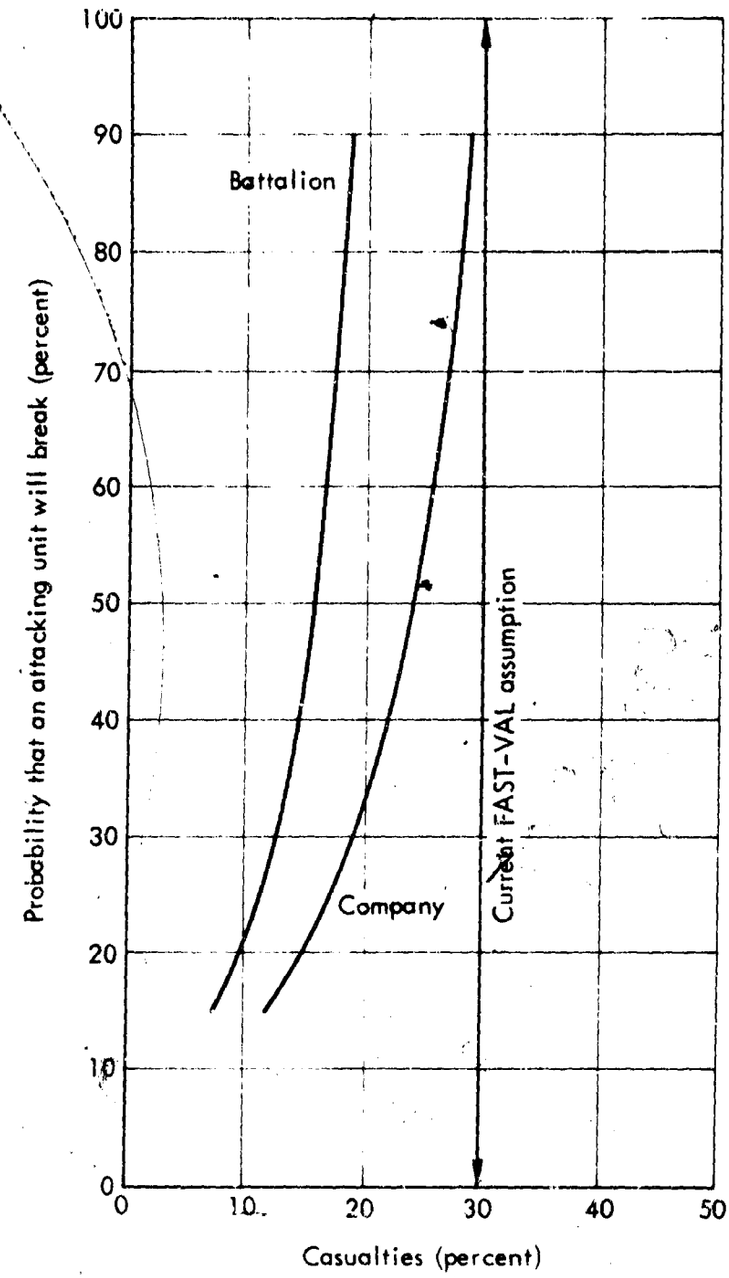

Fig. 1 — Relationship between casualties and the probability that an attacking infantry unit will break

strength of the company to determine the percent of casualties corresponding to each selected point.*

We have assumed the following commitment policy: At the outset of a battle, two of an attacking rifle company's platoons are in contact with the enemy, while the third platoon is in reserve. Thus, about one-third of the company would be excluded from the fight in the initial phase and would be, by definition, ineffective. We assume that three squads of two fire teams each initially make up the reserve platoon. As casualties mount along the line of contact, reserves are committed to maintain the momentum of the attack until all reserves have been committed. The dashed curve in Fig. 2 reflects this commitment policy,** i.e., that reserves are committed in a manner that would produce the same expected or average effective company strength throughout the fire fight as would be accomplished by committing on a one-for-one team basis whenever a team equivalent is lost due to casualties or to troops becoming ineffective. Thus, at 18.5 percent cumulative casualties, for example, all reserves are committed and the percentage of survivors from that point on is the same as would be experienced if the entire attacking company were committed initially.

The percentage of surviving riflemen that are committed and effective, i.e., firing their weapons, expressed as a function of cumulative casualties is a required input to FAST-VAL simulations. The dashed line of Fig. 2 represents the complement of this input currently being used in FAST-VAL simulations.

It is assumed in a FAST-VAL simulation that from the instant an attacking company reaches the final coordination line until the conclusion of the fire fight, all survivors of both the attacking and defending unit are effective. That is, once the attack reaches the final coordination line, (1) all committed surviving troops not engaged in

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*There is no universal agreement on the break-level points. For example, the Research Analysis Corporation has used levels of 40 percent and 60 percent casualties for attacking and defending (infantry and armor) units, respectively.

**A derivation of this curve is given in the Appendix. The actual relationship used is an input specified by the FAST-VAL user. Therefore, the user may compute a relationship that is based on whatever commitment policy applies most appropriately to the battle situation being simulated.

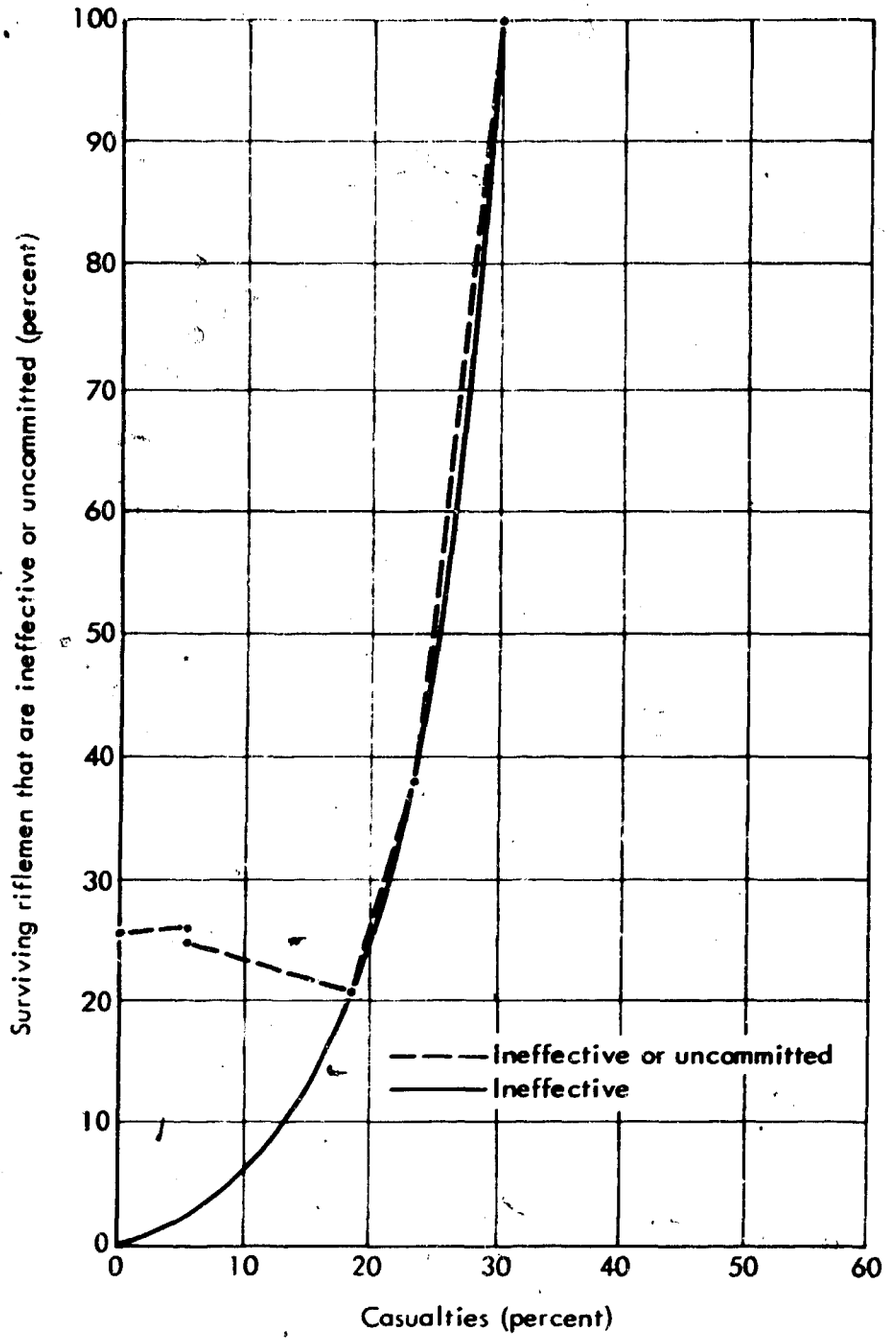

Fig. 2 — Relationship between an attacking infantry company's percentage casualties and the percentage of its surviving riflemen that are ineffective or uncommitted

their primary duty are assumed to return to that duty, and (2) all uncommitted reserves are assumed to be committed to combat at this time.

We have assumed that company-sized infantry units will break when they suffer 30 percent casualties. Also, secondary effects tend to be multiplicative as they accumulate; the overall combat effectiveness of the unit tends to deteriorate slowly at first, and then at some crossover point it deteriorates more rapidly than the proportionate increase in the number killed and incapacitated. The solid curve in Fig. 2 was developed on a judgmental basis, incorporating the concept of an ever-increasing rate of ineffective survivors until the cumulative company casualties reach the 30 percent level, at which time 100 percent of the survivors become ineffective and all of the company's small arms and machine guns cease firing.

Although the break level of 30 percent casualties applies to the entire infantry company, the relationship in Fig. 2 is applied only to the riflemen in a FAST-VAL simulation. This relationship estimates the loss of the capacity of the company's riflemen to deliver fire due to the secondary effects of cumulative casualties. As an example, suppose that 20 percent of the infantry company, including riflemen and machine-gun crewmen, are casualties. Then 80 percent of the original company are survivors, and, from Fig. 2, 74 percent of the survivors are actually effective. Thus only 59.2 percent of the original company strength is effective; that is, no more than 59.2 percent of the rifles with which the attacking company started will be employed when the cumulative company casualties equal 20 percent of the company's initial strength.

Machine-gun crews are treated separately from riflemen in this analysis. The degradation of machine-gun-crew effectiveness and its relationship to cumulative company casualties are discussed on p. 18.

THE DEFENDING RIFLE COMPANY

The relationship between cumulative casualties and the probability of breaking is shown for a defending infantry battalion and company in Fig. 3. As in Fig. 1, the battalion curve is taken from Ref. 2; the company curve has been derived in the same manner as was the attacking-company curve of Fig. 1. From Fig. 3, the break level for a defending

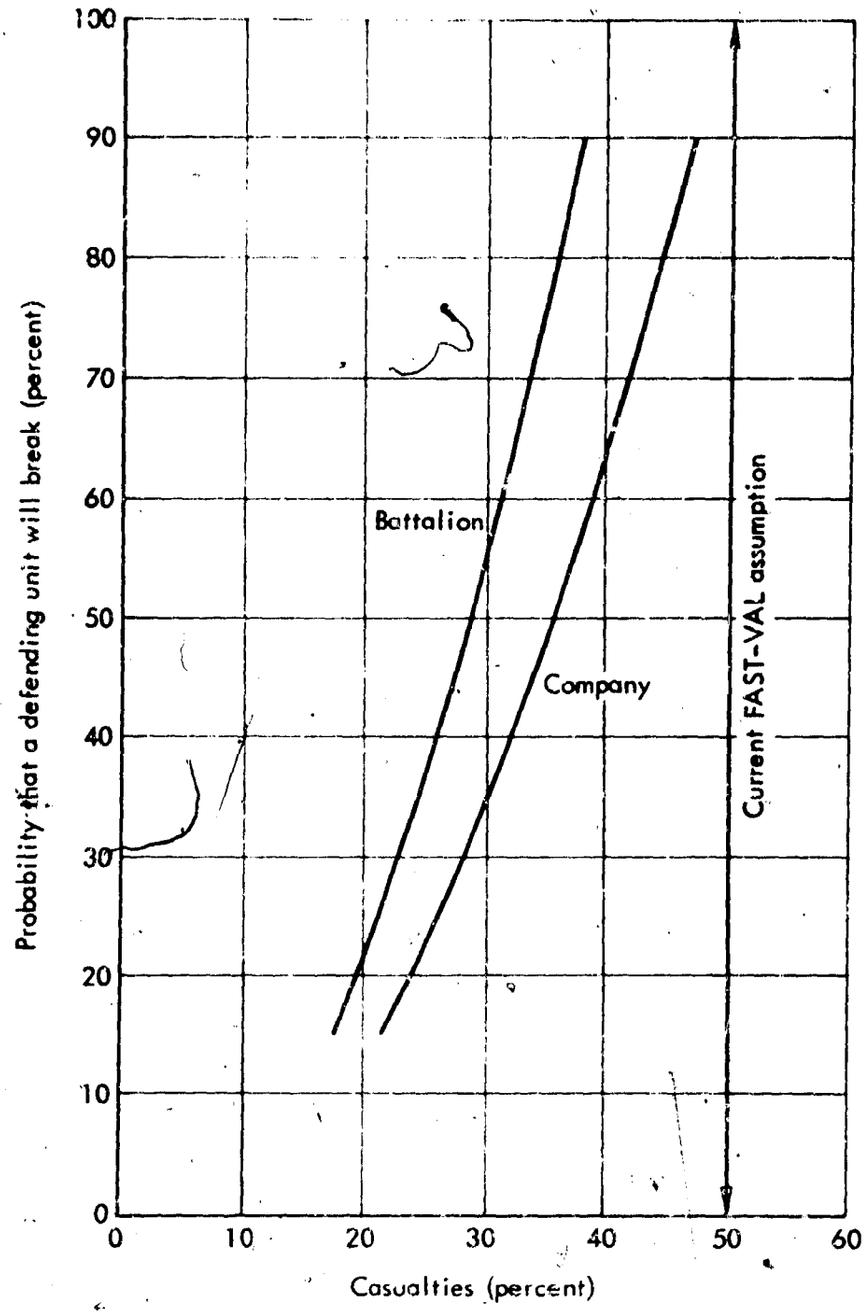

Fig.3—Relationship between casualties and the probability that a defending infantry unit will break

company (which is assumed to be well led, well trained, and possessing a tolerance for the stress of battle*) will be 50 percent casualties. That is, when the cumulative company casualties have reached 50 percent, the company loses its ability to hold hasty or prepared defensive positions or to fight a delaying action. As in the case of an attacking infantry company, the effects of casualties become multiplicative as casualties accumulate.

The relationship between cumulative casualties and the ineffectiveness of surviving riflemen is shown for a defending company in Fig. 4. The curves in this figure were also derived intuitively, because of the unavailability of relevant data.

The solid curve in Fig. 4 represents the case in which the entire defending company is committed to battle initially. This curve shows a monotonically increasing percentage of ineffective survivors with increasing casualties, the rate of increase becoming greater and greater, as indicated by the upward slope. In actual combat, however, a company's platoons usually become engaged at different times, rather than all at once. Therefore, in a FAST-VAL simulation, company combat actions are usually assumed initially to involve only two of a company's three platoons. The reserve troops are then committed to replace casualties along the line of contact, thereby stabilizing the company's defensive posture. This commitment policy produces the relationship between cumulative casualties and ineffectiveness shown by the dashed curve in Fig. 4.**

All reserves are committed when the defending company suffers 24.8 percent cumulative casualties; beyond that level, the solid and dashed curves are the same. At the 50 percent level, the company breaks and 100 percent of the surviving riflemen are ineffective. The degradation of effectiveness of machine-gun crews is discussed later, on p. 18.

At this point we would like to make some comments about the general nature of the curves of Figs. 1 through 4 and the natural phenomena that they represent. If the ordinate of these curves is interpreted as a probability rather than a percentage, each curve is an approximation

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*This assumption is implicit for both attacking and defending infantry companies in the selection of their break levels.

**The derivation of this curve is discussed in the Appendix.

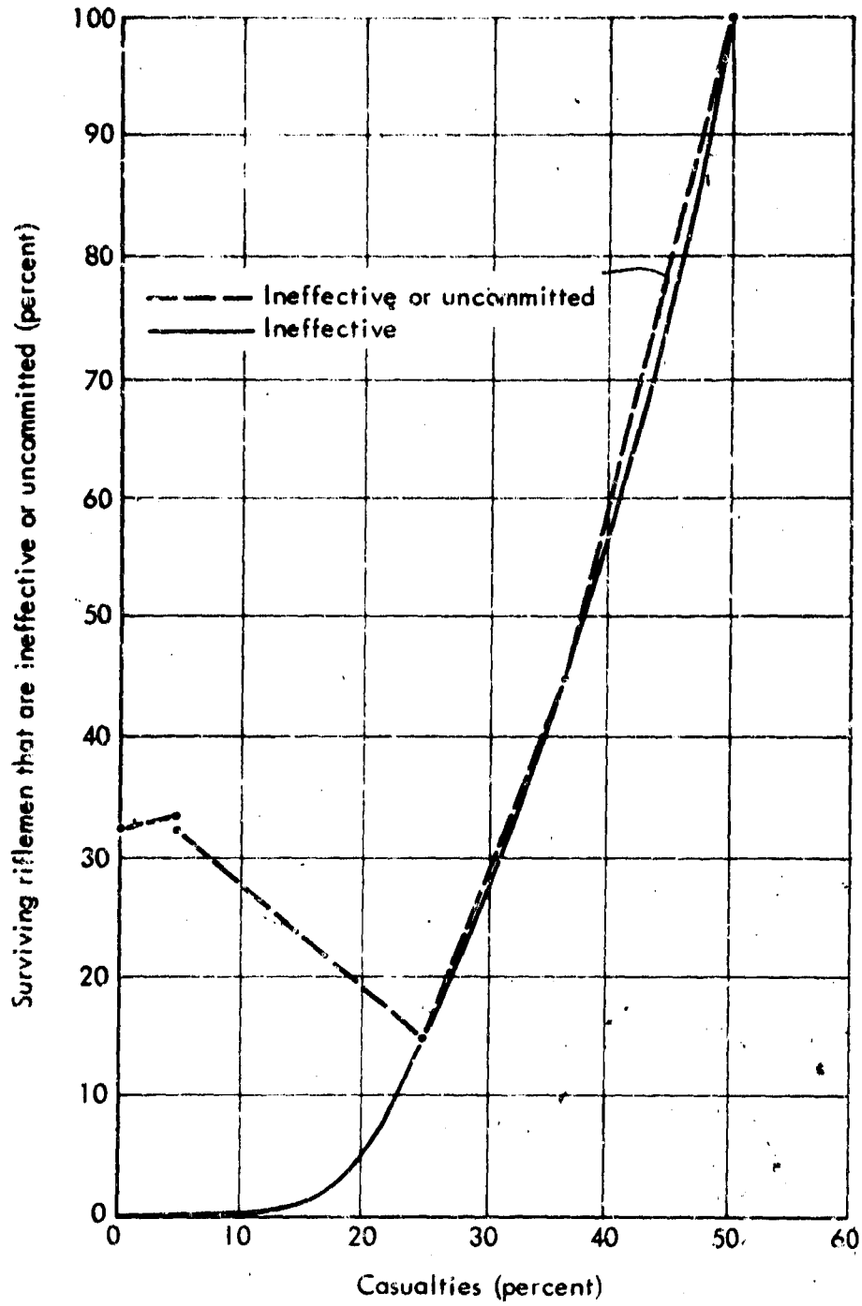

Fig. 4 — Relationship between a defending infantry company's percentage casualties and the percentage of its surviving riflemen that are ineffective or uncommitted

of a statistical cumulative distribution. The percentage of casualties cannot be less than 0 or greater than 100. Since it is theoretically possible that a company could fight to the last man before breaking, the solid curves in the figures should extend from 0 to 100 percent cumulative casualties, with the probability increasing from 0 to 1. The curves would then tend to be S-shaped, with the same general shape, but having tails at each end--one close to 0 probability at the onset of battle, and one close to a probability of 1 as company casualties approach 100 percent. But because units are rarely permitted to suffer casualties close to 100 percent, the S curve is truncated long before it approaches 100 percent. The curves in Figs. 1 through 4 reflect this behavior and form the basis for the relationships presented here.

STALLED INFANTRY COMPANIES

We have defined the stall level for an attacking infantry company that has not reached the final coordination line as 23 percent cumulative casualties. At this point, the company's reserves have all been allocated, and less than 50 percent of the company's initial number of riflemen are effective. In a FAST-VAL simulation, if an attacking company reaches the stall level, it ceases its small-arms fire,* stops its forward movement, regroups, and prepares for a later reinitiation of the attack. While stalled, the company does not receive enemy small-arms fire but is subject to artillery, mortars, and air strikes. In most simulations, a stalled company makes no further contributions to the fire fight; however, if the battle lasts long enough, it is possible to reactivate a stalled company as though it were a new but smaller company, starting from the position at which it originally stalled. We have assumed that once a company reaches the stall level, it no longer makes any effective contribution to the battle for at least some minimum time interval.** At the conclusion of the 60-min period, if the company is reactivated, its new strength is considered equal to the

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*In this study, small arms include machine guns and rifles.

**The time interval required by the company to reorganize is an input specified by the FAST-VAL user. In FAST-VAL simulations at Rand, a time interval of 60 min has been used.

original strength less the casualties suffered from the onset of the battle through the regrouping period. The dashed curve of Fig. 2 can be used for the "new" company thereafter, as though the company casualties were set to zero at the time the attack is reinitiated.

ARTILLERY, MORTAR, AND MACHINE-GUN UNITS

In FAST-VAL, supporting artillery batteries and mortar sections are considered as separate entities, independent of a supported infantry company's state of effectiveness. An artillery battery or supporting mortar section may be effective and continue to fire against the enemy even though one or more of the companies it is supporting are no longer effective. Conversely, an infantry company may be active, either attacking or defending, while its artillery and mortar sections may suffer heavy casualties or equipment damage and become ineffective.

In FAST-VAL, each machine gun assigned or attached to a designated infantry company is treated somewhat independently. As long as the infantry company to which it belongs is active, the machine-gun unit may or may not be active. One machine gun attached to an infantry company may become ineffective due to casualties or equipment damage, while the remainder of the company, the riflemen, and the other machine-gun units assigned to it are still effective.

FAST-VAL computes the degradation of artillery, mortar, and machine-gun units due to equipment damage. This degradation is a primary effect; the technique for making this computation is described in an earlier FAST-VAL Memorandum.(1) The secondary effects--the degradation of the performance of the crews of the artillery pieces, mortars, and machine guns within each 100-ft square--are presented in Fig. 5.* There are two major differences between Fig. 5 and the earlier figures. First, effectiveness is plotted as the ordinate. Second, the calculation is a step function.

FAST-VAL considers primary and secondary effects independently. For example, if elements of an artillery battery within a 100-ft square suffer 25 percent crew casualties and have expected equipment damage of

*This curve is described in Ref. 2.

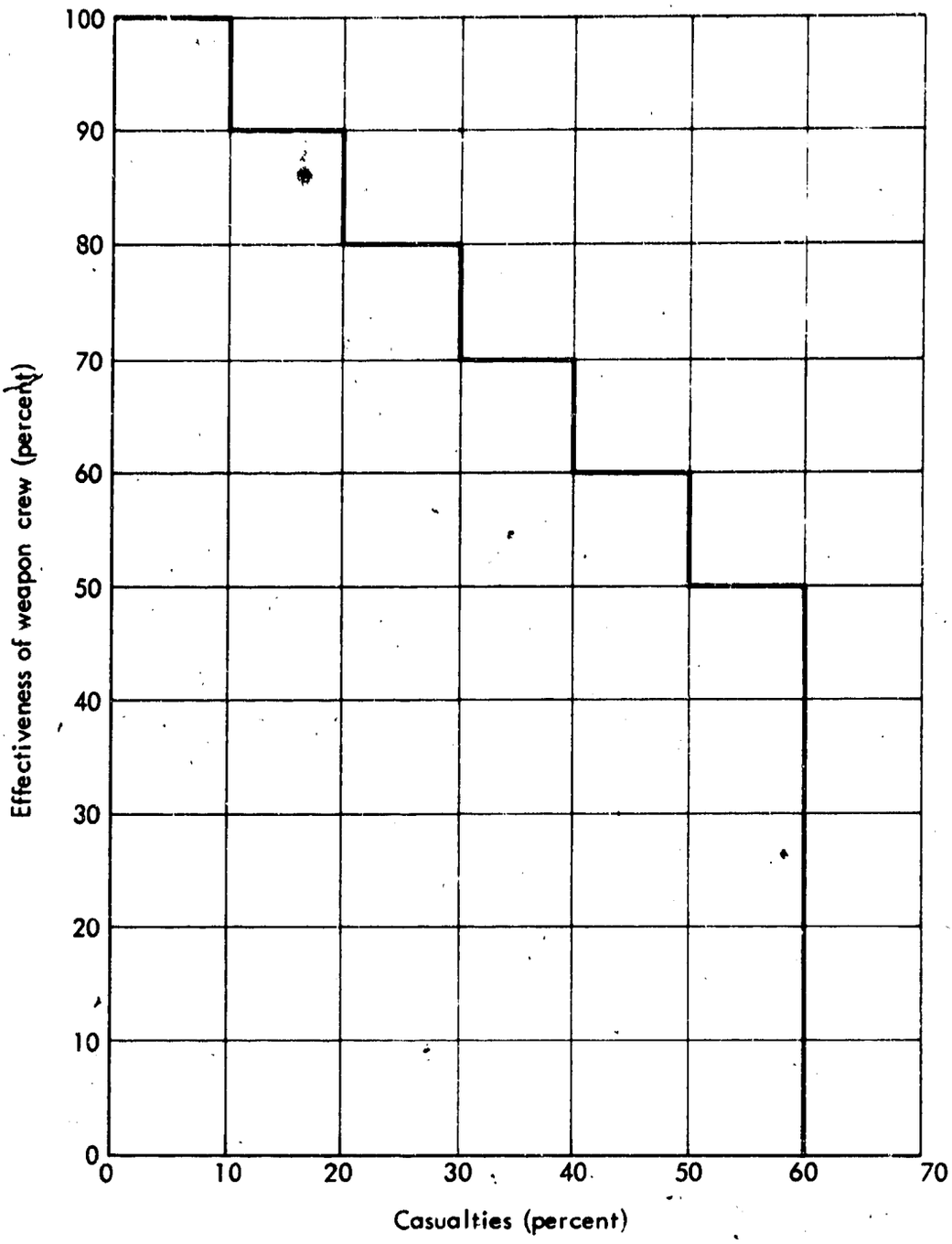

Fig. 5 — FAST-VAL relationship between weapon-crew casualties and the effectiveness of artillery, mortar, and machine-gun units

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50 percent, then the artillery pieces within the square fire at 40 percent* of the rate specified in their battle plan. A similar computation is made for machine guns and mortar pieces in each 100-ft square. Further degradation can result from suppression of weapon crews due to incoming explosive ordnance, as explained below.

SUPPRESSION DUE TO EXPLOSIVE ORDNANCE

Another significant secondary effect, in addition to performance degradation resulting from casualties and equipment losses, is the suppression of troop activity caused by noise and concussion. That is, a near miss or the explosion of several rounds very close at hand is likely to [illegible] troops to take cover or move quickly out of the impact area, mom[illegible] abandoning their missions.

Th[illegible] position that riflemen and weapon crewmen occupy in actual combat--e.g., lying prone, standing in open foxholes, crouching in open foxholes, fighting from covered foxholes or bunkers--undoubtedly influences their reactions to incoming rounds or air strikes. Troops in the open might instantly seek cover from fire that would not be regarded as threatening by men in foxholes or gun pits.

In FAST-VAL simulations, the user decides which postures would be most appropriate to the action being simulated and may then assign two postures for riflemen and two for support personnel and weapon crews. The two sets of postures need not be the same.

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*From Fig. 5, 25 percent cumulative battery casualties corresponds to 80 percent effectiveness. Fifty percent of the artillery pieces are undamaged, and therefore 0.80 x 0.50 = 40 percent of the artillery pieces are effective. Two-fifths of the artillery pieces firing at battle-plan rate produce the same rate of fire as do all pieces firing at two-fifths the battle-plan rate. The careful reader will detect a subtlety overlooked by this FAST-VAL procedure. Battalion rates of fire are almost always limited by "available supply rates" of ammunition, which are generally lower than the theoretical sustained rates of fire. Therefore, it might be feasible for a unit to sustain casualties and at the same time to maintain a battle-plan rate of fire without degradation until the casualties lower the theoretical rate below the battle-plan rate. After this crossover point, the degraded theoretical rate would apply. A change in the FAST-VAL II model to modify this procedure is being considered.

The decision of whether to seek cover or continue the assigned mission is based on involuntary and instantaneous evaluation of the probability of survival. We have concluded, on the basis of the experience and judgment of military consultants, that weapon fire adequate to inflict approximately 1 percent* casualties per min on troops in their upper posture will cause those troops to adopt their lower, less vulnerable posture. The casualty rate that causes troops to take their lower posture is an input variable, and values other than 1 percent may be used in FAST-VAL simulations.

Obviously, considerably more firepower is required to suppress troops in covered foxholes than for troops that are prone and in the open. We have assumed that a suppressed rifleman fires his weapon at 30 percent of his normal rate; a suppressed artillery, mortar, or machine-gun crew fires at 10 percent of its normal rate.** However, the degradation of the weapon firing rate due to suppression is an input parameter, and values other than 30 percent for riflemen or 10 percent for support personnel may be used in FAST-VAL simulations.

In FAST-VAL, since riflemen and support crews are treated separately, it is possible for one type of troop to be suppressed while the other is still fully effective; of course, both may be in the same state.

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*That is, 1 casualty per min per 100 men within a 100-ft square. Casualties due to small-arms fire are not considered in FAST-VAL simulations to determine whether troops are suppressed.

**In the example given earlier, an artillery-battery crew that has sustained 25 percent casualties and has an expected equipment-damage level of 50 percent would fire its weapons at 40 percent of its normal rate if it were not suppressed. If suppressed, the crew would fire at only 4 percent of its battle-plan rate (40 percent multiplied by 10 percent).

IV. SECONDARY EFFECTS OF CASUALTIES AND SUPPRESSION ON GROUND-UNIT MOBILITY

MOVEMENT RATES

The rate of movement of a ground unit not in contact with an enemy is determined primarily by the unit's physical and tactical environment. Physical environment is described, for the most part, by the class of terrain and roads to be traveled and by visibility. The tactical environment is characterized by the estimated distance from enemy forces, i.e., contact is remote, probable, or imminent. The influence of the tactical environment on unit disposition is described in Ref. 3 as follows:

> The formation adopted by the company is based on the imminence of the enemy. When enemy contact is remote, troops are disposed in the column to facilitate ease of control, rapidity of movement, and administrative considerations. Adequate dispersion is maintained to provide protection from air attack and long range artillery fires. As enemy ground contact becomes more probable, elements are grouped tactically in the column to facilitate prompt adoption of combat formation. The tactical grouping is based on the probable future employment of the company. When contact is imminent, troops are deployed in anticipation of enemy ground action.

At ranges of 5000 yd and more, contact between opposing forces is sufficiently remote that the physical rather than the tactical environment tends to be considered dominant by an advancing unit. With little fear of enemy contact, the company would assume a disposition designed for ease of control and rapid movement. Contact becomes probable when forces are separated by less than 5000 yd. Then an advancing unit would be induced to trade some speed of advance for additional security. Quite probably, it would alter its formation to provide suitable security forces in the front and flanks. The chance of contact changes from probable to imminent when armored and mechanized forces come within effective range of enemy antitank weapons, about 1000 yd. The probability of contact changes from probable to imminent for infantrymen when they reach the effective range of enemy rifle fire--that is, 500 yd or less. In tropical zones, dense ground cover may conceal suitable targets from

riflemen who are more than 100 yd distant. Target detection is easier in temperate zones, where rifles may be fired effectively at 500 yd.

To cope with threats posed by imminent enemy contact, an advancing unit divides into small groups and seeks routes concealed to the enemy. These actions decrease its speed; we assume here that an advancing unit's speed is decreased by 40 percent when enemy contact becomes imminent.

Movement rates of combat units under various conditions are given in Tables 1, 2, and 3. These rates are based on data from Refs. 3 and 4, adjusted to fit the situations specified.

Table 1

MOVEMENT RATES OF ARMOR AND MECHANIZED UNITS IN THE TEMPERATE ZONE[a]
(Daylight visibility)

Condition of Road or Terrain	Rate of Movement		
	mph	yd/min	ft/min
Range from Enemy = 1000 - 5000 yd			
Good road	20	600	1800
Fair road	15	450	1350
Poor road	10	300	900
Open terrain	12	350	1050
Medium terrain	10	300	900
Poor terrain	5	150	450
Range from Enemy = < 1000 yd			
Open terrain	7	200	600
Medium terrain	6	180	540
Poor terrain	3	90	270

[a]Corresponding data for other climatic zones were not available to the authors at the time of publication.

Table 2

MOVEMENT RATES OF DISMOUNTED TROOPS
IN THE TEMPERATE ZONE
(Daylight visibility)

Condition of Road or Terrain	Rate of Movement		
	mph	yd/min	ft/min
Range from Enemy = 1000 - 5000 yd			
Good road	2.5	75	230
Open terrain	2.0	60	180
Medium terrain	1.5	45	135
Poor terrain	1.0	30	90
Range from Enemy = < 1000 yd			
Open terrain	1.2	35	105
Medium terrain	0.9	26	78
Poor terrain	0.6	18	54

Table 3

MOVEMENT RATES OF DISMOUNTED TROOPS
THROUGH TROPICAL GROUND COVER
(Daylight visibility)

Condition of Road or Terrain	Rate of Movement		
	mph	yd/min	ft/min
Range from Enemy = 1000 - 5000 yd			
Open terrain	0.34	10	30
Medium terrain	0.24	7	21
Poor terrain	0.14	4	12
Range from Enemy = < 1000 yd			
Open terrain	0.20	6	18
Medium terrain	0.14	4	12
Poor terrain	0.17-0.10	2-3	6-9

THE EFFECT OF CASUALTIES ON UNIT MOBILITY*

Conceptually, mounting casualties will cause a progressive erosion of an attacking unit's speed of advance. The rate of movement wanes and the unit's advance slows until cumulative casualties reach the stall or break level (presuming that the unit presses its attack and that its advance is not altered by contravening orders).

As discussed in Section III, we have assumed that the stall level of an attacking infantry company occurs at 23 percent cumulative casualties. At the start of an attack, the attacking unit's movement would proceed at battle-plan rate and would subsequently be degraded, we suggest, as shown in Fig. 6. The shape of the curve, determined judgmentally, reflects the concept that the movement rate decreases more rapidly as cumulative company casualties increase, until the stall level is reached, at which time the advance stops completely.

A further assumption in FAST-VAL simulations is that casualties do not degrade an attacker's speed once the unit reaches the final coordination line, which is generally about 100 yd from the objective in temperate zones and much closer in areas with tropical ground cover.

Figure 6, used in conjunction with appropriate movement rates from Tables 2 and 3, gives the expected speed of an attacking infantry company with allowance for cumulative casualties.

THE EFFECT OF SUPPRESSION ON UNIT MOBILITY

In the absence of relevant combat data, our tentative premise is that casualties degrade movement at twice the rate that suppression does. In addition, FAST-VAL simulations have assumed that explosive ordnance is not delivered and that suppression does not occur after the attacking force has crossed the final coordination line.

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*Some researchers and tacticians feel that once the advancing infantry comes within range of small-arms fire, only the accuracy and intensity of that fire will have an effect on the attacker's speed of advance. That is, a defender may halt or slow an attacker with a sufficient margin of fire superiority even though he is not inflicting a large number of casualties.

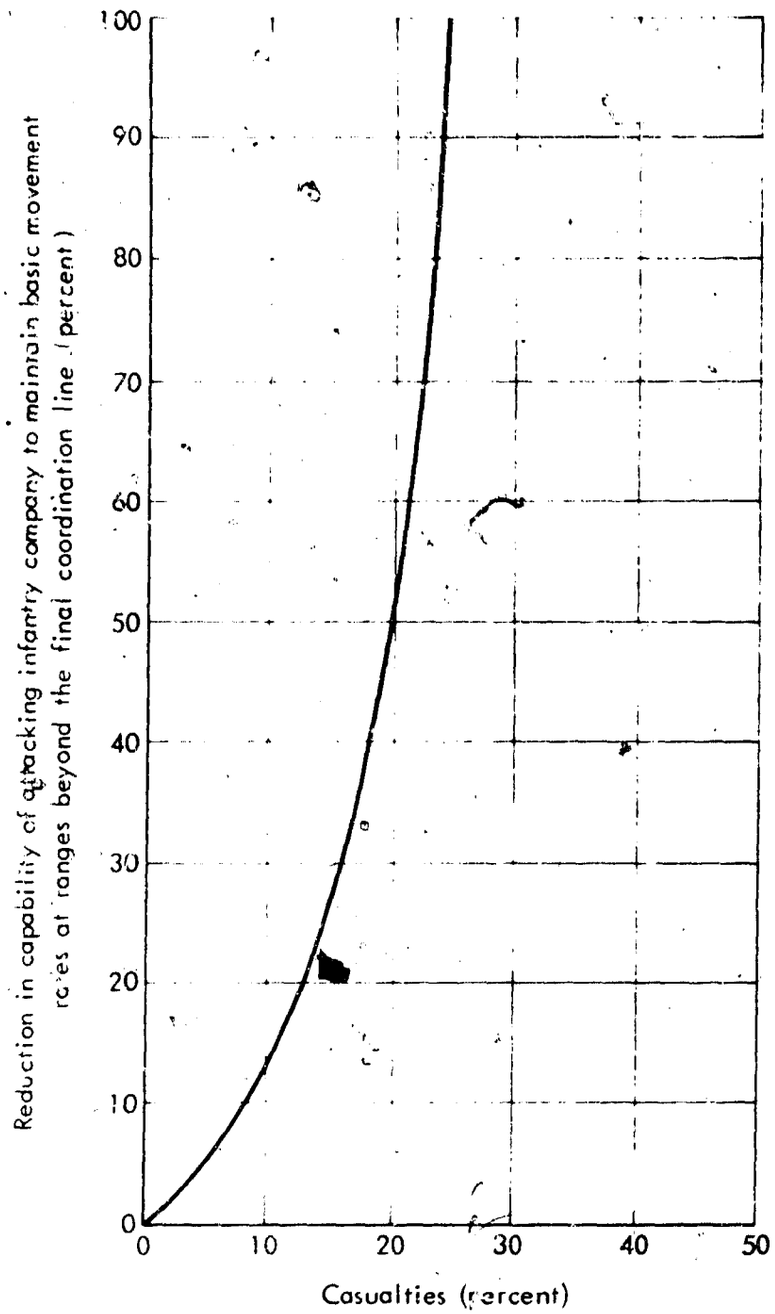

Fig.6 — Relationship between casualties and the movement rate of an attacking infantry company

For example, consider an attacking company in a temperate zone in open terrain, 1000 yd from its objective and not yet at the final coordination line. The company has sustained 20 percent cumulative casualties, and 40 percent of its riflemen and machine-gun crews are suppressed (i.e., if in the upper posture, 40 percent of the men would have a casualty rate greater than 1 per 100 men per min, during the specified time interval). Then the company's rate of movement is

$$60 \times 0.51 \times 0.51 = 15.6 \text{ yd/min},$$

where the initial movement rate of 60 yd/min is taken from Table 2; 0.51 is the percent reduction in movement rate due to casualties at 20 percent casualties, from Fig. 6; and 0.51 is the percent reduction in movement rate due to suppression, also from Fig. 6 (40 percent x 0.5 = 20 percent).

THE EFFECT OF LOSS OF COMBAT VEHICLES ON UNIT MOBILITY

The distance of a company from its objective is, in a FAST-VAL simulation, the distance from the attacking company's center of mass to the objective's center of mass. Prior to reaching the line of departure, the company may be mounted on armored personnel carriers (APCs) or other vehicles. A mounted attacking company will be assumed to move at the APCs' maximum rate of advance during the unengaged phase. As combat vehicles are lost, prior to the company's reaching the line of departure, the rate at which the company advances decreases. Our estimate of the relationship between vehicle losses and unit movement rates is shown in Fig. 7, which is based on the discussion in Ref. 2.

All troops are assumed to dismount when the attacking company's center of mass crosses the line of departure. (The basic movement rates for dismounted troops are given in Tables 2 and 3.)

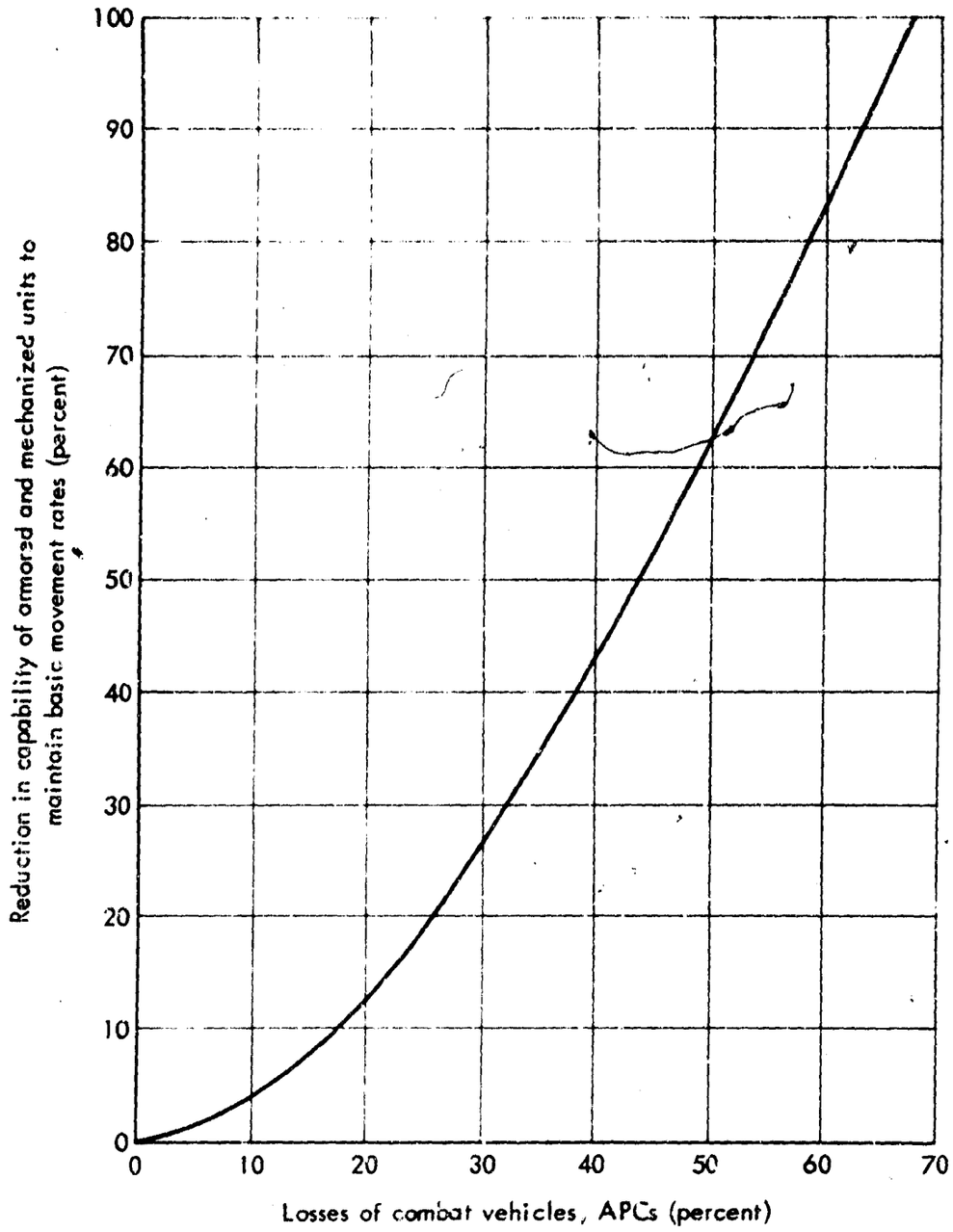

Fig. 7 — Relationship between losses of combat vehicles and movement rates of armored and mechanized units

V. FAST-VAL GUIDELINES FOR EVALUATING HAND-TO-HAND COMBAT

When two forces intermingle in hand-to-hand combat, the side that can bring the most effective manpower to bear should win. Here, effective manpower may be regarded as the number of troops multiplied by their relative efficiency. In the assault of a defense position, an attacker capable of reaching his objective is believed to have a psychological advantage that might enhance the strength of a soldier by about 25 percent. That is, the attacker's efficiency, on a man-to-man basis, relative to the defender would be 1.25.

It is presumed that the attacker would be half as effective in hand-to-hand fighting, where weapons fire would be replaced largely by bayonets and rifle butts, as he would be in the fully engaged phase. Thus we propose, for FAST-VAL purposes, that each attacking rifleman be assumed to have the capability to fire his weapon in hand-to-hand fighting at one-half the rate he had in the fully engaged phase, but with the same "lethality." As noted above, the rate of fire of an attacking rifleman is taken to be 125 percent of that of a defending rifleman. The fires of both sides are presumed to have equal "lethality."

It is assumed that there is no suppression of either side during this terminal phase. If the attacker does not break before the defender does, he will win; otherwise, the attacker loses.

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Appendix

COMPUTATION OF THE PERCENTAGE OF A COMPANY'S SURVIVING RIFLEMEN THAT ARE COMMITTED AND EFFECTIVE

INTRODUCTION

For FAST-VAL input we require the fraction of surviving riflemen that are committed and effective, expressed as a function of the company's casualties. The two fundamental considerations leading to the desired input are (1) the fraction of the surviving riflemen that are ineffective, as a function of company casualties, and (2) the policy or manner in which troops are committed to battle.

Let*

$S \equiv 1 \equiv$ normalized number of initial riflemen in the company

$B \equiv$ fraction of initial riflemen that are reserves at the start of a fire fight

$F(j) \equiv$ fraction of initial company personnel that are casualties at the jth casualty level, $j = 0, 1, 2, \ldots, N$, with $F(0) = 0$

$C(T,j) \equiv$ fraction of initial riflemen that are casualties at the jth casualty level,** with $C(T,0) = 0$

$m(T,j) \equiv$ fraction of initial riflemen that are committed and firing their rifles, i.e., effective riflemen, at the jth casualty level, with $m(T,0) = 1 - B$

$s(T,j) \equiv$ fraction of initial riflemen that are surviving, i.e., not casualties, at the jth casualty level, with $s(T,0) = 1$

---

*In this appendix we are using the symbol $\equiv$ to mean "equals, by definition" and notation that has been constructed for use with the Rand JOSS time-shared computer. Notation of variable names is limited to one letter of the alphabet, upper or lower case, with subscripts permitted within accompanying parentheses.

**The subscript T denotes total riflemen. Later in this appendix the subscript E will denote riflemen originally committed, and the subscript b will denote riflemen originally in reserve. Thus it will follow that $C(T,j) = C(E,j) + C(b,j)$, and so forth, for other similar variables.

$g(j)$ fraction of surviving riflemen that are ineffective at the jth casualty level

As indicated by the solid curves of Figs. 2 and 4 (pp. 12 and 16) for attacking and defending infantry companies, $F(j)$ and $g(j)$ are functionally related. We assume that the company's casualties are uniformly distributed among all personnel, including reserves. Therefore,

$$C(T,j) = F(j),$$

and

$$F(j) + s(T,j) = 1.$$

The required input to FAST-VAL, the fraction of surviving riflemen that are committed and effective as a function of company casualties, is given by

$$\frac{m(T,j)}{s(T,j)} = \frac{m(T,j)}{1 - F(j)} . \qquad (1)$$

To compute $m(T,j)$, the fraction of initial riflemen that are committed and effective at the jth casualty level, we will consider that the company riflemen are composed of two groups: (1) those originally committed and (2) those originally in reserve.

The riflemen originally committed will be in one of three states at the jth casualty level, and the fraction of initial riflemen in each state is given by

1. $m(E,j) \equiv$ committed and effective, with $m(E,0) = 1 - B$
2. $C(E,j) \equiv$ casualties, with $C(E,0) = 0$
3. $i(E,j) \equiv$ ineffective, with $i(E,0) = 0$

The riflemen that were originally in reserve will be in one of four states at the jth casualty level, and the fraction of initial riflemen in each state is given by

1. $m(b,j) \equiv$ committed and effective
2. $W(b,j) \equiv$ uncommitted (i.e., still in reserve but not ineffective or casualties), with $W(b,0) = B$

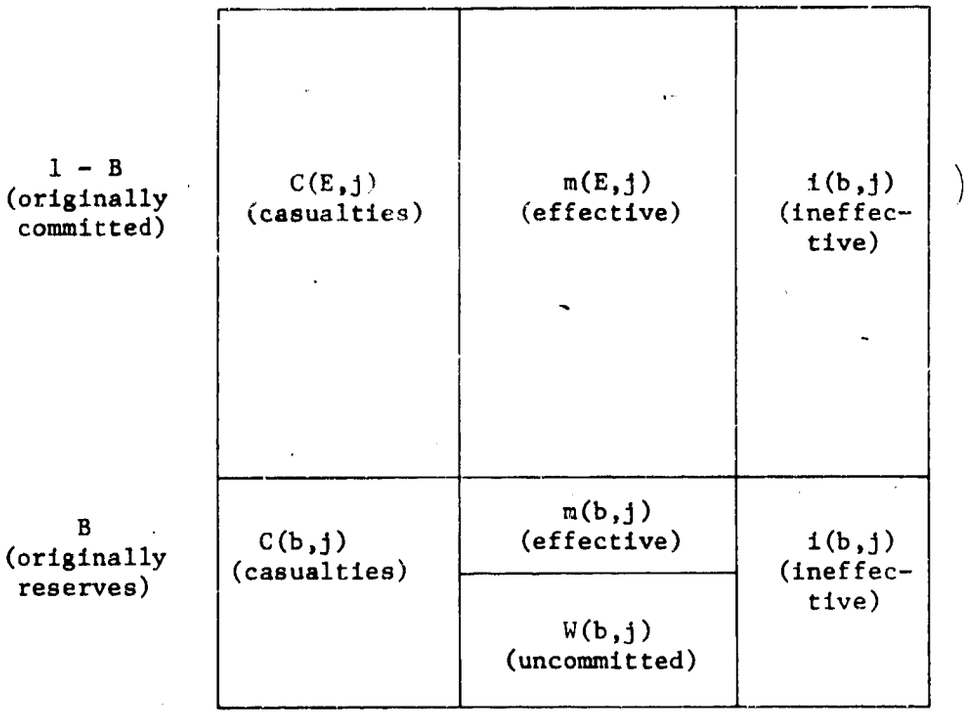
3. $i(b,j)$ = ineffective, with $i(b,0) = 0$
4. $C(b,j)$ = casualties, with $C(b,0) = 0$

The above seven states are mutually exclusive and exhaustive with regard to the initial riflemen in the company. Thus, for every casualty level

$$m(E,j) + C(E,j) + k(E,j) = 1 - B,$$

$$m(b,j) + C(b,j) + i(b,j) + W(b,j) = B,$$

and the sum of the fractional parts of initial riflemen in all seven states equals 1, the normalized number of initial company riflemen. The fractional parts of initial riflemen in each of the seven states are illustrated below. The area of the outer square = 1 = normalized number of initial riflemen in an infantry company.



At any casualty level j,

$$m(T,j) = m(E,j) + m(b,j), \tag{2}$$

with

$$m(T,0) = (1 - B),$$

where m(E,j), the fraction of initial riflemen that are committed and effective among those originally committed, is given by

$$\begin{aligned} m(E,j) &= [1 - B] \cdot [1 - F(j)] \cdot [1 - g(j)] \\ &= [\text{not originally reserves}] \cdot [\text{not casualties}] \\ &\quad \cdot [\text{not ineffective}], \end{aligned} \tag{3}$$

with

$$m(E,0) = (1 - B);$$

and m(b,j), the fraction of initial riflemen that are committed and effective among those originally reserves, is given by

$$\begin{aligned} m(b,j) &= m(b,j-1) + I(10,j) - I(1,j) - I(3,j) \\ &= [\text{effective riflemen at } (j-1) \text{ that originally were reserves}] \\ &\quad + [\text{reserves committed at or before } j \text{ but after } (j-1)] \\ &\quad - [\text{committed reserves that have become casualties at or before } j \text{ but after } (j-1)] \\ &\quad - [\text{committed reserves that have become ineffective at or before } j \text{ but after } (j-1)], \end{aligned} \tag{4}$$

with

$$m(b,0) = 0.$$

The remainder of this appendix provides details of computing $I(10,j)$, $I(1,j)$, and $I(3,j)$ and explains how their computation is affected by (1) the fraction of surviving riflemen that are ineffective, $g(j)$, and (2) the policy or manner in which troops are committed.

COMMITTED RESERVES

The commitment policy determines how and when riflemen originally in reserve are to be committed to combat, as a function of company casualties. We shall give several examples of commitment policies later, including commitment of reserves by platoon, by fire team, etc., that may be used by an infantry company to accomplish its mission.

Let $Y(b,j) \equiv$ the cumulative commitment of riflemen, consistent with the commitment policy, beginning with the start of the fire fight, that is required to replace committed riflemen that have become casualties or ineffectives up to and including the jth casualty level, with

$$Y(b,0) = 0.$$

Thus $Y(b,j)$ is a function of the commitment policy and of the jth casualty level. Since cumulative commitments cannot exceed the original number of riflemen reserves,

$$0 \leq Y(b,j) \leq B.$$

Later, we shall show how $Y(b,j)$ is determined for each of the examples of commitment policies.

In Eq. (4), the number of reserves committed at or before the jth casualty level but after the $(j-1)^{st}$ casualty level, $I(10,j)$, is given by

$$I(10,j) \leq Y(b,j) - Y(b,j-1), \tag{5}$$

with

$$I(10,0) \equiv 0.$$

There will be a critical casualty level, k, at which the requirement for committed riflemen, $Y(b,k) - Y(b,k-1)$, will become greater than or equal to the number of available uncommitted reserve riflemen. At the critical casualty level, k, the number of riflemen committed is equal to the number of available uncommitted riflemen. Subsequent to the critical casualty level, k, all reserve riflemen will have been committed. Therefore,

$$I(10,j) = 0 \quad \text{for } j > k.$$

Thus in Eq. (5) strict equality holds for $j < k$ but not thereafter.

Committed Reserves That Have Become Casualties

The fraction of the initial company that are casualties at the jth casualty level, $F(j)$, is the key factor in determining riflemen that are casualties. Based on the assumption that casualties are uniformly distributed among all riflemen including reserves, we have seen that the fraction of initial riflemen that are casualties at the jth casualty level, $C(T,j)$, is given by

$$C(T,j) = F(j).$$

It also follows from this assumption that

$$\begin{aligned} C(E,j) &= [1 - B] \cdot F(j) \\ &= [\text{not in reserves}] \cdot [\text{company casualties}] \\ &\equiv \text{riflemen that were originally committed that} \\ &\quad \text{are casualties at the } j^{th} \text{ casualty level,} \end{aligned}$$

and

$$\begin{aligned} C(b,j) &= (B) \cdot F(j) \\ &= [\text{reserves}] \cdot [\text{company casualties}] \\ &\equiv \text{riflemen that were originally reserves that} \\ &\quad \text{are casualties at the } j^{th} \text{ casualty level.} \end{aligned}$$

The fraction of initial riflemen that are originally reserves and become casualties between casualty level (j-1) and j, I(8,j), is computed by

$$I(8,j) = C(b,j) - C(b,j-1),$$

with

$$I(8,0) \equiv 0.$$

These casualties, I(8,j), are proportioned among two subgroups:

1. m(b,j-1), effective riflemen, i.e., riflemen that originally were reserves and had been committed and were firing their rifles at casualty level (j-1)
2. W(b,j-1), uncommitted riflemen at casualty level (j-1) (see p. 39 for a further discussion of W(b,j-1))

Correspondingly, the ratios or factors of proportionality for each group are given by

$$r(3,j) = m(b,j-1)/(m(b,j-1) + W(b,j-1)),$$

with

$$r(3,0) \equiv 0,$$

and

$$r(4,j) = W(b,j-1)/(m(b,j-1) + W(b,j-1)),$$

with

$$r(4,0) \equiv 1.$$

Then the number of casualties among the committed reserves that become casualties between casualty level (j-1) and j, I(1,j) is computed by

$$\begin{aligned} I(1,j) &= r(3,j) \cdot I(8,j) \\ &= [m(b,j-1)/(m(b,j-1) + W(b,j-1))] \cdot [C(b,j) - C(b,j-1)]. \end{aligned}$$

Committed Reserves That Have Become Ineffective

The ineffective riflemen are also considered in two groups: (1) those originally committed and (2) those originally in reserve.

Let

$i(T,j)$ = surviving riflemen that are ineffective at casualty level j

$i(E,j)$ = surviving ineffective riflemen among those originally committed, $(1 - B)$

$i(b,j)$ = surviving ineffective riflemen among those originally in reserve, B

Then

$$\begin{aligned} i(T,j) &= g(j) \cdot (1 - F(j)) \\ &= [\text{fraction of surviving riflemen that are ineffective}] \cdot [\text{surviving riflemen}] \\ &= i(E,j) + i(b,j). \end{aligned}$$

We assume that the ineffectives are proportioned in terms of the ratio of riflemen that were originally reserves, so that

$$\begin{aligned} i(E,j) &= (1 - B) \cdot i(T,j) \\ &= (1 - B) \cdot [g(j) \cdot (1 - F(j))] \end{aligned}$$

and

$$\begin{aligned} i(b,j) &= B \cdot i(T,j) \\ &= B \cdot [g(j) \cdot (1 - F(j))]. \end{aligned}$$

Among the riflemen that were originally in reserve, the ineffectives are proportioned between committed and uncommitted survivors, as were the casualties. Between casualty level (j-1) and j, the increase in ineffectives among riflemen that were originally in reserve, $I(9,j)$, is computed by

$$I(9,j) = i(b,j) - i(b,j-1),$$

with

$$I(9,0) \equiv 0,$$

and the ineffectives among the committed reserves in the casualty interval (j-1) to j, I(3,j), is given by

$$I(3,j) = I(9,j) \cdot r(3,j),$$

$$I(3,j) = [i(b,j) - i(b,j-1)] \cdot [m(b,j-1)/(m(b,j-1) + W(b,j-1))], \qquad (6)$$

with

$$I(3,0) \equiv 0.$$

UNCOMMITTED RESERVES

Finally, a computation must be made of those riflemen that were originally in reserve that have not become casualties or ineffective and have not been committed by the jth casualty level, W(b,j). These riflemen compose the remaining strength among the riflemen that originally were in reserve.

Thus

$$\begin{aligned} W(b,j) &\equiv \text{uncommitted riflemen at casualty level } j \\ &= W(b,j-1) - I(4,j) - I(2,j) - I(10,j) \\ &= [\text{uncommitted riflemen at } (j-1)] \\ &\quad - [\text{casualties among uncommitted riflemen between } (j-1) \text{ and } j] \\ &\quad - [\text{ineffectives among uncommitted riflemen between } (j-1) \text{ and } j] \\ &\quad - [\text{reserves committed between } (j-1) \text{ and } j], \end{aligned}$$

with

$$W(b,0) = B.$$

The computation of I(10,j) has been discussed earlier (see p. 35). Therefore, we will explain only the computation of I(4,j) and I(2,j).

In a manner similar to that used to compute casualties among committed reserves (see p. 37), I(8,j), the casualties among reserves between casualty level (j-1) and j are proportioned to uncommitted reserves as follows:

$$I(4,j) = r(4,j) \cdot I(8,j)$$

$$= [W(b,j-1)/(m(b,j-1) + W(b,j-1))] \cdot [C(b,j) - C(b,j-1)],$$

with

$$I(4,0) \equiv 0.$$

Similiarly, for ineffectives (see p. 39), I(9,j), the increase between casualty level (j-1) and j of ineffectives among riflemen that originally were in reserve is proportioned to uncommitted riflemen as

$$I(2,j) = r(4,j) \cdot I(9,j)$$

$$= [W(b,j-1)/(m(b,j-1) + W(b,j-1))] \cdot [i(b,j) - i(b,j-1)].$$

with

$$I(2,0) \equiv 0.$$

KEY FORMULAS TO BE EVALUATED AT THE jth CASUALTY LEVEL

Table A-1 presents a summary of the key formulas to be evaluated at the jth casualty level that have been discussed thus far.

ATTACKING-COMPANY COMMITMENT POLICIES

A wide variety of commitment policies have been used in actual fire fights, ranging from committing an entire company initially to committing one platoon and holding two in reserve. Since the technique of initially committing two platoons and holding one in reserve is frequently used, several variations of this technique are illustrated: reserves committed by fire team, reserves committed to maintain constant effective firing strength, reserves committed by platoon

Table A-1

KEY FORMULAS TO BE EVALUATED AT THE jth CASUALTY LEVEL[a]

Personnel	j = 0 (initial conditions)	j ≥ 1
Casualties		
Originally reserves	C(b,0) = 0	C(b,j) = B · F(j)
Originally committed	C(E,0) = 0	C(E,j) = (1-B) · F(j)
Total riflemen	C(T,0) = 0	C(T,j) = F(j)
Survivors		
Ineffectives		
Originally reserves	i(b,0) = 0	i(b,j) = B · g(j) · (1-F(j))
Originally committed	i(E,0) = 0	i(E,j) = (1-B) · g(j) · (1-F(j))
Total riflemen	i(T,0) = 0	i(T,j) = g(j) · (1-F(j))
Uncommitted, originally reserves	W(b,0) = B	W(b,j) = W(b,j-1) - I(4,j) - I(2,j) - I(10,j)
Effectives		
Originally reserves	m(b,0) = 0	m(b,j) = m(b,j-1) - I(3,j) - I(1,j) + I(10,j)
Originally committed	m(E,0) = (1-B)	m(E,j) = (1-B) · (1-F(j)) · (1-g(j))
Total riflemen	m(T,0) = (1-B)	m(T,j) = m(b,j) + m(E,j)
Incremental[b] casualties, originally reserves		
From committed (effectives)	I(1,0) = 0	I(1,j) = [m(b,j-1)/(m(b,j-1) + W(b,j-1))] · I(8,j)
From uncommitted	I(2,0) = 0	I(2,j) = [W(b,j-1)/(m(b,j-1) + W(b,j-1))] · I(8,j)
Total	I(8,0) = 0	I(8,j) = C(b,j) - C(b,j-1)
Incremental[b] ineffectives, originally reserves		
From committed (effectives)	I(3,0) = 0	I(3,j) = [m(b,j-1)/(m,j-1) + W(b,j-1))] · I(9,j)
From uncommitted	I(4,0) = 0	I(4,j) = [W(b,j-1)/(m(b,j-1) + W(b,j-1))] · I(9,j)
Total	I(9,0) = 0	I(9,j) = i(b,j) - i(b,j-1)
Commitments	I(10,0) = 0	I(10,j) ≤ Y(b,j) - Y(b,j-1)
Fraction of survivors that are		
Ineffective	i(T,0)/(1-F(0)) = 0	i(T,j)/(1-F(j))
Uncommitted	W(T,0)/(1-F(0)) = B	W(T,j)/(1-F(j))
Effective	m(T,0)/(1-F(0)) = 1 - B	m(T,g)/(1-F(j))

[a] F(j) = fraction of the initial company that are casualties.
g(j) = fraction of surviving riflemen that are ineffective.
Y(b,j) = total cumulative commitment requirement since the start of the fire fight as determined by F(j) and the commitment policy.
B = fraction of initial riflemen that originally were reserves.

[b] In the casualty interval at or before j but after (j-1).

as a unit, and reserves committed arbitrarily. The illustrations considered below are for attacking-infantry commitment policies. Defending-infantry commitment policies will be discussed later.

No Reserves Committed

First, in an examination of reserves, the number of riflemen that are effective at the jth casualty level, $m(T,j)$, must be determined. We set

B = fraction originally reserves = 0

$Y(b,j)$ = cumulative commitment requirement = 0 for $j \geq 0$

For this illustration we consider that no reserves are committed. The values of $F(j)$, in percentages, are given in Table A-2, first column, with $F(0) = 0$. The other inputs required to compute $m(T,j)$ are the values of $g(j)$, the fraction of surviving riflemen that are ineffective, which may be read from the curve of Fig. A-1. Using these inputs and the formulas, we obtain the results shown in Table A-2. The percent of initial riflemen that are committed and effective is given in the fourth column, $100 \cdot m(T,j)$, and the percentage of surviving riflemen that are committed and effective, $100 \cdot m(T,j)/(1 - F(j))$, is given in the seventh column for each casualty level $j \geq 1$. The values in other columns are self-explanatory.

Reserves Committed by Fire Team

Next, we consider that reserves of an attacking infantry company are committed by fire team. It is assumed that a company consists of three platoons, two of which are committed initially, and one held in reserve. Each platoon is assumed to consist of three squads having two fire teams each. The first fire team includes three riflemen, while the second fire team includes five riflemen. With nine squads per company, the first team has 3/72 (3/8 · 1.9) and the second has 5/72 of the company's riflemen.

The commitment policy is

1. Commit no reserves until the company has received 5 percent casualties

Table A-2

PERCENTAGE OF SURVIVORS OF AN ATTACKING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: ALL TROOPS INITIALLY COMMITTED

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	j
4.99	.79	.00	94.22	.83	.00	99.17	1
5.00	.79	.00	94.21	.83	.00	99.17	2
5.36	.84	.00	93.80	.89	.00	99.11	3
5.39	.85	.00	93.76	.90	.00	99.10	4
8.00	3.31	.00	88.69	3.60	.00	96.40	5
10.50	5.41	.00	84.09	6.05	.00	93.95	6
10.52	5.44	.00	84.04	6.08	.00	93.92	7
12.00	7.04	.00	80.96	8.00	.00	92.00	8
12.96	8.18	.00	78.86	9.40	.00	90.60	9
12.98	8.44	.00	78.58	9.70	.00	90.30	10
14.00	9.46	.00	76.54	11.00	.00	89.00	11
16.25	12.86	.00	70.89	15.36	.00	84.64	12
16.27	13.13	.00	70.60	15.68	.00	84.32	13
17.77	15.98	.00	66.25	19.43	.00	80.57	14
17.80	16.03	.00	66.17	19.50	.00	80.50	15
18.45	17.46	.00	64.09	21.41	.00	78.59	16
20.00	20.80	.00	59.20	26.00	.00	74.00	17
22.00	26.13	.00	51.87	33.50	.00	66.50	18
22.90	29.30	.00	47.80	38.00	.00	62.00	19
24.00	32.83	.00	43.17	43.20	.00	56.80	20
26.00	41.88	.00	32.12	56.60	.00	43.40	21
27.00	47.45	.00	25.55	65.00	.00	35.00	22
28.00	54.00	.00	18.00	75.00	.00	25.00	23
29.00	60.00	.00	11.01	84.50	.00	15.50	24
30.00	70.00	.00	.00	100.00	.00	.00	25

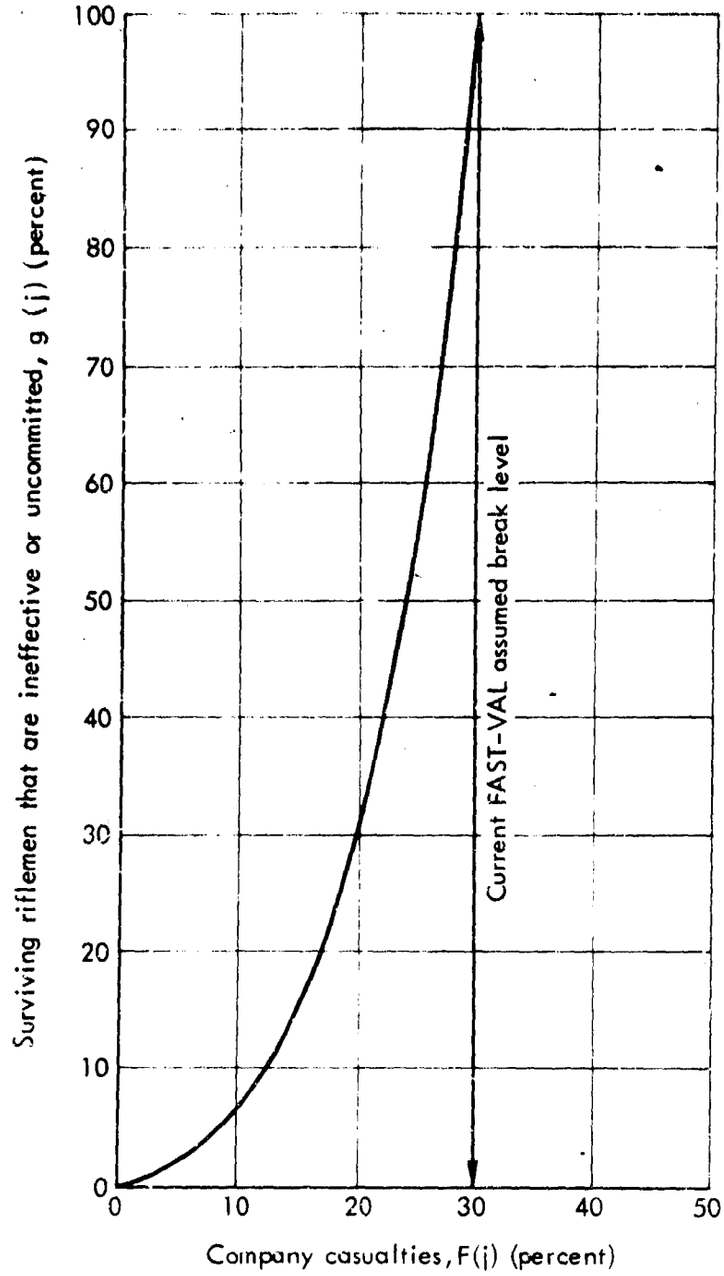


Fig. A-1—FAST-VAL relationship between an attacking infantry company's casualties and its surviving riflemen that are ineffective or uncommitted

2. Replace by fire team the effective riflemen that have become casualties or ineffectives

Thus the cumulative commitment requirement, Y(b,j), is

$$Y(b,j) = \begin{cases} 0 & \text{if } F(j) < c \text{ or } u(j) < 3/72 \\ 3/72 & \text{if } F(j) \geq c \text{ and } 3/72 \leq u(j) < 8/72 \\ 8/72 & \text{if } F(j) \geq c \text{ and } 8/72 \leq u(j) < 11/72 \\ 11/72 & \text{if } F(j) \geq c \text{ and } 11/72 \leq u(j) < 16/72 \\ 16/72 & \text{if } F(j) \geq c \text{ and } 16/72 \leq u(j) < 19/72 \\ 19/72 & \text{if } F(j) \geq c \text{ and } 19/72 \leq u(j) < 24/72 \\ 24/72 & \text{if } F(j) \geq c \text{ and } 24/72 \leq u(j) \end{cases}$$

where

$c = 0.05$

$B = 1/3$

$u(j) \equiv$ effective riflemen that have become casualties or ineffective by casualty level j.

Now

$$u(j) = u(j-1) + [C(T,j) - C(T,j-1) - I(2,j)] + [i(T,j) - i(T,j-1) - I(4,j)]$$

= [effective riflemen that become casualties or ineffectives by (j-1)]
+ [effective riflemen that become casualties in period (j-1) to j]
+ [effective riflemen that become ineffectives in period (j-1) to j].

Table A-3 shows the results of the computation using the input F(j) shown in the first column, with F(0) = 0; g(j) taken from Fig. A-1; and the formulas developed earlier. The casualty levels, F(j), have been selected to be representative of all casualty levels and to represent the casualty level just before and just after a team commitment is made. It is noted that within this commitment policy only four

Table A-3

PERCENTAGE OF SURVIVORS OF AN ATTACKING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVES COMMITTED BY FIRE TEAM

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	j
4.99	.79	31.09	63.13	.83	32.73	66.44	1
5.00	.79	31.09	63.12	.83	32.73	66.44	2
5.36	.84	30.95	62.84	.89	32.71	66.40	3
5.39	.85	26.77	66.99	.90	28.30	70.80	4
8.00	3.31	25.33	63.36	3.60	27.53	68.87	5
10.50	5.41	24.01	60.07	6.05	26.83	67.12	6
10.52	5.44	17.05	66.99	6.08	19.06	74.86	7
12.00	7.04	16.43	64.53	8.00	18.67	73.33	8
12.96	8.18	16.00	62.86	9.40	18.39	72.21	9
12.98	8.44	11.78	66.80	9.70	13.54	76.76	10
14.00	9.46	11.47	65.07	11.00	13.34	75.66	11
16.26	12.86	10.63	60.26	15.36	12.69	71.95	12
16.27	13.13	3.64	66.96	15.68	4.35	79.97	13
17.77	15.98	3.41	62.84	19.43	4.15	76.42	14
17.80	16.03	.00	66.17	19.50	.00	80.50	15
18.45	17.46	.00	64.09	21.41	.00	78.59	16
20.00	20.80	.00	59.20	26.00	.00	74.00	17
22.00	26.13	.00	51.87	33.50	.00	66.50	18
22.90	29.30	.00	47.80	38.00	.00	62.00	19
24.00	32.83	.00	43.17	43.20	.00	56.80	20
26.00	41.88	.00	32.12	56.60	.00	43.40	21
27.00	47.45	.00	25.55	65.00	.00	35.00	22
28.00	54.00	.00	18.00	75.00	.00	25.00	23
29.00	60.00	.00	11.01	84.50	.00	15.50	24
30.00	70.00	.00	.00	100.00	.00	.00	25

full teams are committed plus a final partial team that is committed when the company casualty level reaches 17.8 percent. At higher casualty levels, the numbers of committed and effective riflemen decrease in the same manner as though the entire company were committed initially. The percentage of initial riflemen that are committed and effective, i.e., the company effectiveness, that results for this policy is shown as the solid curve in Fig. A-2 and is plotted from the values in the fourth column of Table A-3. A similar curve (the dashed line) is plotted for the case where the entire company is committed initially (no reserves); this curve is plotted from the values in the fourth column of Table A-2. The third curve in Fig. A-2 is discussed below.

Reserves Committed Continuously

The average effective strength when the commitment is by fire team is 0.64 (see Fig. A-2). To simplify the input to FAST-VAL, a continuous replacement of riflemen was investigated as an approximation to the fire-team commitment. The assumptions are

1. Reserves constitute one platoon (B = 1/3)
2. No reserves are committed until the company has received 5 percent casualties (c = 0.05)
3. Effective riflemen casualties and ineffectives will be replaced to maintain effective riflemen at 0.64

Thus

$$Y(b,j) = \begin{cases} 0 \text{ if } F(j) < c, \\ i(E,j) + C(E,j) - 0.03 \text{ if } F(j) = c, \text{ or} \\ \text{Min}\,\{B,\ Y(b,j-1) + [C(T,j) - C(T,j-1) - I(2,j)] \\ \qquad + [i(T,j) - i(T,j-1) - I(4,j)]\}. \end{cases}$$

The first condition on Y(b,j) permits no reserves to be committed until casualty level c (i.e., 5 percent) is reached.

The second condition on Y(b,j) permits reserves to be committed at casualty level c (i.e., 5 percent) and to bring the effective riflemen to 0.64 at that time.

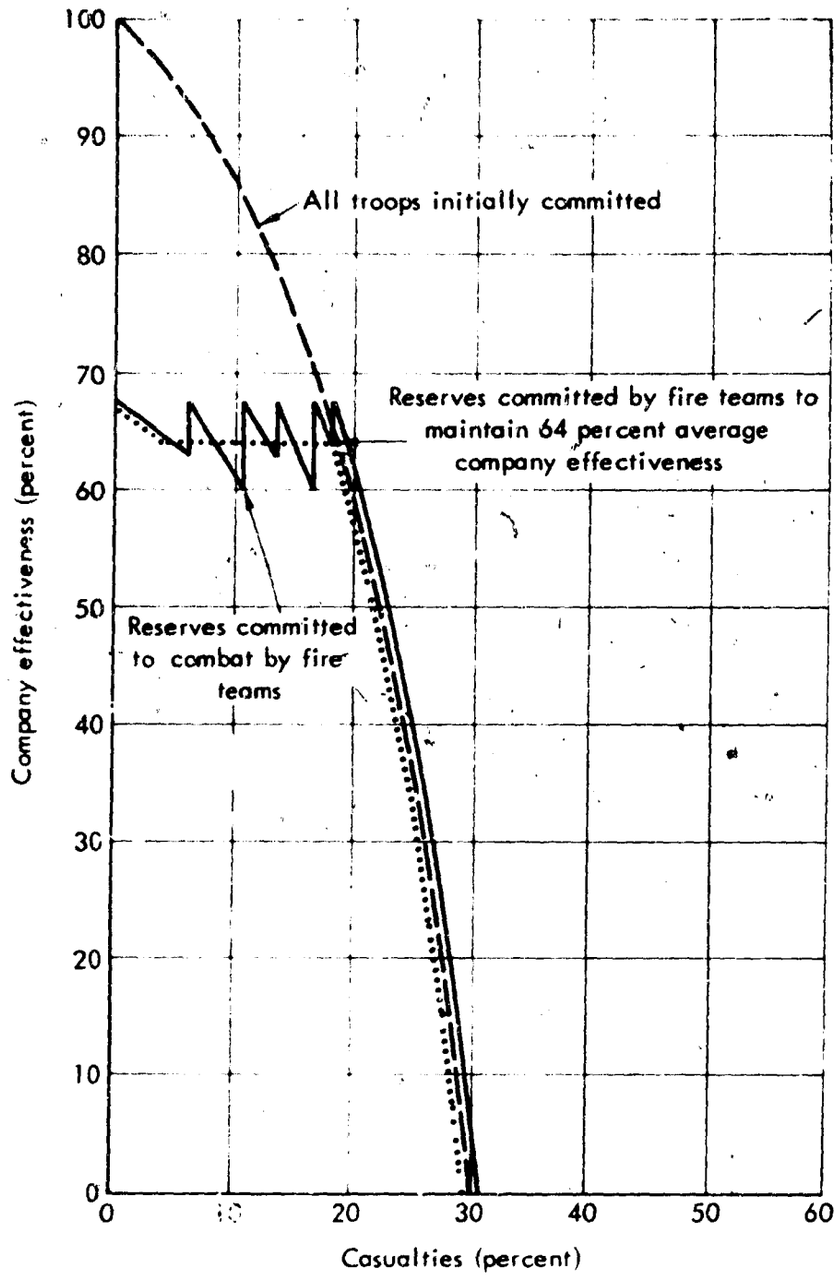


Fig. A-2—Relationship between an attacking infantry company's percentage casualties and effectiveness

At $F(j) = c$,

Commitment requirement = [committed riflemen that have become ineffective] + [committed riflemen that have become casualties] - 0.03,

where

0.03 = [initial fraction effective (0.67)] - [desired fraction effective (0.64)].

The third condition permits the cumulative requirement $Y(b,j)$ to increase to its maximum, B, but does not permit $Y(b,j)$ to exceed the number of riflemen that were initially reserves, B.

Table A-4 shows the results of this commitment policy using the same values of $F(j)$ and $g(j)$ as in the earlier examples. The company effectiveness that results from this commitment policy is shown by the dotted curve of Fig. A-2, plotted from the values in the fourth column of Table A-4.

The sum of fractional parts of initial riflemen in all possible states equals 1. Thus, for the jth casualty level,

$$m(T,j) + W(b,j) + i(T,j) = 1 - C(T,j) = 1 - F(j),$$

and

$$\frac{m(T,j)}{1-F(j)} = 1 - \frac{W(b,j) + i(T,j)}{1 - F(j)}.$$

This indicates that the fraction of surviving riflemen that are committed and effective is complementary to the fraction of surviving riflemen that are uncommitted or ineffective, and that given one fractional part, the other is readily computed as its complement. Also, the sum of columns five and six of each of the tables equals the percentage of surviving riflemen that are ineffective or uncommitted. Figure A-3 shows the relationship between the percentage

Table A-4

PERCENTAGE OF SURVIVORS OF AN ATTACKING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVES COMMITTED CONTINUOUSLY

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	
4.99	.79	31.09	63.13	.83	32.73	66.44	1
5.00	.79	30.21	64.00	.83	31.80	67.37	2
5.36	.84	29.80	64.00	.89	31.49	67.62	3
5.39	.85	29.76	64.00	.90	31.46	67.65	4
8.00	3.31	24.69	64.00	3.60	26.83	69.57	5
10.50	5.41	20.09	64.00	6.05	22.44	71.51	6
10.52	5.44	20.04	64.00	6.08	22.40	71.52	7
12.00	7.04	16.96	64.00	8.00	19.27	72.73	8
12.96	8.18	14.86	64.00	9.40	17.07	73.53	9
12.98	8.44	14.58	64.00	9.70	16.75	73.55	10
14.00	9.46	12.54	64.00	11.00	14.58	74.42	11
16.25	12.86	6.89	64.00	15.36	8.22	76.42	12
16.27	13.13	6.60	64.00	15.68	7.88	76.44	13
17.77	15.98	2.25	64.00	19.43	2.74	77.83	14
17.80	16.03	2.17	64.00	19.50	2.64	77.86	15
18.45	17.46	.09	64.00	21.41	.11	78.48	16
20.00	20.80	.00	59.20	26.00	.00	74.00	17
22.00	26.13	.00	51.87	33.50	.00	66.50	18
22.90	29.30	.00	47.80	38.00	.00	62.00	19
24.00	32.83	.00	43.17	43.20	.00	56.80	20
26.00	41.88	.00	32.12	56.60	.00	43.40	21
27.00	47.45	.00	25.55	65.00	.00	35.00	22
28.00	54.00	.00	18.00	75.00	.00	25.00	23
29.00	60.00	.00	11.01	84.50	.00	15.50	24
30.00	70.00	.00	.00	100.00	.00	.00	25

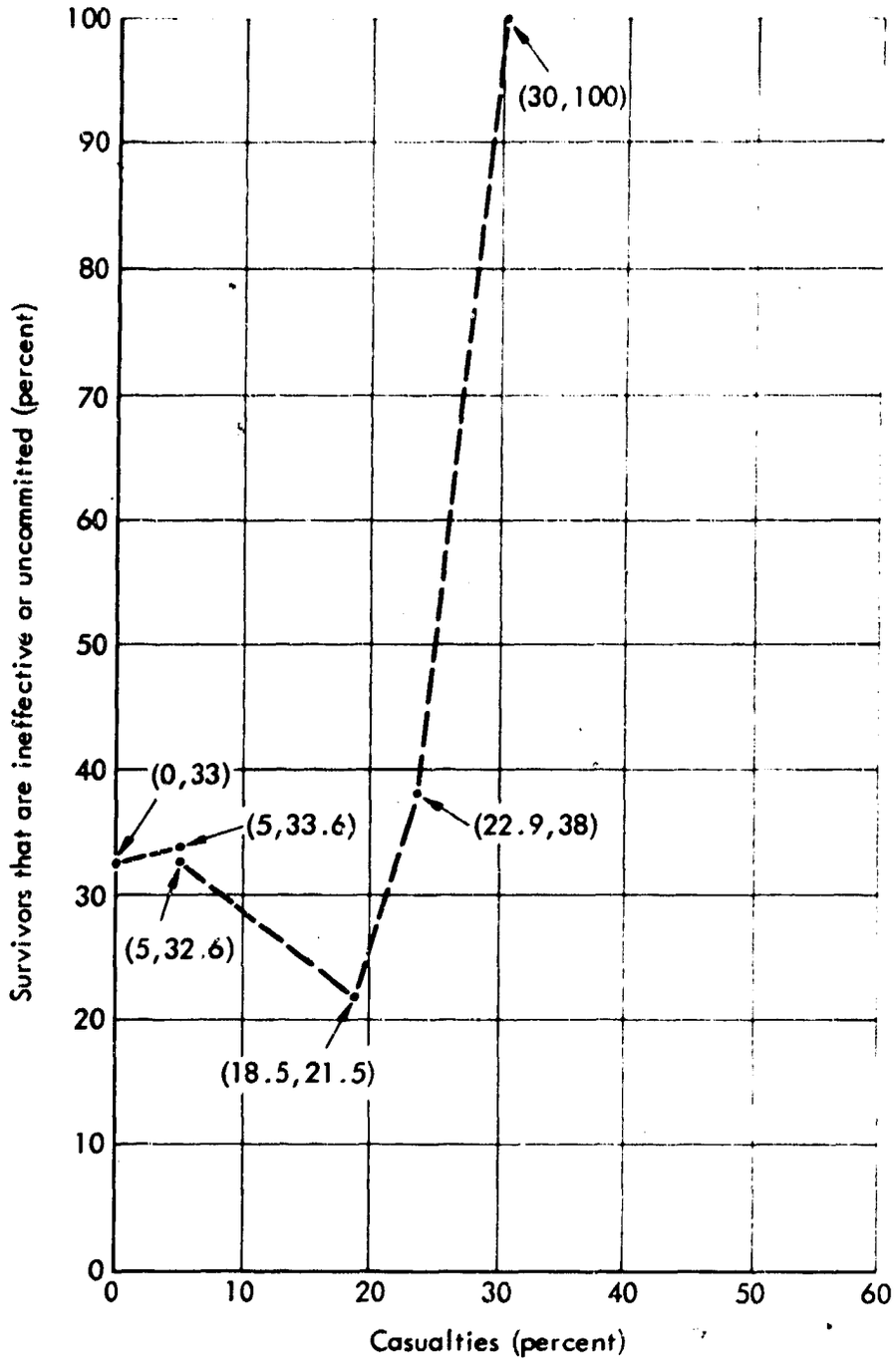


Fig. A-3 — Relationship between an attacking infantry company's percentage casualties and the percentage of its survivors that are ineffective or uncommitted (reserves committed continuously)

casualties and the percentage of surviving riflemen that are ineffective or uncommitted for an attacking infantry company whose reserves are committed according to this policy.

Reserves Committed by Platoon

Now we will consider that two platoons are initially committed and one is held in reserve. This commitment policy, often used, requires the commander in the field to judge the situation and commit his reserves, the entire platoon, at the time when he feels his objective will be accomplished by this sudden increase in forces. Analytically, the commitment of reserves can occur in one of two ways: (1) when the unit crosses the final coordination line or (2) at a time before the unit reaches the final coordination line.

The second way, which is developed here, requires the user to make the judgment of when (at what casualty level) the reserves are to be committed. Let the decision be to commit the platoon when the casualties reach c.

Analytically the commitment by platoon is given by

$$B = 1/3,$$

and

$$Y(b,j) = \begin{cases} 0 \text{ if } F(j) < c \\ B \text{ if } F(j) \geq c. \end{cases}$$

Two cases bound the commitment policy: first, when c = 0 and all reserves are committed immediately, and second, when c = 1/3 and reserves are never committed. Figure A-4 illustrates these two commitment policies and includes a line indicating the number of surviving riflemen. These survivors all become effective in a FAST-VAL simulation when the unit crosses the final coordination line, independent of the commitment policy.

The effective number of riflemen follows the lower bound (c = 1/3) until the reserves are committed, at which time the number of effectives

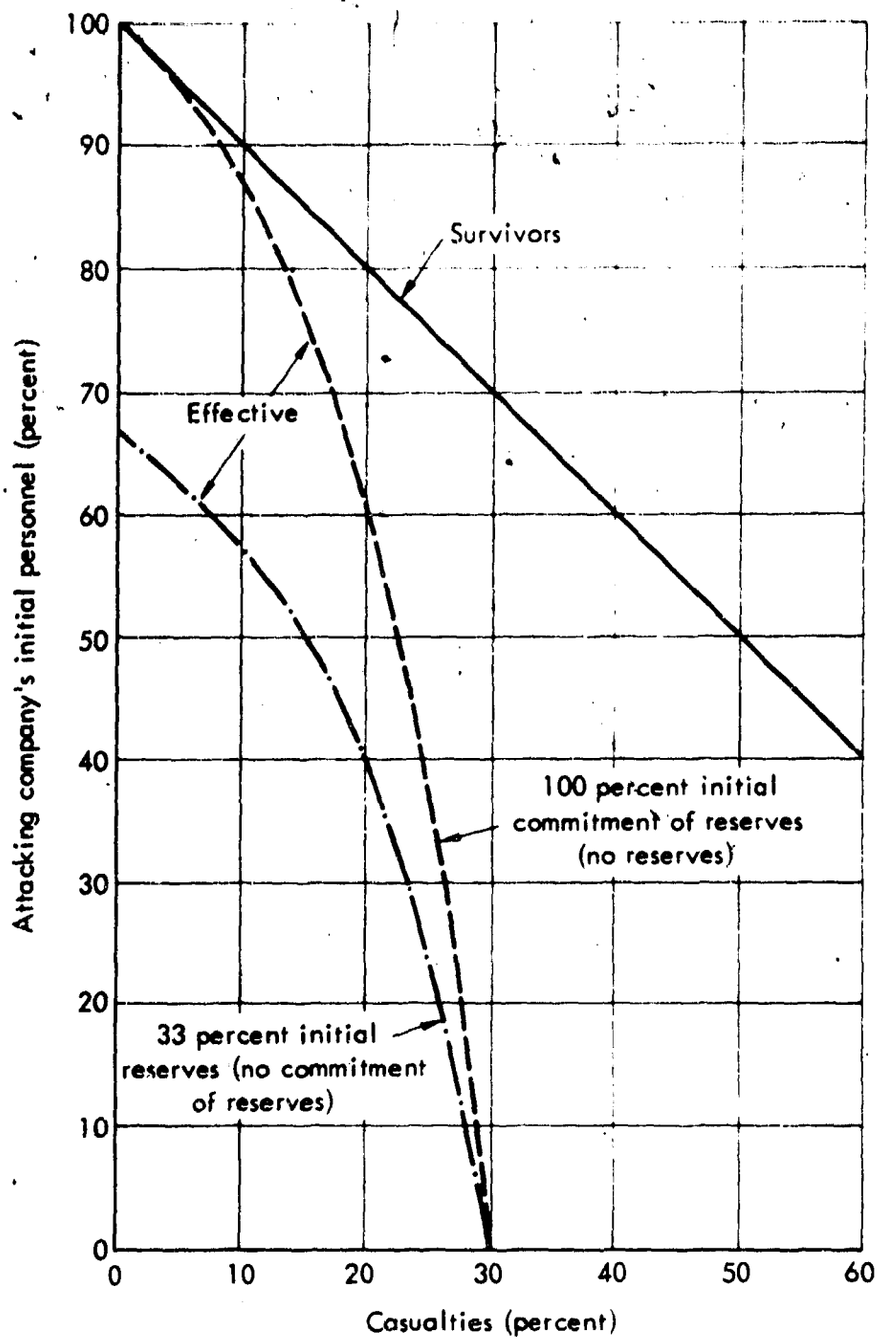


Fig. A-4 — Relationship between an attacking infantry company's percentage casualties and the percentage of its initial personnel that are effective

rises to the upper bound ($c = 0$) at the specified quantity of casualties, c. Figure A-5 illustrates the policy when reserves are committed at $c = 0.05$, and Fig. A-6 when reserves are committed at $c = 0.229$, with Tables A-5 and A-6 showing the computed results for both policies, respectively. Again, in both cases the same values of F(j) and g(j) for an attacking infantry company are used in the computation; only the commitment policy is changed.

Arbitrary Commitment Policy

It is, of course, possible to have commitment policies other than those already outlined. The following policy was used in early FAST-VAL simulations. It was assumed that originally two platoons were committed and one was held in reserve. The fractional part of riflemen survivors that are ineffective or uncommitted increases linearly from 0.33 to 0.38 as company casualties increase from 0 to 10 percent. Thereafter, the reserves are committed so that the fraction of survivors that are ineffective or uncommitted remains at 0.38 for an attacking infantry company until all reserves are committed. The solid curve in Fig. A-7 illustrates this policy for an attacking infantry company; the dashed curve represents a defending company.

Defending Company Commitment Policies

The commitment policy of a defending infantry company can follow the same sequence that has been discussed for an attacking infantry company. However, the casualty levels, F(j), and the percentage of surviving riflemen that are ineffective, g(j), will be different. The functional relationship between g(j) and F(j) for a defending infantry company is given by the solid curve in Fig. 4 (p. 16). Using these inputs, the fraction of initial riflemen that are effective (i.e., company effectiveness), computed as a function of company casualties, F(j), is illustrated for three commitment policies in Fig. A-8. The dashed curve represents the case where all troops are committed initially and is based on the data in Table A-7; the solid curve represents the case in which reserves are committed by fire teams, based on the data in Table A-8; and the dotted curve represents the case where

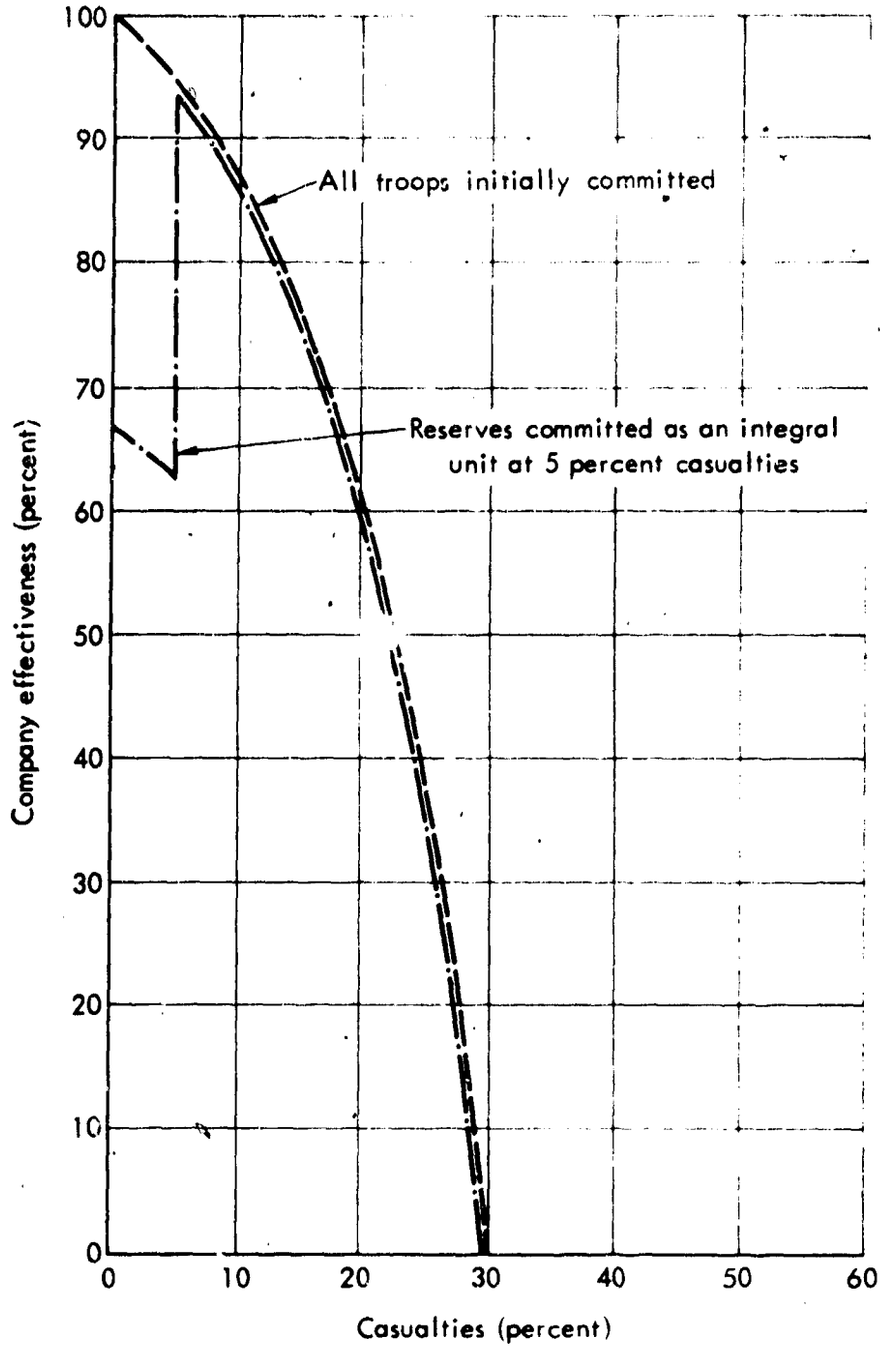


Fig. A-5—Relationship between an attacking infantry company's percentage casualties and company effectiveness (reserves committed as an integral unit at 5 percent casualties).

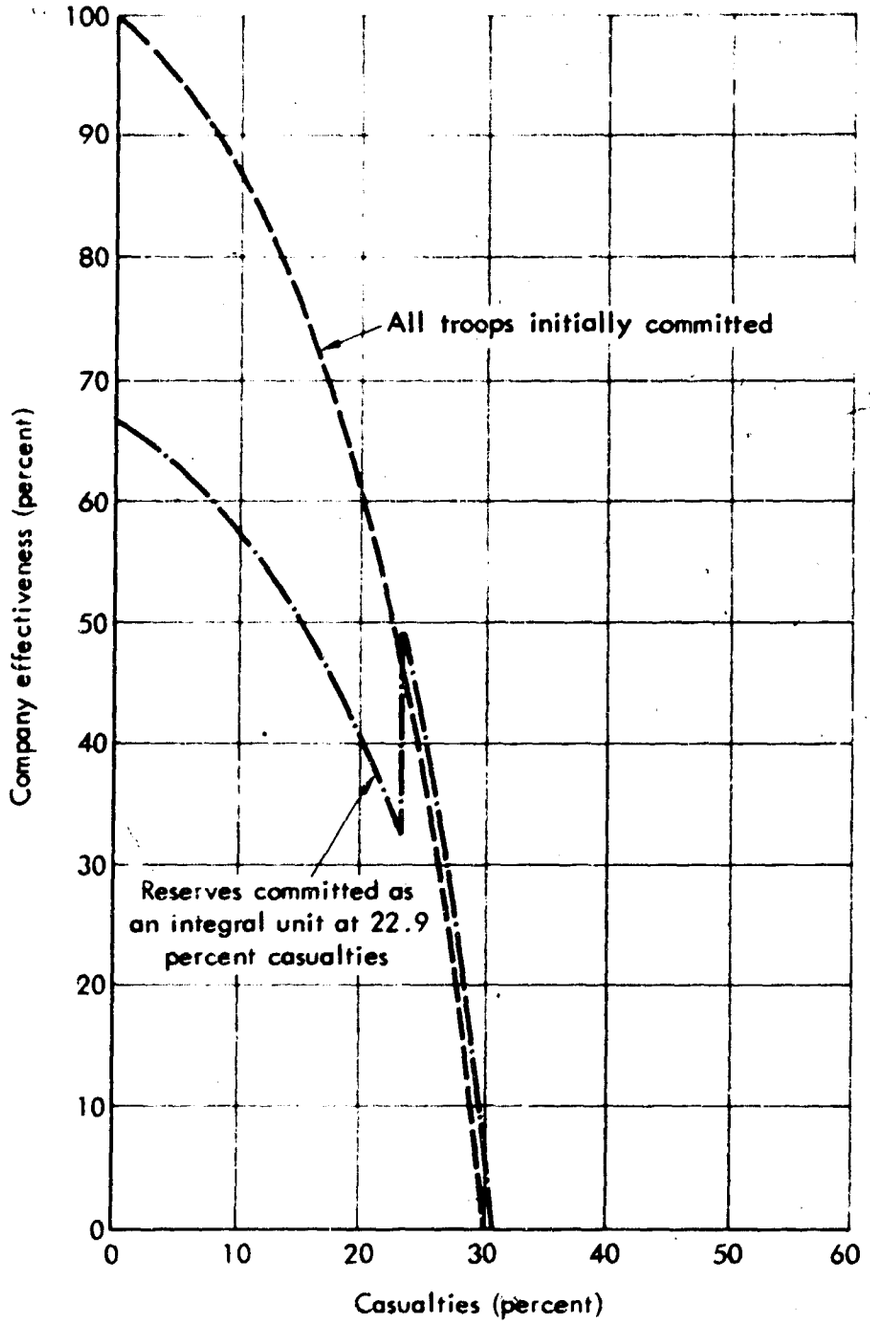


Fig. A-6 — Relationship between an attacking infantry company's percentage casualties and company effectiveness (reserves committed as an integral unit at 22.9 percent casualties)

Table A-5

PERCENTAGE OF SURVIVORS OF AN ATTACKING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVE PLATOON COMMITTED AT 5 PERCENT CASUALTY LEVEL

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective		Ineffective	Effective		j
		Uncommitted	Committed		Uncommitted	Committed	
4.99	.79	31.09	63.13	.83	32.73	66.44	1
5.00	.79	.00	94.21	.83	.00	99.17	2
5.36	.84	.00	93.80	.89	.00	99.11	3
5.39	.85	.00	93.76	.90	.00	99.10	4
8.00	3.31	.00	88.69	3.60	.00	96.40	5
10.50	5.41	.00	84.09	6.05	.00	93.95	6
10.52	5.44	.00	84.04	6.08	.00	93.92	7
12.00	7.04	.00	80.96	8.00	.00	92.00	8
12.96	8.18	.00	78.86	9.40	.00	90.60	9
12.98	8.44	.00	78.58	9.70	.00	90.30	10
14.00	9.46	.00	76.54	11.00	.00	89.00	11
16.25	12.86	.00	70.89	15.36	.00	84.64	12
16.27	13.13	.00	70.60	15.68	.00	84.32	13
17.77	15.98	.00	66.25	19.43	.00	80.57	14
17.80	16.03	.00	66.17	19.50	.00	80.50	15
18.45	17.46	.00	64.09	21.41	.00	78.59	16
20.00	20.80	.00	59.20	26.00	.00	74.00	17
22.00	26.13	.00	51.87	33.50	.00	66.50	18
22.90	29.30	.00	47.80	38.00	.00	62.00	19
24.00	32.83	.00	43.17	43.20	.00	56.80	20
26.00	41.88	.00	32.12	56.60	.00	43.40	21
27.00	47.45	.00	25.55	65.00	.00	35.00	22
28.00	54.00	.00	18.00	75.00	.00	25.00	23
29.00	60.00	.00	11.01	84.50	.00	15.50	24
30.00	70.00	.00	.00	100.00	.00	.00	25

Table A-6

PERCENTAGE OF SURVIVORS OF AN ATTACKING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVE PLATOON COMMITTED AT 22.9 PERCENT CASUALTIES

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	j
4.99	.79	31.09	63.13	.83	32.73	66.44	1
5.00	.79	31.09	63.12	.83	32.73	66.44	2
5.36	.84	30.95	62.84	.89	32.71	66.40	3
5.39	.85	30.94	62.82	.90	32.70	66.40	4
8.00	3.31	29.27	59.42	3.60	31.81	64.59	5
10.50	5.41	27.75	56.34	6.05	31.00	62.95	6
10.52	5.44	27.73	56.31	6.08	30.99	62.93	7
12.00	7.04	26.72	54.24	8.00	30.36	61.64	8
12.96	8.18	26.02	52.84	9.40	29.90	60.70	9
12.98	8.44	25.93	52.65	9.70	29.80	60.50	10
14.00	9.46	25.26	51.28	11.00	29.37	59.63	11
16.25	12.86	23.39	47.49	15.36	27.93	56.71	12
16.27	13.13	23.30	47.30	15.68	27.83	56.49	13
17.77	15.98	21.86	44.39	19.43	26.59	53.98	14
17.80	16.05	21.84	44.33	19.50	26.57	53.94	15
18.45	17.46	21.15	42.94	21.41	25.93	52.65	16
20.00	20.80	19.54	39.66	26.00	24.42	49.58	17
22.00	26.13	17.12	34.75	33.50	21.95	44.56	18
22.90	29.30	.00	47.80	38.00	.00	62.00	19
24.00	32.83	.00	43.17	43.20	.00	56.80	20
26.00	41.88	.00	32.12	56.60	.00	43.40	21
27.00	47.45	.00	25.55	65.00	.00	35.00	22
28.00	54.00	.00	18.00	75.00	.00	25.00	23
29.00	60.00	.00	11.01	84.50	.00	15.50	24
30.00	70.00	.00	.00	100.00	.00	.00	25

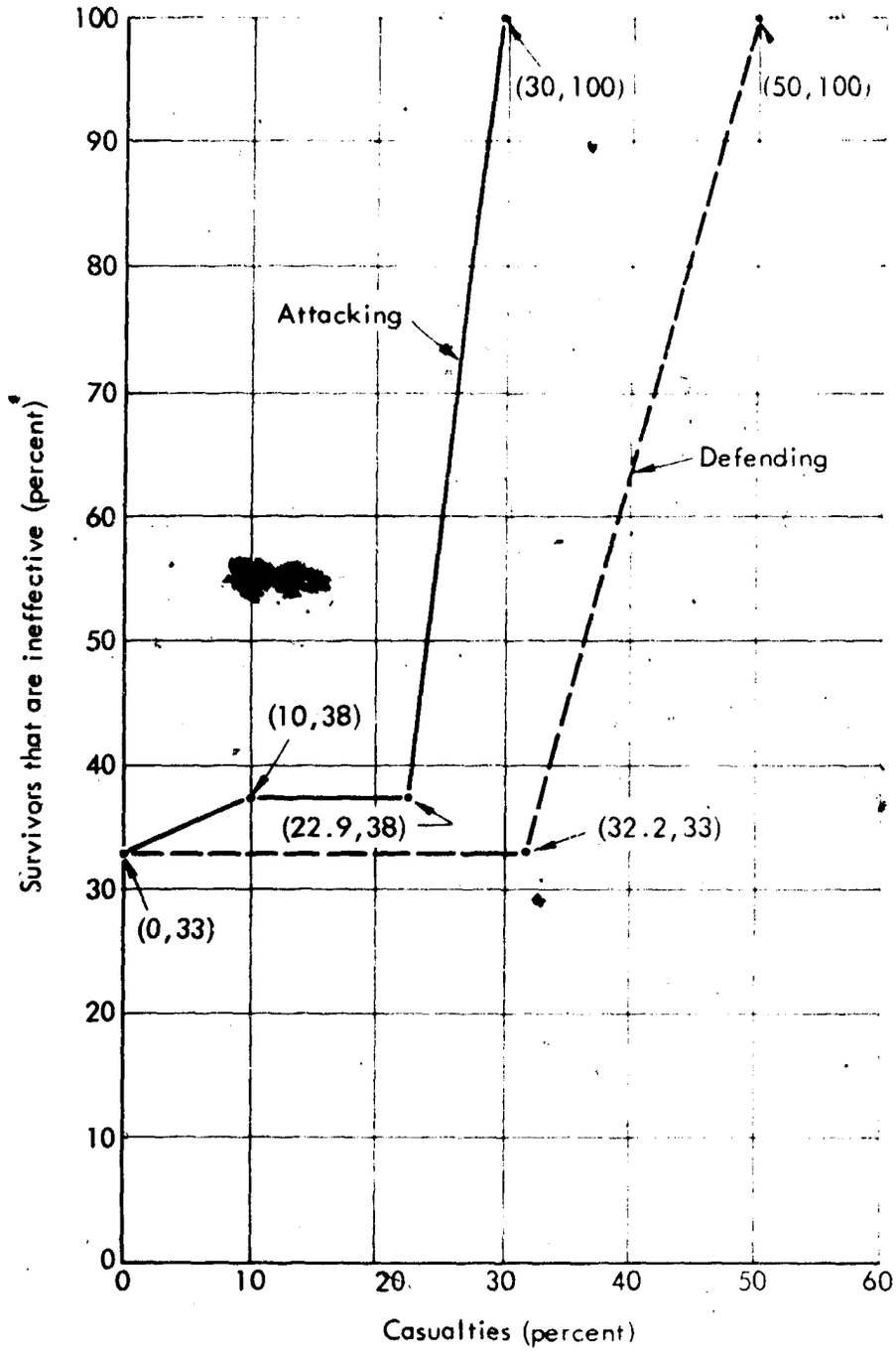


Fig. A-7 — Relationship between an infantry company's percentage casualties and the percentage of survivors that are ineffective (reserves committed as required to maintain level of ineffective or uncommitted survivors at 38 percent)

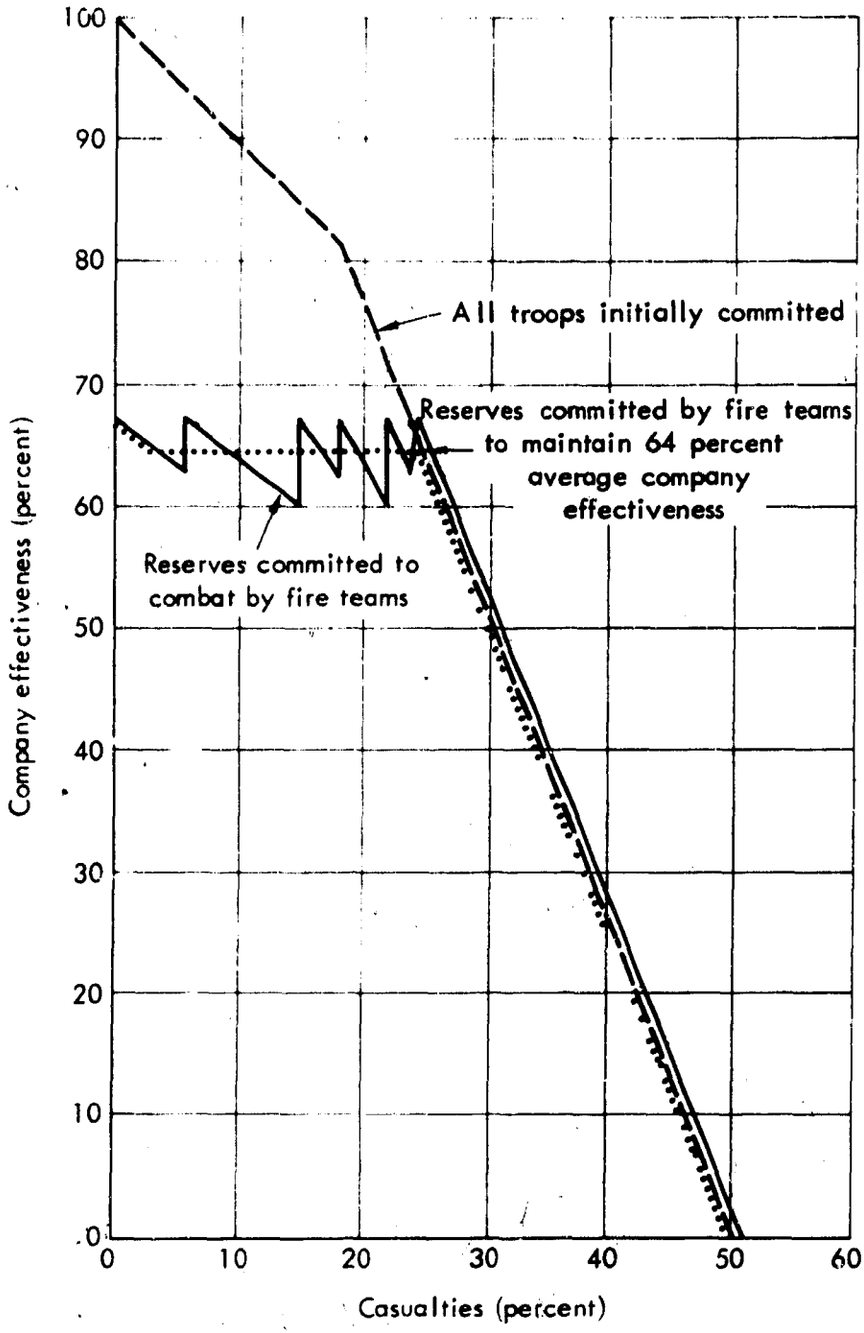


Fig. A-8 — Relationship between a defending infantry company's percentage casualties and effectiveness

Table A-7

PERCENTAGE OF SURVIVORS OF A DEFENDING INFANTRY COMPANY
THAT ARE COMMITTED AND EFFECTIVE: ALL TROOPS
INITIALLY COMMITTED

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	j
4.99	.25	.00	94.76	.26	.00	99.74	1
5.00	.25	.00	94.75	.26	.00	99.74	2
5.94	.27	.00	93.79	.29	.00	99.71	3
5.95	.27	.00	93.78	.29	.00	99.71	4
8.00	.32	.00	91.68	.35	.00	99.65	5
12.00	.46	.00	87.54	.53	.00	99.48	6
14.00	.53	.00	85.47	.61	.00	99.39	7
15.36	.57	.00	84.07	.67	.00	99.33	8
15.38	.57	.00	84.05	.67	.00	99.33	9
16.00	.59	.00	83.41	.70	.00	99.30	10
18.16	2.98	.00	78.86	3.64	.00	96.36	11
18.18	3.00	.00	78.82	3.67	.00	96.33	12
20.00	5.12	.00	74.88	6.40	.00	93.60	13
21.86	7.47	.00	70.67	9.56	.00	90.44	14
21.88	7.50	.00	70.62	9.60	.00	90.40	15
23.88	9.82	.00	66.30	12.90	.00	87.10	16
23.90	9.84	.00	66.26	12.94	.00	87.07	17
24.77	11.22	.00	64.01	14.92	.00	85.08	18
28.00	16.49	.00	55.51	22.90	.00	77.10	19
32.00	22.10	.00	45.90	32.50	.00	67.50	20
36.00	28.54	.00	35.46	44.60	.00	55.40	21
40.00	35.28	.00	24.72	58.80	.00	41.20	22
44.00	41.44	.00	14.56	74.00	.00	26.00	23
48.00	47.58	.00	4.42	91.50	.00	8.50	24
50.00	50.00	.00	.00	100.00	.00	.00	25

Table A-8

PERCENTAGE OF SURVIVORS OF A DEFENDING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVES COMMITTED BY FIRE TEAM

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	j
4.99	.25	31.27	63.49	.26	32.91	66.83	1
5.00	.25	31.27	63.48	.26	32.91	66.82	2
5.94	.27	30.95	62.84	.29	32.90	66.81	3
5.95	.27	26.78	67.00	.29	28.47	71.24	4
8.00	.32	26.18	65.50	.35	28.46	71.19	5
12.00	.46	25.00	62.54	.53	28.41	71.07	6
14.00	.53	24.41	61.06	.61	28.38	71.01	7
15.36	.57	24.01	60.06	.67	28.37	70.96	8
15.38	.57	17.06	66.99	.67	20.16	79.17	9
16.00	.59	16.93	66.48	.70	20.15	79.15	10
18.16	2.98	16.00	62.86	3.64	19.56	76.80	11
18.18	3.00	11.83	66.99	3.67	14.46	81.87	12
20.00	5.12	11.24	63.64	6.40	14.05	79.55	13
21.86	7.47	10.61	60.06	9.56	13.57	76.86	14
21.88	7.50	3.65	66.97	9.60	4.68	85.73	15
23.88	9.82	3.43	62.87	12.90	4.51	82.59	16
23.90	9.84	.00	66.26	12.94	.00	87.07	17
24.77	11.22	.00	64.01	14.92	.00	85.08	18
28.00	16.49	.00	55.51	22.90	.00	77.10	19
32.00	22.10	.00	45.90	32.50	.00	67.50	20
36.00	28.54	.00	35.46	44.60	.00	55.40	21
40.00	35.28	.00	24.72	58.80	.00	41.20	22
44.00	41.44	.00	14.56	74.00	.00	26.00	23
48.00	47.58	.00	4.42	91.50	.00	8.50	24
50.00	50.00	.00	.00	100.00	.00	.00	25

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reserves are committed continuously to achieve 64 percent average company effectiveness, based on the data in Table A-9. The relationship between the defending company's percentage casualties and its percentage of ineffective or uncommitted survivors is shown in Fig. A-9, where reserves are assumed to be committed continuously.

The basic FAST-VAL input is the fraction of surviving riflemen that are committed and effective, which may be found in the seventh column of the tables, or its complement, the fraction of survivors that are ineffective or uncommitted, which is the sum of the fifth and sixth columns of the tables. Figure A-9 shows the relationship between percentage casualties and the percentage of surviving riflemen that are ineffective or uncommitted when policy is to commit reserves continuously. This policy will achieve the same average company effectiveness, 0.64, as would be achieved by committing reserves by fire team. The curve that appears in Fig. A-9 is also shown as the dashed curve in Fig. 4, since we are currently assuming the policy of continuous commitment of reserves to obtain the input that determines the percentage of surviving riflemen that are committed and effective, as a function of a company's percentage casualties.

SUMMARY

For FAST-VAL input we require the fraction of surviving riflemen that are committed and effective or its complement, the fraction of surviving riflemen that are ineffective or uncommitted, expressed as a function of company casualties. The two fundamental considerations that lead to this input are (1) the fraction of surviving riflemen that are ineffective, $g(j)$, and (2) the cumulative commitment requirement, $Y(b,j)$, that is determined by the commitment policy. We have developed the general formulas that apply to all commitment policies and have developed formulas to compute $Y(b,j)$ for several examples of commitment policies that are used for attacking or defending infantry companies. The required FAST-VAL input may be computed for any of these policies and used in a simulation as best accomplishes the objective of the study. We currently are assuming a policy of continuous commitment of reserves to compute the fraction of surviving riflemen that are committed and effective.

Table A-9

PERCENTAGE OF SURVIVORS OF A DEFENDING INFANTRY COMPANY THAT ARE COMMITTED AND EFFECTIVE: RESERVES COMMITTED CONTINUOUSLY

PERCENTAGE OF INITIAL COMPANY				PERCENTAGE OF SURVIVORS			
Casualties	Ineffective	Effective Uncommitted	Effective Committed	Ineffective	Effective Uncommitted	Effective Committed	
4.99	.25	31.27	63.49	.26	32.91	66.83	1
5.00	.25	30.75	64.00	.26	32.37	67.37	2
5.94	.27	29.79	64.00	.29	31.67	68.04	3
5.95	.27	29.78	64.00	.29	31.66	68.05	4
8.00	.32	27.68	64.00	.35	30.08	69.57	5
12.00	.46	23.54	64.00	.53	26.75	72.73	6
14.00	.53	21.47	64.00	.61	24.97	74.42	7
15.36	.57	20.07	64.00	.67	23.71	75.61	8
15.38	.57	20.05	64.00	.67	23.69	75.63	9
16.00	.59	19.41	64.00	.70	23.11	76.19	10
18.16	2.98	14.86	64.00	3.64	18.16	78.20	11
18.18	3.00	14.82	64.00	3.67	18.11	78.22	12
20.00	5.12	10.88	64.00	6.40	13.60	80.00	13
21.86	7.47	6.67	64.00	9.56	8.53	81.90	14
21.88	7.50	6.62	64.00	9.60	8.48	81.93	15
23.88	9.82	2.30	64.00	12.90	3.02	84.08	16
23.90	9.84	2.26	64.00	12.94	2.97	84.10	17
24.77	11.22	.01	64.00	14.92	.01	85.07	18
28.00	16.49	.00	55.51	22.90	.00	77.10	19
32.00	22.10	.00	45.90	32.50	.00	67.50	20
36.00	28.54	.00	35.46	44.60	.00	55.40	21
40.00	35.28	.00	24.72	58.80	.00	41.20	22
44.00	41.44	.00	14.56	74.00	.00	26.00	23
48.00	47.58	.00	4.42	91.50	.00	8.50	24
50.00	50.00	.00	.00	100.00	.00	.00	25

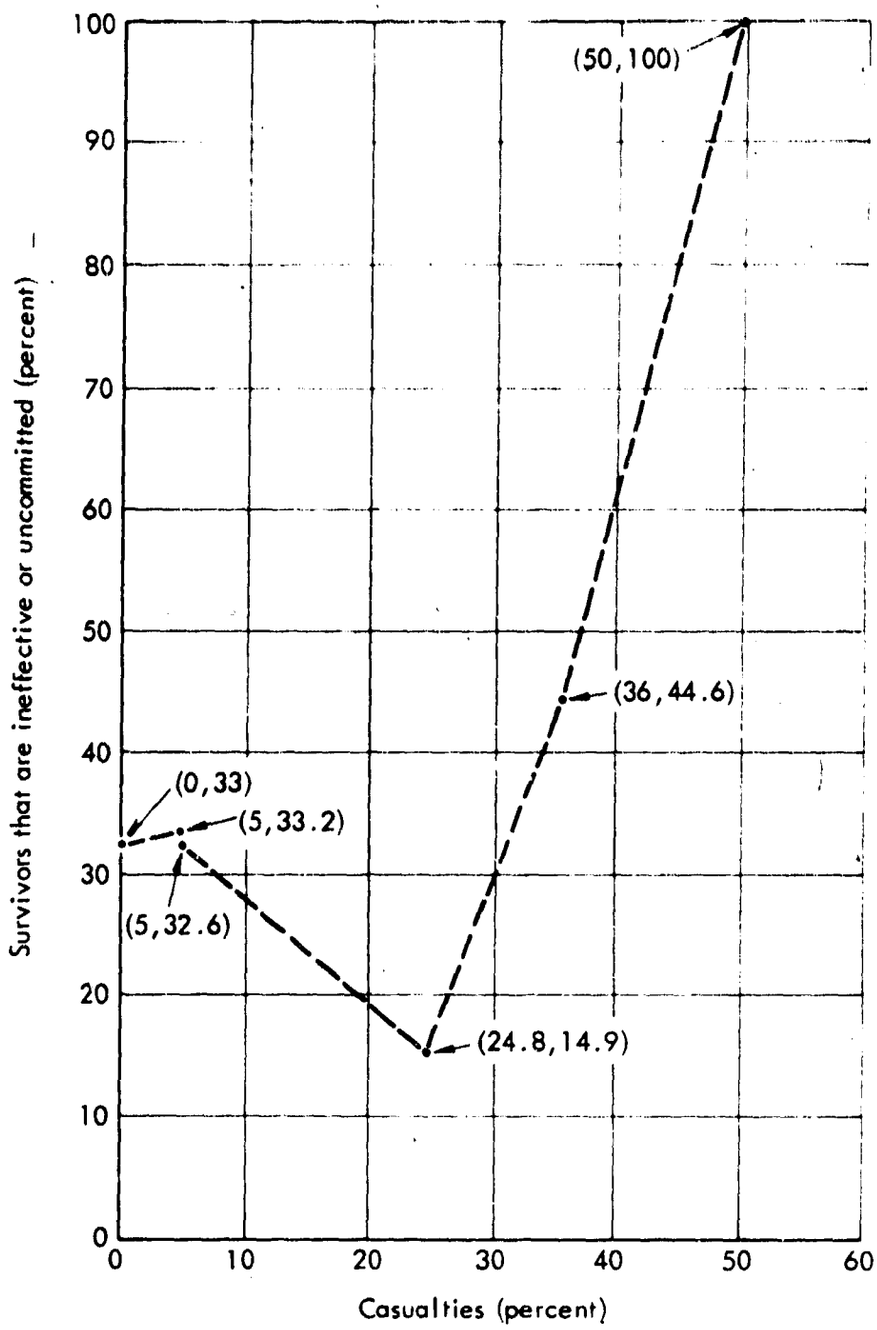

Fig.A-9 — Relationship between a defending infantry company's percentage casualties and the percentage of its survivors that are ineffective or uncommitted (reserves committed continuously)

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REFERENCES

1. Harris, K., R. Snow, and J. R. Lind, *FAST-VAL: Target Coverage Model*, The Rand Corporation, RM-4567-PR, March 1966.

2. Department of the Army, *Maneuver Control*, FM 105-5, April 17, 1964.

3. Department of the Army, *Rifle Company, Infantry, Airborne Infantry and Mechanized Infantry*, FM 7-11, January 1962.

4. Department of the Navy, Office of the Chief of Naval Operations, *The Effectiveness of a Neutralization Fire Against Many Troops in Open Positions*, Operations Evaluation Group, Study No. 385, April 27, 1949.

5. Allen, F., and J. Sperazza, *New Casualty Criteria for Wounding by Fragments* (U), Ballistic Research Laboratories, Report No. 996, October 1956 (Confidential).

6. Clark, Dorothy K., *Casualties as a Measure of the Loss of Combat Effectiveness of an Infantry Battalion*, Operations Research Office, The Johns Hopkins University, ORO-T-289, December 1954.

7. Department of the Army, Headquarters U.S. Army Continental Army Command, *War Gaming Handbook* (U), September 1961 (Secret).

8. U.S. Army Infantry School, *Infantry Reference Data*, June 1966.

9. Berry, S. B., "Observations of a Brigade Commander," *Military Review*, Vol. 48, No. 1, January 1968, pp. 3-21.

10. Lind, J. R., *FAST-VAL: Forward Air Strike Evaluation Model (Phase I Computer Model)*, The Rand Corporation, RM-4352-PR, December 1964.

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10. ABSTRACT

Describes the secondary effects, as input to FAST-VAL simulations, of casualties, equipment losses, and fire exchange on the performance of individual combat troops. These effects--including diversion of survivors, suppression, and loss of leadership and cohesion--are calculated in terms of break and stall levels, company effectiveness, weapon-crew effectiveness, suppression of fire, movement rate, suppression of mobility, and hand-to-hand combat performance. In a FAST-VAL simulation, the percentage of surviving effective riflemen is computed as a function of the preplanned rate of fire, reserve-commitment policy, cumulative casualties, and suppression. An attacking company breaks when it has sustained 30 percent casualties; a defending company, 50 percent. The artillery, mortar, and machine-gun rates of fire are computed separately. An attacking company's forward movement ceases at 23 percent casualties; an attacking armored unit stalls with 70 percent vehicle losses. Discussion includes detailed computations for deriving the percentage of riflemen still effective.

11. KEY WORDS

FAST-VAL (Forward Air Strike Evaluation)
Computer Simulation
Casualties
Attrition
Military Operations
Tactical Warfare
Weapons Effects