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INFANTRY WEAPONS TEST METHODOLOGY STUDY

FINAL REPORT

VOLUME IV

GRENADE LAUNCHER TEST METHODOLOGY

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Major, Infantry
R&D Coordinator

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# INFANTRY WEAPONS TEST METHODOLOGY STUDY

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## APPENDICES

## 1. INTRODUCTION AND SCOPE.

It summarizes

a. Introduction. This is the fourth in a series of five reports which summarize the findings of the Infantry Weapons Test Methodology Study conducted by the United States Army Infantry Board. ~~Volume IV contains a summary of~~ findings concerning the operational evaluation of grenade launching weapon systems. The complete historical record of the study appears in the form of monthly progress reports in Appendix XI of Volume I.

and also

This report includes four appendices. Appendix I contains a description of a grenade impact scoring system which was developed during the ~~methodology~~ study. Appendix II is composed of the recommended subtests for evaluating grenade launcher performance. Appendix III contains a description of an analytical technique for ~~the~~ evaluation of weapon system performance; this appendix and the methodology described under Objective 2 are designed to provide the basis for an operational test procedure for grenade launching weapon systems. Appendix IV is a technical memorandum which describes the method used to determine the resolution and accuracy of the grenade impact scoring system.

b. Scope. This report is concerned with the development of hardware, computer programs, mathematical and statistical models, and field testing techniques required for the complete evaluation of the operational performance of grenade launching systems. Three specific types of weapon systems are discussed: single purpose, single round launchers such as the M79; automatic firing grenade launchers; and the grenade launcher of the combination or dual purpose weapon systems. The major aspects analyzed are measures of effectiveness, major influencing factors, and test techniques and instrumentation.

This report attempts to answer the following four objectives with respect to grenade launcher test methodology:

(1) Determine those factors influencing the evaluation of grenade launching weapons in a realistic combat environment.

(2) Develop techniques and methods to measure critical factors influencing weapon evaluation.

(3) Isolate those factors which are subjective in nature, involving judgement and experience, and which are not amenable to measurement from those which are, and establish the relative importance of each.

(4) Develop plans for automated test facilities that will permit operational testing with a minimum of maintenance and technical support.

Paragraph 2, BACKGROUND, contains a chronological listing of the major events related to the grenade launcher study. Paragraph 3 presents a description of the major activities and accomplishments and an estimate of the manpower necessary to support the grenade launcher phase of the study. Paragraph 4 answers the four major objectives described above. Paragraph 5 contains a description of an automated test facility which incorporates the major influencing factors of grenade launcher test methodology; and paragraph 6 references the procedures for employing the test facility in the operational evaluation of system performance. Finally, the last paragraph presents recommendations for further work which will add to the capability thus far achieved.

2. BACKGROUND.

a. Purpose of Report is to summarize the findings of the Infantry Weapons Test Methodology Study with reference to the operational evaluation of 40mm grenade weapon systems. Support was provided for this study by the Mellonics Division of Litton Industries, Inc., Sunnyvale, California, Contract Number 18-68-C-0004.

b. Chronology. The first four years of the Study was oriented toward the testing and evaluation of small arms weapon systems. This portion focused primarily upon the rifle. Much of the knowledge acquired concerning the measurement of rifle effectiveness can be applied to other members of the small arms family of weapons. The technique for completion of this portion of the study was to apply the methodology acquired empirically during the early phases of the study to the analysis of grenade launcher weapon performance. The major events of the Methodology Study which are related to grenade weapon system evaluation are listed below.

Jul 66 - Directive (Volume I, Appendix I).
Aug 67 - Contract support begins.
Oct 67 - Specifications for an automatic data acquisition system completed.
Nov 67 - Laboratory evaluation of an acoustic time difference locating system completed.
Apr 68 - Acoustic 40mm impact location system fabricated.
Aug 68 - PERT Analysis of indirect fire work program completed (includes impact location study for 40mm grenades).
Nov 68 - Field test of acoustic impact location system completed.
Nov 68 - Bibliography of works concerning indirect fire test methodology completed.
Jan 69 - Computer software package for impact location system completed.
Feb 69 - Seismological analysis of Nolan range terrain characteristics completed (Volume V, Appendix I).
Mar 69 - Field test of HE grenade impact scoring system completed.

Apr 69 - Support provided for service test of a prototype sight for the M79 launcher.
Apr 69 - Support provided for service test of XM434, 40mm dual purpose cartridge.
May 69 - Support provided for service test of the XM203, launcher attachment for the M16 rifle.
Nov 69 - Support provided for service test of an improved grenade fuze.
Mar 70 - Seismic sound ranging system test on Griswold Range.
Jul 70 - ADPS received.
Aug 71 - Impact location system for 40mm practice grenade completed.
Aug 71 - Software for reduction of impact location system output completed.
Mar 72 - Grenade Launcher Test Methodology Study report published.

3. EXECUTIVE SUMMARY.

a. The primary effort during the early part of the Methodology Study focused on the development of an impact location device for impacting grenades. Any analysis of weapon system performance would depend heavily on accuracy as determined by selected measures of effectiveness (MOE) based on the probability of achieving a hit or impact near the target. Consequently, the initial effort, which was carried on concurrently with other methodology and instrumentation development activities, was oriented toward scoring systems.

b. Early success in the development of a time difference measurement system for rifle projectiles was the deciding factor in adopting a time difference measuring technique for grenades. Under controlled conditions, near misses of rifle projectiles could be measured to within 6 inches. Since the geometry is more complex with moving rifle projectiles than with stationary impact points, the time difference system appeared to be well suited for grenade scoring. It was felt that even though the scoring area would be larger, causing wider separation between adjacent sensors, the same scoring precision could be achieved.

c. Early field tests involved two types of projectiles--the practice grenade with its low audio signature and the high explosive (HE) grenade. Success was achieved with the practice grenade and a working scoring system has been developed. This system (described in detail in Appendix I) uses a set of acoustic sensors separated by approximately 60 feet over the desired impact area. Point of impact is measured to within 3 inches. Appendix IV is a technical memorandum which describes the method used to determine resolution of the system.

d. Attempts to develop a scoring system for the HE projectile were made during the development of the practice grenade

| (1) Scoring System Development | Man Month(s) |
|---|---|
| Engineering Design | 1 |
| Technical | 2 |
| Statistical | 1 |
| Engineering Development | 1 |
| Documentation | ½ |

| (2) Evaluation of Scoring System | Man Month(s) |
|---|---|
| Engineering | ½ |
| Technical | 1 |
| Statistical | 1½ |
| Documentation | ½ |

| (3) Preparation of Evaluation Procedure | Man Month(s) |
|---|---|
| Statistical | 1 |
| System Analysis | 2 |

| (4) Preparation of Final Report | Man Month(s) |
|---|---|
| Statistical | 1 |
| Engineering | ½ |
| System Analysis | 2 |

| (5) Service Test Support | Man Month(s) |
|---|---|
| Engineering | ½ |
| Technical | 1 |
| Statistical | ½ |

| (6) Summary of Contractor Support | Man Month(s) |
|---|---|
| Engineering | 3½ |
| Technical | 4 |
| Statistical | 4 |
| Systems Analysis | 4 |
| Documentation | 3/4 |

| (7) Total Support | 16 Man Months |
|---|---|

| (1) Scoring System Development | Man Month(s) |
|---|---|
| Engineering Design | 1 |
| Technical | 2 |
| Statistical | 1 |
| Engineering Development | 1 |
| Documentation | ¼ |

| (2) Evaluation of Scoring System | Man Month(s) |
|---|---|
| Engineering | ½ |
| Technical | 1 |
| Statistical | 1½ |
| Documentation | ½ |

| (3) Preparation of Evaluation Procedure | Man Month(s) |
|---|---|
| Statistical | 1 |
| System Analysis | 2 |

| (4) Preparation of Final Report | Man Month(s) |
|---|---|
| Statistical | 1 |
| Engineering | ½ |
| System Analysis | 2 |

| (5) Service Test Support | Man Month(s) |
|---|---|
| Engineering | ¼ |
| Technical | 1 |
| Statistical | ¼ |

| (6) Summary of Contractor Support | Man Month(s) |
|---|---|
| Engineering | 3¼ |
| Technical | 4 |
| Statistical | 4 |
| Systems Analysis | 4 |
| Documentation | 3/4 |

(7) Total Support — 16 Man Months

4. TECHNICAL OBJECTIVES. The support contract for the Methodology Study specifically stated in the work statement that the primary effort would be oriented toward four specific technical objectives. The efforts and findings in pursuing each of these objectives are described below.

a. Technical Objective 1.

(1) Introduction. The first technical objective of the Infantry Weapons Methodology Study is stated as follows:

> Determine those factors which are critical to the evaluation of Infantry Weapons in a quasi-tactical environment.

The normal procedure in pursuing this objective is to prepare a project review followed by a project analysis to determine how specific factors relate to weapon performance. However, the grenade launcher phase of the study was added near the end of the contract period, the earlier stages of the analysis were bypassed in favor of using the results of previous Infantry weapon studies. The grenade launcher is primarily a member of the small arms family and, hence, shares the same tactical purpose, namely, to close with and defeat the enemy.

(a) Development of Combat Actions. In determining factors that are related to combat performance, it is helpful to list the combat actions in which the weapon system is used. From the Infantry Rifle Methodology Review (Volume I, Appendix II), the list of combat actions was analyzed and those pertaining to the use of grenade launchers were selected. The selected actions are:

(1) Combat Outpost

(2) Delaying Action

(3) Roadblocks

(4) Retrograde Operations

(5) Collapsing Defense

(6) Deliberate Defense

(7) Hasty Defense

(8) Area Security

(9) Ambush

(10) Fire and Movement

(11) Frontal Attack

(12) Counterattack

(13) Close Combat

(14) Advance to Contact

(15) Combat in Cities

(16) Search and Clear

(17) Combat Patrol

(18) Reconnaissance Patrol

(19) Counterambush

(b) Reduction to Combat Tasks. After considering the nature of several of these actions, it was concluded that there was a similarity among subsets that could be characterized by specific tasks required of the grenadier depending on the type of weapon he was carrying. Therefore, an attempt was made to reduce the number of actions in terms of the grenadier's tasks in handling the various types of launchers. The combination weapon is not considered in the discussion below.

Combat actions 1 through 9 above are specifically related to defensive situations and are characterized by the following grenadier tasks:

Long range aimed fire - greater than 300 meters

Medium range aimed fire - between 100 and 300 meters

Short range aimed fire - less than 100 meters

In each case, the target will be a point target or a suspected enemy position. In the case of a suspected position, the target could be defined as an area target; however, the grenadier will normally choose one aiming point in the target area. Consequently all firing can be defined as point firing. Normally, the grenadier will fire from a supported firing position, either from a prepared defensive position or from the prone position behind whatever cover is available. To duplicate the important characteristics of defensive combat actions, the test situation must use supported firing positions at point targets at several representative ranges. The recommended test facility, described in para 5, incorporates these factors to the extent possible.

Combat actions 10 through 13 are associated with various phases of the attack situation. In the classical attack situation, the grenadier will likely remain with the base of fire element to provide covering fire on the objective. If the grenadier should stay with the maneuver element, his tasks include firing from a standing, kneeling or prone position at concealed targets or prepared positions. In either case, the target can best be defined as a point target, and direct comparison shows that the grenadier's tasks in the attack situation do not vary significantly from the tasks associated with the defense situation. He must fire the weapon from the standing, kneeling, or prone position at point targets at varying ranges within the maximum effective range of the weapon. The primary difference between attack and defense situations is the movement required of the grenadier when employed with the maneuver element. Since the portability of the weapon is tested elsewhere during the service test, the testing of the grenade launcher in both the attack and defense situations can be accomplished on the same test facility as long as different firing positions are used.

The remaining tasks, 13 through 19, are primarily meeting engagements where the prime objective is to take charge of the firefight as soon as possible. Normally, this places emphasis on a high volume of fire immediately upon contact with the enemy. The characteristics desired of the grenade launcher are to be sufficiently mobile or portable in the combat area, and to fire rounds into the enemy position as rapidly as possible to assist in taking the initial advantage. From there, the unit commander can elect to move into one of the several options available in either the attack or defense. The grenadier's task then is to provide high volume, short-range fire. This task can also be accommodated on a single grenade launcher test facility along with tasks associated with the attack and defense. To make the test facility more suited to measuring grenade launcher effectiveness in the combat in cities role, specific target types are recommended. Paragraph 5 contains a description of the recommended test facility which will accommodate the grenadier's tasks

(c) Evaluation of the Single Purpose Weapon System. The evaluation of the grenade launcher follows the procedure established for other small arms weapons. The weapon system is tested in a quasi-combat environment which is rich in influencing variables such as realistic targets at appropriate ranges with representative test soldiers. Two types of launchers are in existence: the hand held individual weapon and the crew served automatic grenade launchers. The factors which influence the evaluation of these two weapon types are essentially identical although their combat roles and, hence, operational test procedures may vary considerably. The major influencing factors are listed below:

Weapon Performance Measurement

Human Factors

Test Soldier Selection

Sample Size

Weapon Assignment

Training

Scheduling

The rationale for the selection of each of these influencing factors appears in subsections (2) through (8). Procedures for incorporating these factors into the test situation are described under Objective 2. Factors which have been identified as subjective in nature and not amenable to measurement are discussed under Objective 3. Instrumentation and test facilities for weapon system evaluation are discussed under Objective 4.

(d) Evaluation of the Combination Weapon. Evaluation of the combination weapon system is much more difficult to handle. The technique recommended is to treat the combination weapon as if it were two single purpose weapons. In the case of the combination weapon, the grenade launcher test should be followed by a test of the rifle to insure that the rifle performance is not degraded by the addition of the grenade launcher. Several rifle tests should be undertaken. The rifle should be tested on the quickfire facility with the launcher loaded and with the launcher empty. The task of firing the launcher intermittently with the rifle should be undertaken; this test is designed to check for loosening rifle components as a result of the launcher recoil. The grenades used should be practice grenades if available. Otherwise, an impact area for HE grenades must be established to preclude damage to the test facility. The grenade launcher attachment is to receive the same evaluation, described in the Appendix II, as the single purpose launcher while the rifle is evaluated under conditions described in a document published as part of the small arms portion of the Methodology Study entitled, Integrated Operational Test and Analysis Procedures for Small Arms Weapon Systems Evaluation. The two tests provide input to a set of models and a computer simulation (see Paragraph 7) in which the many combinations of variables can be properly assessed.

Even though each capability of the combination weapon can be tested and evaluated, the maximum potential cannot be assessed in this manner. Characteristics such as the terrain, the type of enemy, and the weapon capability influence the doctrine to provide for maximum efficiency in utilization of the weapon system. Hence, several doctrines may be necessarily evaluated during the test. The doctrine selected will, in turn, impact on the basic load, the number and mix of each ammunition type carried. It would be impossible to field test all of the factors influencing the combination weapon even if test facilities were available at the Infantry Board which could accurately score both weapon systems simultaneously.

The only feasible means of handling a problem this complex appears to be the computer simulation, in which many combinations of user doctrine, terrain, and basic load can be evaluated, to determine which of two or more dual purpose weapons is more effective in the combat environment.

The paragraphs which follow treat the major influencing variables for evaluation of the grenade launcher single purpose weapon system or the grenade launcher attachment of the combination weapon without regard to specific problems of evaluating the combination weapon. This latter problem is approached in Paragraph 7.

(2) Weapon Performance Measurement. Several measures are available to quantify weapon system performance while the system is engaged in the specific tasks of engaging targets or suspected target position. The specific characteristics to be quantified are accuracy, responsiveness, mobility, reliability, sustainability, and durability. The expanded service test will focus primarily on accuracy, sustainability and responsiveness. Reliability will be an integral part of all phases of the expanded service test as will durability. The number of rounds fired during the operational evaluation is normally too few to provide a sufficiently large data base for quantification of reliability. However, the firing in this phase will contribute to the overall evaluation of weapon system reliability. Durability and portability tests may be made on the Infantry Board's clothing equipment test facility. The operational test facility does not adequately test portability or durability; these characteristics can be more adequately evaluated by timing test soldiers through and over various obstacles. Average movement speed or course completion times will provide measures to compare competing weapon systems.

(a) Accuracy Measures. The objective of the grenadier is to place the grenade as near the target as possible. The nearness of the impact and the size of the lethal area of the grenade determine the weapon system's effectiveness. Other factors such as target hardness play an important role but are not a characteristic of the weapon system. It is expected that lethal bursting radius will be provided from engineering test data. In some cases, both (or all) competing weapons will use the same projectile which will cancel bursting effects and leave nearness of impact to the target the primary measure of accuracy. If competing weapons are not of the same caliber or lethality, then a hybrid measure, which takes into account the different terminal effects of the respective projectiles, will be required. Further, if the weapons are capable of or have different inherent rates of fire, the number of rounds that can be delivered per unit of time must be considered. If either of these two cases occurs, a sustainability analysis will be required; for weapons of different caliber, weight and lethality of the weapon and ammunition will likely vary, causing a difference in the sustainability of the systems. Weapons of different firing rates may have different engagement kill probabilities since one weapon system may be able to place more rounds per unit time into the target area. This, in turn, is also related to sustainability or staying power of the weapon. Figure 1 shows a summary of the major test parameters and the recommended accuracy MOE for each combination of variables. The specific combination of weapon characteristics dictates whether a subsequent analysis is required. Should the results of the accuracy analysis and sustainability analysis indicate that there is no significant difference between competing weapons, a third analysis is required--a responsiveness analysis.

(1) Accuracy Analysis Comparison of Weapon Systems Having Identical Rates of Fire and Lethal Bursting Radii. Two MOE appear valid for making accuracy comparisons: hit probability and miss distance. A hit is defined as a round falling in the target area such that the target is within the lethal bursting radius of the projectile. Using this MOE, selection of the superior weapon would be based on the weapon producing the highest hit probability ($P_h$). A second applicable MOE is miss distance which is defined as the distance from the center of impact to the center of the target. Using miss distance, the superior weapon is the weapon which produces the smallest mean value for miss distance. Both of these measures are developed as a function of range.

Analysis of miss distance is recommended for decision purposes. The rationale for this recommendation is that hit probability data are essentially binomial (hit or miss) while, contrarily, the distribution of near misses is normal, or can be assumed normal. This provides slightly better information hedging against the possibility of choosing the more erratic weapon system. This places some importance upon achieving a near miss, assuming that near misses are valuable due to the expected suppressive value. Thus, even if two weapons should

| WEAPON CONDITION | ACCURACY MOE | SUBSEQUENT ANALYSIS |
| --- | --- | --- |
| 1) Same Lethality<br>Same Rate of Fire | Miss Distance (1)* | None |
| 2) Different Lethality<br>Same Rate of Fire | Miss Distance (2) | Sustainability Analysis |
| 3) Same Lethality<br>Different Rate of Fire | Hit Probability (3) | Sustainability Analysis |
| 4) Different Lethality<br>Different Rate of Fire | Hit Probability (4) | Sustainability Analysis |

*Refers to numbered sub paragraph in Text

SUMMARY OF ACCURACY MEASURES

Figure 1

have the same hit probability, the weapon system which comes closer to the target will be selected.

If no difference in mean miss/distance is observed, a first round accuracy analysis should be undertaken. The mean miss distance of all first rounds of each engagement should be compared to all subsequent rounds fired where multiple rounds are fired semiautomatically. If a significant difference in first round hit probability occurs, the weapon with the highest $P_h$ for the first round should be considered. With the characteristic fleeting target of the battlefield, emphasis should be placed on first round capability.

(2) Comparison of Weapon Systems Having Identical Rates of Fire and Different Lethality. Two MOE appear valid for making accuracy comparisons under these conditions: hit probability and miss distance (as defined above). The comparison is complicated because of the varying lethality or bursting radius. One round could conceivably be a hit even though the impact occurred at a greater distance from the target than a round from the competing weapon which was classified as a miss. Taking into account the different bursting radii, hit probability may be used as the primary MOE; however, the objection mentioned above, binomial distribution, still exists. Therefore, the miss distance MOE adjusted for lethality is recommended. For decision purposes, miss distance should be calculated using the following formula:

$$\bar{X} = \sum_{i=1}^{n} \frac{(MD)i - (LR)i}{n}$$

Where MD = miss distance of individual rounds

LR = lethality radius

n = number of rounds fired at the target

Adjustments do not have to be made for the standard deviation estimates since they are not affected by the addition of a constant. All data should be collected as a function of range.

As described in the preceding section, should single shot hit probability fail to show a significant difference, an analysis of first round hit probability should be undertaken before proceding to the next stage of the analysis.

(3) Comparison of Weapon Systems Having Different Rates of Fire and Identical Lethalities. Use of the MOE described here occurs when the competing weapon systems have different operational

rates of fire, that is, soldiers firing with weapon A tend to fire more rounds in t seconds than soldiers firing weapon B at realistic targets. Both weapons use the same round or rounds of equal lethality, i.e., bursting radius.

Two MOE are described. Selection of the appropriate MOE depends on the amount of interdependence between rounds. For weapons which fire semiautomatically or simply produce one round per trigger pull, the individual rounds are assumed to be independent; the point of impact of one round is not dependent or related to the point of impact of subsequent rounds. Under this condition, the MOE selected is hit probability as defined for grenade launchers in the paragraphs above. The following equations describe the comparison to be made:

$$P_h \text{ for Weapon A in t seconds } = \sum_{i=1}^{x} \binom{x}{i} (P_1)^i (1-P_1)^{x-i}$$

$$P_h \text{ for Weapon B in t seconds } = \sum_{i=1}^{y} \binom{y}{i} (P_2)^i (1-P_2)^{y-i}$$

Where, $P_1$ and $P_2$ are the single shot hit probabilities for weapon systems A and B, respectively, for engagements of t seconds, and X and Y are the number of rounds fired by weapon systems A and B, respectively, in time t.

This measure is essentially an engagement hit probability in order to compare weapon system performance under identical conditions.

For cases where round to round independence cannot be assumed, such as in the case of an automatic grenade launcher, or a weapon that fires in salvos, the MOE recommended for use is the number of targets hit per unit time (t), that is, the number of different targets that fall within the lethal radius of at least one round of the burst or salvo. The number of targets hit per burst should be the basis of comparison.

(4) Comparison of Weapon Systems Having Different Rates of Fire and Different Lethalities. The procedure outlined in paragraph (3) above is suitable for analysis of weapon performance under these conditions. The number of targets hit and the hit probability used must be adjusted to compensate for the different terminal effects.

(b) Sustainability Analysis. The next step in the analysis is to take into account the impact or the staying power of the weapon as a function of the different rates of fire and ammunition weights of competing weapon systems. It is assumed that projectiles of different lethalities will have other differing characteristics such as caliber size and weight. The important characteristic is weight since the combat soldier is limited to what he can carry in his basic load. If a difference exists in terms of rate of fire or lethality, the impact on the total combat potential must be taken into account, even if the accuracy analysis fails to show a performance difference. A single measure is required: hits per basic load. This measure is an estimate of combat potential of each weapon system and takes into account the number of rounds in the basic load and the weight of the total system.

It is assumed that competing weapon systems (including basic load of ammunition) will have identical weights. The amount of weight allowed for ammunition of each system is equal to the system's total weight minus the weight of the weapon itself. Dividing the remaining ammunition weight by the weight per round yields the number of rounds on the basic load. In the semiautomatic mode, the number of rounds is equal to the number of trigger pulls available to the combat unit for each weapon system.

Hit probability curves for each weapon system as a function of range can be computed from the data available in the accuracy analysis; the curve should show the probability of hitting one target from the minimum range of the weapon to the maximum effective range of the weapon. The next step is to take into account the number of trigger pulls or the cumulative hit probability of the basic load. The seemingly inferior system in terms of hit probability may have more combat potential due to number of rounds in its basic load. Consider the example below:

Figure 2 shows the curve estimate of hit probability for the two weapon systems over the relevant range.

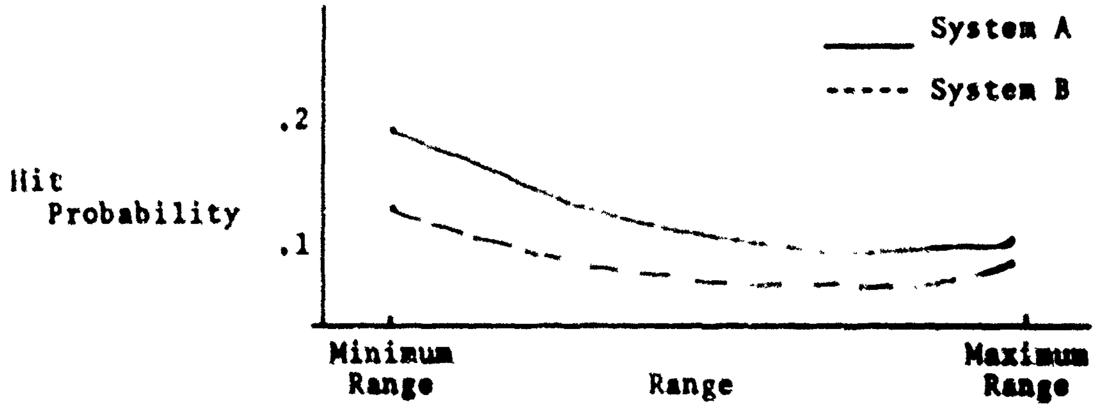



Figure 2

Figure 3 shows the two weapon systems graphed over the relevant range but with the vertical axis changed to target hits.

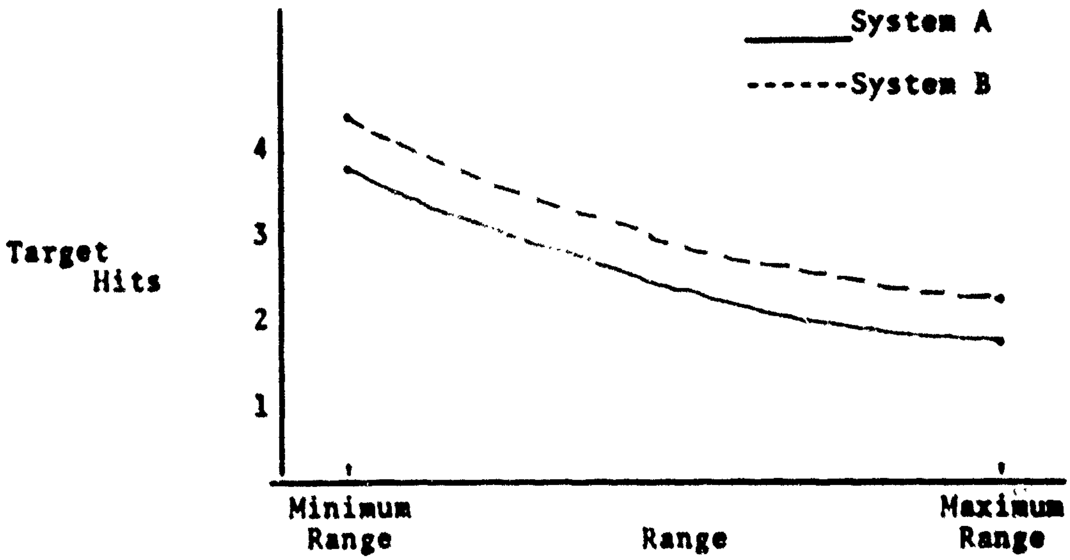



Figure 3

In the example above System A has the advantage on hit probability but when basic load is introduced the picture can change as indicated. The degree of shift would depend on the difference between hit probability of the two systems and the difference in the basic load. Target hits can be measured by firing many basic loads, at a sufficient number of ranges, to allow the curves to be drawn, or it can be determined by multiplying the single round hit probability, at a sufficient number of ranges, by the number of rounds in the basic load. If round-to-round independence cannot be assured, the first method is preferred. If rounds are in short supply and many basic loads cannot be fired at each range, the second method appears better; the evaluator should recognize that less confidence can be placed in the data when smaller samples are used and assumptions are not fully met.

(c) Responsiveness Analysis. This phase of the analysis of weapon performance provides a measure of the quickness of the weapon system during the task of engaging fleeting battlefield targets. The primary measure is time to first hit as measured from the time of the targets appearance until the first hit occurs. Whether or not a hit occurs will not be determined until the post event analysis since the lethal area must be added to the practice grenade before a hit determination can be made. Consequently, the grenadier will continue to fire until the target disappears (the subtests for the

Consequently, the test officer must use several MOE to describe weapon system performance. This is a critical problem in weapon system performance evaluation. The procedure for accomplishing this task is discussed under objective 2, methodology and techniques for using the recommended measures in operational service tests.

(3) Human Factors. There are two distinct types of human factors problems. The first type is the set which is related to the interface between the soldier and the weapon system; the set includes the position and type of sights, the weight and recoil of the weapon, and type and location of magazine. The second set of human factor problems which are a critical part of weapon evaluation are those that deal with motivation and stress.

(a) Interface Problems. Several measures are available for quantifying interface problems. These measures include:

Time to first trigger pull

Time between trigger pulls

Time to reload

Time to recharge magazine or belt

Each of these measures provides quantitative information on a specific aspect of the man/weapon system interface problem. The use and interpretation of these MOE are discussed below.

(1) Time to first trigger pull - This measure spans the time from when the target first appears until the grenadier fires the first round. It may include some target acquisition time; however, the acquisition times should be relatively short and should affect each candidate weapon equally. Any significant difference between weapon systems can be attributed to interface problems such as weapon weight or sight alignment.

(2) Time between trigger pulls - As mentioned above, if the weapon must be reloaded between rounds, this measures the grenadier's ability to reload, reacquire the target, aim and fire. A significant performance difference is an indicator of an interface problem in one of these tasks.

(3) Time to reload - For weapons which are not reloaded for each trigger pull, this measure is useful in isolating potential problems with the magazine component of the weapon system. Tasks evaluated include removal of the round(s)

from the carrying pouch, inserting the rounds into the weapon, and placing a round on the chamber.

(4) Time to charge magazine or belt - This measure is less important than the previous measures since the task of charging the magazine or belt can be done during combat lulls or at the ammunition breakdown point. However, the task can have an effect on weapon system performance and should be considered in an operational evaluation. If different procedures are used for competing weapons, the times should be measured.

(b) Motivation and Stress. The behavior of the combatant under the stress of the combat environment and the effect of this behavior on the efficiency of the weapon system have thus far eluded quantification. Several stress substitutes have been used, such as fatigue, constant repetition, sleep deprivation, and staged emergency situations, but the effectiveness of these efforts in simulating stress and the effect of stress on individual motivation are not known.

Combat studies have shown that three basic types of behavior can take place within the individual in stressful situations. The soldier may function normally, he may react to the threat with extreme courage and fortitude, or he may withdraw entirely by seeking refuge from any available cover or by leaving the combat area. The latter case presents little problem since the weapon system ceases to function entirely and hence potential interface problems vanish. Only the former situations need to be of concern.

The purpose of stress substitutes is to force the individual to work under pressure so that weapon system weaknesses, if they exist, can be uncovered. Unfortunately, none of the substitutes can reproduce the threat of physical injury or death that is inherent in the combat situation. There is no credible threat to life itself. Stress substitutes may cause the test soldier to feel less motivated to perform in retaliation for the physical and emotional abuse induced by the implementation of the stress substitutes. Rather than receiving extreme adrenalin induced motivation from the dangers of combat, he may simply go through the motions lethargically. The result would be the opposite of what was intended. Consequently, the use of stress substitutes is not recommended. The test officer should rely on the high motivation that can be expected of the test soldier from participation in the service test. The opportunity for live fire usually enhances motivation even further. Stress should be included wherever possible during the test, but it should be in the form of time pressures inherent in the combat environment. That is, targets should appear for short durations or multiple targets should be placed at varied ranges separated by sizable distance. This would cause the grenadier to perform efficiently if he is to maximize his performance.

(4) Test Soldier Selection. All tests should be carefully planned using an experimental design which focuses directly on the test objectives. A test is designed as a microcosm of some larger situation or phenomenon. The aim is to have findings and recommendations which apply not only to the test situation, but to the real world situation from which the test was derived. The most carefully designed service test with perfect implementation is valueless unless the results can be generalized to the Army as a whole. One of the critical factors that permits this generalization is the selection of representative test soldiers for participation in the service test. The sample should consist of an average set of soldiers typical of the population as a whole. Statistically sound sampling methods have been used throughout the methodology study and are described in each of the three field study reports. Random sampling from populations of typical soldiers should be used to insure that the composition of grenadiers reflects the characteristics of the parent population. As in combat, grenadiers should be selected from sets of soldiers who have good, uncorrected vision; who are physically strong enough to cope with the recoil; and who are right-handed, if being left-handed interferes in any way with the operation of the weapon system. Any other critical characteristics should also be taken into account. Recommended procedures for sample selection are discussed under Objective 2.

(5) Sample Size. The goal of the service test is to select the most suitable weapon system for combat use. Consequently, the service test must measure relative performance of the two weapon systems, in such a manner that, any difference observed would have occurred if the test was actually performed under combat conditions. Adequate sample size is a critical factor in measuring relative performance of competing weapon systems. Close competing weapons have small operational differences which require an adequate sample size to isolate performance differences. The procedures for estimating sample size are discussed under Objective 2.

(6) Weapon Assignment. The assignment of the test soldier sample to test conditions (i.e. test weapons) is the next critical factor. Normally, an experimental design is carefully balanced by rotating the sample among test con-

ditions, in this case weapons. If each person fires each weapon under as an identical set of conditions as possible, the problem of potential bias normally disappears. However, this was not found to be the case when testing the rifle. If the subject of the test was the weapon user or the weapon itself, rotation of users among weapons would be a desirable technique. However, the operational service test is not concerned with users or weapons. It is concerned with the user/weapon system.

Rather than reducing bias by rotating users, this procedure was found to be a source of bias in small arms evaluation, especially when testing weapons of different basic designs. Two potential problems exist: the familiarity of the population stereotype and negative transfer. The former occurs when one of the competing weapons is of conventional design. That is, it may be familiar because it resembles the target pistol, shotgun, or deer rifle with which many people have prior experience. As the firer switches from one test weapon to another he vacilates between the familiar and unfamiliar actually emphasizing dissimilarities. Negative transfer takes place when learning or familiarity with one weapon causes the individual to perform more poorly when rotated to the next weapon. This can occur, for example, with similar but not identical sighting mechanisms. Learning to use one sight correctly and then using the same technique (identical sight picture) on the next weapon whose sights require a slightly different technique can cause the individual to perform more poorly than if he had no prior training or experience.

The implementation of recommended weapon assignment procedures is discussed under Objective 2.

(7) Training. The impact of training was found to be an influencing factor in the evaluation of weapon system performance. In the case of rifles, test soldiers were generally found to be familiar with the rifle currently in the inventory because they used that rifle in their basic training and advanced Infantry training. When introduced to the test item and given several hours of familiarity training and live fire training, a pronounced bias was found to exist in favor of the standard rifle. Further, the training methods adapted to the training of the individual assigned the test item were based on the methods in use with the standard item.

To reduce the impact of bias, care should be taken in selecting training methods that school the individual in the techniques of weapon employment that optimize weapon system effectiveness. The training program must be of sufficient length to insure an equitable level of proficiency between sets of soldiers using the candidate weapons. (The standard weapon should be treated as a candidate weapon in an expanded service test; this will help reduce any stigma concerning "old versus new" by personnel who conduct the test or by the test soldiers.)

During the Advanced Infantry Training course, the Infantryman is introduced to a variety of Infantry weapons. He is not expected to be proficient in the use of all weapons, but he is expected to be able to handle the weapons in combat. He is trained to replace a wounded machine gunner to insure that a minimum loss of unit fire power takes place with attrition. Training and testing procedures should take this factor into account. Partially trained soldiers should be tested for proficiency to determine the ease with which new weapons can be used by test soldiers.

(8) Scheduling. The final critical factor is that of scheduling the weapon systems through the various subtests of the expanded service test. All experimental designs should be balanced with equal numbers of trials for each candidate weapon system. The only precaution required of the test officer is to insure that the trials are paired in such a manner as to allow the candidate weapons to compete under as identical conditions as can be produced. Normally, this means that weapon systems should be used in pairs, alternating from trial to trial. A recommended schedule is presented under Objective 2.

b. Technical Objective 2.

(1) Introduction. This objective is directly concerned with methods and techniques for incorporating critical factors into the expanded service test. The objective as stated in the test directive is shown below:

> Develop the techniques and methods for generating meaningful numerical measures of critical factors on a real time basis, i.e., determine instrumentation sample size, calibrations and controls, while permitting unimpeded tactical movement of soldiers in a reasonably realistic environment.

The paragraphs which follow describe the findings to date concerning techniques and methodology for testing grenade launchers. Each of the factors critical to grenade launcher evaluation is discussed, and recommended procedures for insuring their incorporation into the test situation are included. This objective is supplemented by two appendices. Appendix II describes the subtests required to incorporate the critical factors, and Appendix III describes the analytical procedures for generating and handling the test data. The analysis in Appendix III leads to the final decision node concerning selection of the superior weapon system based on the expanded service test.

Whether testing the single purpose weapon system or the grenade launcher capability of the combination weapon, the field tests and analysis are identical; however, the technique used for the evaluation of performance is different for the two weapon configurations. In either case, combination or single purpose weapons, the test officer need only be concerned with test procedures described in Appendices II and III. In the case of the combination weapon, the decision maker should refer to Paragraph 6 to equate the performance of two competing combination weapons.

(2) Weapon Performance Comparison. Weapon performance comparisons are normally accomplished in a series of side-by-side subtests. The new or improved weapon is compared to the standard weapon with reference to a specified set of characteristics. The weapon characteristics normally accounted for are accuracy, sustainability, responsiveness, reliability and durability. In the discussion of factors critical to weapon system performance under Objective 1 above, it was determined that the performance comparison of the operational service test would focus on accuracy, responsiveness, and sustainability. Reliability and durability would be treated in this phase of the service test as a part of an overall reliability and durability subtest which covers all phases of the service test.

(a) Accuracy Analysis. Three major tasks are required by the grenadier; these are:

Long range aimed fire

Medium range aimed fire

Short range aimed fire

Two MOE were selected under Objective 1 to provide the basic data for these tasks. The subtests outlined in Appendix II provide for the necessary engagements to establish the weapon systems capability with respect to these three accuracy tasks. The data from this analysis will be presented in the form of performance curves for each candidate weapon which can be directly compared in terms of accuracy.

The hand-held launchers will produce single-shot hit probabilities and mean miss distance distributions. Each round is considered independent, but all first rounds should be compared to all second, third, and fourth rounds to determine if this assumption is warranted. If subsequent rounds show no improved performance or if the degree of improvement is identical for both weapon systems the entire set of rounds can be combined into a single hit probability curve. If subsequent rounds for the two weapon systems show different degrees of improvement, any decisions concerning accuracy capability should be made on the first round, since first-round hit probability is by far more important in combat than any slight improvement in subsequent rounds. The weapon systems should be thoroughly examined to determine the cause of improvement in order to incorporate the most desirable characteristics of both weapons into the superior weapon system, if possible.

Evaluation of automatic grenade launchers is also based on hit probability and mean miss distance; however, the rounds within the burst cannot be considered independent from each other. Therefore, the measures which are to be used for comparing weapon system performance are burst hit probabilities and mean miss distance of all rounds within the burst.

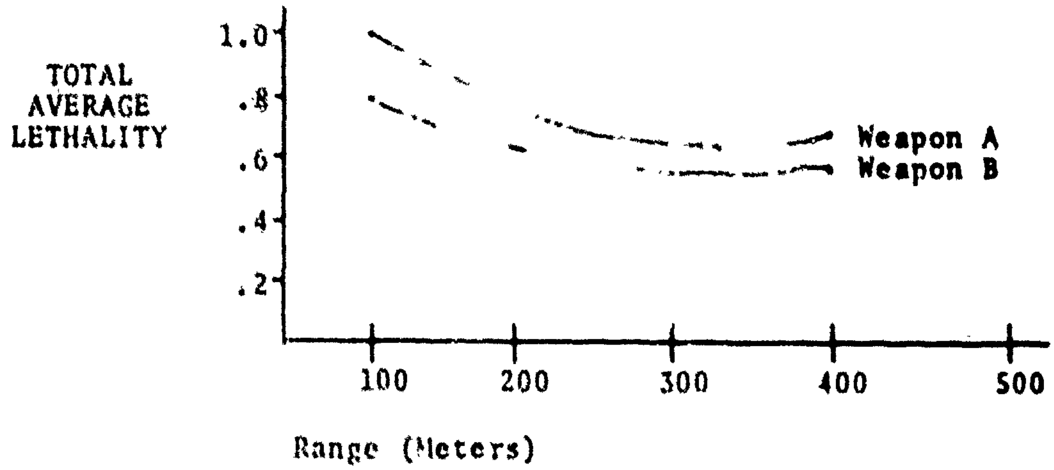
Specific instructions for proceeding with the analyses described above are provided in Appendix III, which describes the plan for analyzing the output of the recommended subtests.

(b) Sustainability Analysis. As described under Objective 1, the basic sustainability measure is based on lethality per round of ammunition. By multiplying the single-shot hit probability times the number of rounds in the basic load, the total lethality of the weapon system can be estimated. To insure an unbiased comparison, the comparison is based on weight of the weapon, ammunition, and ancillary equipment. If the grenadier with the standard weapon normally carries 25 pounds in his combat load, the sustainability should be based on the same total weight for the new system. Therefore, the weight of the weapon and any ancillary equipment must be subtracted from the 25-pound limit. The weight of a single round of ammunition must then be divided into the remaining weight.

$$\text{Number of Rounds in Basic Load} = \frac{\text{Total Allowable Weight} - \text{Weapon Weight}}{\text{Weight Per Round}}$$

The result is the number of rounds in the basic load. Multiplying this figure times the average kill probability at each range will produce total average lethality curve as a function of range. The result will appear in the form of a sustainability curve as shown in Figure 4.

Since the field evaluation is not based on a simulated combat scenario, this measure cannot be expressed as a given number of combat minutes, although this measure can be estimated using the rate of fire and the number of rounds expended per trigger pull. From a combat standpoint, this measure of sustainability is not as applicable to special




TOTAL AVERAGE LETHALITY CURVE

Figure 4

purpose weapons, such as grenade launchers, because these weapons were not designed to maintain the high volume, constant rate of fire that is characteristic of the rifle. The launcher is employed against special target types when the opportunity presents itself. Therefore, the recommended procedure is to compare the sustainability characteristics of two or more weapons using the measures shown in equation above.

(c) Responsiveness Analysis. The responsiveness analysis is accomplished by analyzing the measure mean time to first hit. The data are presented as a function of range without respect to the different target types. A hit is defined as a hit in the case of the bunker and window targets when a round is placed through the opening. Against personnel targets, a hit occurs when at least one of the targets is within the kill radius of the projectile. The resulting curves can be expected to show the characteristics shown in Figure 5. It must be emphasized that this measure is not applied unless no significant differences have been isolated in the previous analyses, accuracy and sustainability. This point is stressed in the analytical procedures described in Appendix III. If significant differences occurred in the earlier analyses, selection of the superior weapon will have taken place before

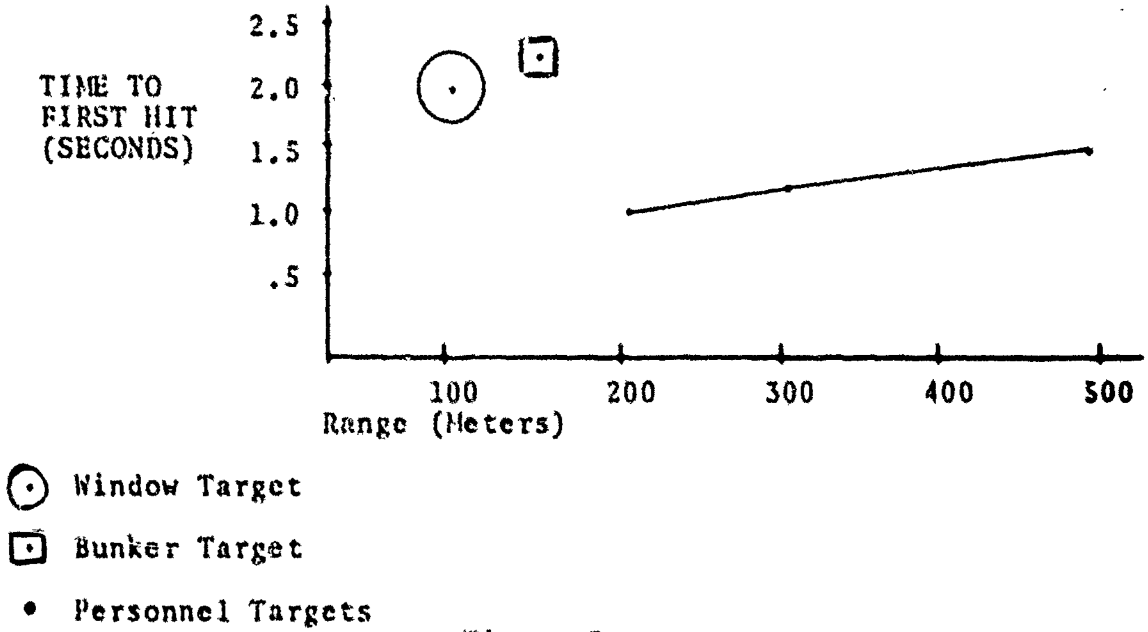


Figure 5

the responsiveness analysis. This measure is meaningless if the weapons have different hit probabilities, especially first-round hit probabilities*.

(d) Ease of Employment by Partially Trained Soldiers. The last test is to determine whether one weapon system is more easily used by soldiers who are not grenadiers but who can be assumed to be potential users on the battlefield under certain conditions. Weapons that become effective with a minimum training are a distinct asset in battle.

(e) Combining Multiple Measures of Effectiveness. Combining the output of the three analyses in the preceding paragraphs cannot be done with scientific objectivity. For decision purposes, the weighting of these outputs requires a subjective analysis. This procedure is discussed under Objective 3, which presents a discussion of subjective critical factors, and described in detail in Appendix III.

*NOTE: It can be shown mathematically that weapons having significantly different first round hit probabilities will produce unequal, skewed, truncated distributions with reference to time to first hit. Reference: Cohen, A. C., Jr., "Estimating the Mean and Variance of Normal Populations from Singly Truncated and Doubly Truncated Samples," Annals of Mathematical Statistics, 21, 557.

(3) Human Factors

(a) Interface Problem Assessment. The analysis described in Appendix III delineates procedures for isolating interface problems. All measures used in the analysis are time dependent and are produced from the round count data and impact scoring data which are acquired automatically on the test facility with one exception, hit and near miss data for the window target; these data are fed into the computer contained data base manually. Any differences between competing weapons isolated by the time dependent MOE are indicative of possible interface problems. Cause and effect will have to be determined by observation during the initial subtests. If cause cannot be isolated and if the difference between weapon systems is large, subsequent tests should be designed to examine cause and effect in order to isolate the problems source.

(b) Introduction of Stress. The technique for introducing stress into the combat situation is simple and straightforward. Prior to the test, each soldier is instructed to behave as he would in combat - to keep exposure to a minimum and to make his fire power as effective as possible. He is told that controlled targets are programmed for limited exposure and that he will have to react hurriedly to get his grenades into the target area. Due to the limited exposure time of the controlled targets, much of the effectiveness of an extremely slow system will be lost. This is characteristic of combat in general and was an important consideration in determining exposure time for personnel targets.

The troops should be told of the importance of the test and of their contribution to the test. This, plus the normal business-like manner in which service tests are conducted, should provide sufficient motivation to elicit an acceptable level of motivation from the test soldiers.

(4) Test Soldier Selection Technique. The sampling procedure recommended is similar to the procedure described in Volume I for Small Arms Weapon Systems. The test sample should be randomly selected from a group of test soldiers that have the characteristics of good combat grenadiers. The normal technique is to screen 201 files from the unit supplying the test soldiers and to eliminate the extremes of the troop with respect to physical size, intelligence and aptitude scores, and age. In each case the candidate for selection should fall within 1½ standard deviations from the mean with respect to all these variables. If the populations have normal distributions with respect to these three var-

iables, the test officer will have approximately 65 percent of the original sample who qualify as test subjects. From the remaining group, visual acuity tests should be run, subdividing the group further. The final set of candidates should all have 20/20 uncorrected vision. From this remaining group, simple random sampling should be used to determine which test soldiers are to participate in the service test.

(5) Sample Size. Sample size is an important consideration in developing the test cycle whether two systems are being evaluated in side-by-side test or one system is being evaluated against established criterion. Before presenting any formulas for determining sample size, consider what is actually being sought when two competing systems are subjected to a series of subtests. Whether stated formally or not, a test of hypothesis is involved, i.e., a determination of relationship between two performance levels such as $\theta_1 = \theta_2$, $\theta_1 \leq \theta_2$ or $\theta_1 \geq \theta_2$, where $\theta_1$ and $\theta_2$ are parameters of the two system populations. For the sake of simplicity, choose the hypothesis ($H_0$) that $\theta_1 = \theta_2$ and since most test of hypothesis are concerned with population means, change $\theta_1$ and $\theta_2$ to $\mu_1$ and $\mu_2$. Therefore, the statement $H_0 : \mu_1 = \mu_2$ is essentially asking the question, does the population mean of system 1 equal the population mean of system 2. $H_0$ implies the existence of an alternative hypothesis $H_a$: $\mu_1 \neq \mu_2$ since if test results will not allow $H_0$ to be accepted then $H_a$ must be.

Under strict interpretation of $H_0$ and $H_a$, is a test procedure really necessary? The answer to this is obviously no since one merely has to accept $H_a$ prior to the test and be virtually 100% right all of the time. Given sufficient resolution, the two population means will be different. Consequently, the concept of the size of the difference between $\mu_1$ and $\mu_2$ must be introduced. A difference of 1 unit between $\mu_1$ and $\mu_2$ may not be of any real world significance, whereas a difference of 10 units might. Therefore, one merely has to find $\mu_1$ and $\mu_2$ and compare. However, problems are created in the process of determining accurate values for $\mu_1$ and $\mu_2$ except in finite sample population. The problem of extrapolating to a larger universal population is of considerably greater magnitude and cannot be determined efficiently except through sampling. Since $\mu_1$ and $\mu_2$ for the universal population cannot be found they have to be estimated; the estimates are $\overline{X}_1$ and $\overline{X}_2$ where $\overline{X}_1$ and $\overline{X}_2$ are to a sample what $\mu_1$ and $\mu_2$ are to a population.

If two sample means are calculated and if $\bar{X}_1 > \bar{X}_2$, does it necessarily follow that $\mu_1 > \mu_2$? Consider a case where a sample is taken from two different populations of field mice and another case where a sample is taken from two different herds of elephants.

If sample 1 of field mice had a mean weight 8 ounces greater than sample 2, would $\mu_1 > \mu_2$ be a logical conclusion? If sample 1 of elephants had a mean weight 75 pounds greater than sample 2, does $\mu_1 > \mu_2$ logically follow? Which of the two above conclusions merit the most confidence? The conclusion that one population of field mice is heavier appears to be sounder, because if an elephant weighed 75 pounds more than another elephant it might mean that the first elephant just finished lunch. In other words, the concept of variability of individuals within a population has to be taken into consideration. If the number of elephants sampled was quite large and the number of mice sampled quite small would the degree of personal confidence be shifted in any manner?

Statistics can be used to estimate how much populations differ with respect to some performance criteria; however, statistics will not determine if the magnitude of the difference is of any practical significance. If certain values are translated into numerical equivalents then some elements of decision theory can be used; however, it will be assumed for purposes of this discussion that differences that constitute real-world significance are known. Note that replacement decisions, i.e., replacement of an old system with a new system, should be arrived at differently than introduction decisions. In replacement decisions it is desired to know if the new system represents sufficient product improvement to replace the old system, but in introduction decisions, assuming one of two items will be incorporated into the arsenal, the objective is to choose the best system.

When decisions are made to either accept or reject a system, two errors of decision are possible. One error called a Type I error results when the true difference between $\mu_1$ and $\mu_2$ does not exceed the specified practical difference and the conclusion is made that it does. The other error, called a Type II error, is made when the difference between $\mu_1$ and $\mu_2$ does exceed the specified practical difference and the conclusion is drawn that it does not. What are the consequences of making either of the errors? If a Type I error is made the result could be a large cost associated with changing over to a new system when the improvement sought does not exist. A Type II error is a different kind of cost and is subjective since it is the cost of failure to up-date capabilities when capabilities could have been improved. Can the two types of decision errors be eliminated? The answer is no but the possibility of occurrence can be minimized if one is willing to pay the price of minimization.

Assumptions have to be made concerning attributes of the populations under examination if effective error control is to be administered. These assumptions are primarily concerned with the underlying distributions of populations and equality of the variances of those distributions. Techniques exist for determining the reasonableness of the assumptions, but they have to be used somewhat after the fact. The reasonableness of the assumptions have to be gleened from past test of similar items and similar measures. Normality of distributions is oftentimes assumed and this assumption has validity in light of the Central Limit Theorem. The assumption of variance equality is generally not as stringent as it appears since variances have to be grossly different to make a real difference in the analytical results.

Error control is effected by imposing probabilities of occurrence on each of the two errors. The probabilities can be adjusted to suit the needs of the particular test. The probability of a Type I error is set by the experimenter and is somewhat arbitrary depending on the decision maker's belief in the importance of making a Type I error. Type II error is not subject to direct control since it depends on the true difference between $\mu_1$ and $\mu_2$ and since $\mu_1$ and $\mu_2$ cannot be determined neither can the true difference. However, conditions can be imposed to the effect that if a true difference as large as d exists it is desired to be 90-percent confident of detecting that difference. It is assumed that d is a difference of practical significance.

Sample size becomes extremely important if control over a Type II error is to be established. Formulas and tables are given in books to aid in sample size estimations. The formulas have the general form:

$$n = \frac{2(A+B)^2\sigma^2}{d^2}$$

where n is the number of each system that must be tested, A and B are tabular values with the two types of errors (A and B are generally looked up in either the standard normal or t distribution tables), $\sigma^2$ is the population variance, and d is the difference that is to be detected.

The equation above will be used in an example. The difference and variance estimates used in the example are approximations taken from old grenade launcher studies. Suppose that it is desired to be able to detect a difference in miss distance greater than or equal to 2 meters between two competing weapon systems at a range distance of 200 meters. How large a sample must be used? The value used for A will depend on the desired probability of rejecting the hypothesis, $\mu_1=\mu_2$, when the true difference between $\mu_1$ and $\mu_2$ is less than d. If the probability of a Type I error is chosen to be .05 then A would be equal to 1.96 as determined from the standard normal tables. To determine B in the formula, being able to detect a difference between $\mu_1$ and $\mu_2$ greater than or equal to d has to be translated into a probability of confidence. Assume that the decision maker determines that the justification for desiring a 90-percent confidence of detecting a difference of size d exists. The value substituted for B would be 1.645. The final item that must be supplied to the formula is $\sigma^2$. This is generally the most difficult input to determine. It can be estimated from a pilot study but most often will be approximated from past tests of similar items. A standard deviation of 5 meters was found to be a reasonable estimate for variability for the problem under examination. Therefore, using the formula mentioned above, sample size of 160 rounds will be required for each range:

$$n = \frac{2(1.96+1.645)^2 \times 25}{(2)^2}$$

$$= 162.5$$

$$\approx 160 \text{ rounds}$$

This is not an exacting technique since estimates have to be used and probably all assumptions are not fully met. However, the approximation is regarded as adequate.

It will be assumed that sample size determination made at a range of 200 meters would provide an adequate estimate of the population means for ranges greater than and less than 200 meters. The subtest is such that approximately 5 rounds will be fired per soldier. Therefore, approximately 37 soldiers for each weapon type would be required. An analysis would then be based on the usuage of the average performance per soldier, i.e., the average miss distance per soldier would be treated as a data point.

(6) Weapon Assignment Procedures. Two methods are normally used for assigning candidate weapons to test soldiers: random assignment and balanced group assignment methods. Using the random assignment method, weapons are assigned to test soldiers in such a manner that each soldier in the sample has an equal chance of being assigned each candidate weapon.* Any means of making weapon assignments is acceptable as long as a random assignment technique is used. This method attempts to minimize the probability that groups of soldiers with a different average capability are assigned to the candidate weapons.

The second method is based on some method of balancing the test groups. Soldiers may be divided into equal groups according to any of several possible characteristics: age, height, weight, intelligence quotient. However, to be meaningful the balancing characteristic should be related to the skill required for good performance. All of the above examples are related in some manner to performance, but the manner in which they are related is not known. The task of determining this relationship is formidable and undertaking such a task would be costly. The recommended procedure is to select a characteristic that is obviously closely related to the skills required and use this characteristic as the balancing factor. Past studies at the Infantry Board have used the soldier's ability to handle a rifle as the balancing characteristic. The measure used is the tightness of the soldier's shot group when firing a rifle, with a sighting similar to that used on the candidate weapons, on a known distance range. The Canadian bull's-eye target is used and the available measures are mean spread, extreme spread, and offset error. Mean spread is used as a measure of the soldier's capability with the rifle. Since the grenade launcher is a member of the small arms family, it is reasonable to assume that a soldier's marksmanship is related to his capability with the grenade launcher. This assumption is extremely strong when testing weapons with dual capabilities. In either case, with dual or single capability weapons, the assumption is warranted.

*NOTE: The term "candidate weapon" normally refers to new weapons which are competing for selection and not to the standard or inventory weapon. The standard weapon should always be referred to as one of the candidates to preclude introducing an attitude bias by assigning some troops an "old" weapon and others a "new" weapon.

This method of assigning soldiers to candidate weapons has proved successful in the past. Tests on balanced groups after assignment have been conducted and no statistically significant bias has been found.

The method of assignment is to have the entire group of test soldiers fire for record with the service rifle on the 25-meter range. The mean spread of the shot group is measured and the two soldiers with the tightest groups are selected. Using a random assignment method, one soldier is assigned to one candidate weapon and the other to the alternate candidate weapon. Next, the two soldiers which ranked third and fourth in the competition are assigned randomly to test weapons until the entire group has been assigned. The groups are now balanced on a characteristic related to combat performance. The test soldiers should retain these assignments throughout the training and familiarity period and through the subsequent service test.

(7) Training Methodology. Marksmanship training attempts to teach the grenadier the fundamentals of firing the grenade launcher in preparation for combat. A good training program covers firing positions that are associated with the employment of the weapon in combat. The positions that should be stressed are those described in the subtests: kneeling and standing, and prone. Sight alignment, sight picture, and sight manipulation must be covered. If candidate weapons differ markedly, increased training time must be allotted to soldiers with the unfamiliar weapon to assure a like capability and familiarity between the weapons and the grenadiers.

Past studies with small arms have shown empirically that training can introduce bias. In each case during the rifle portion of the methodology study, the candidate rifle that proved superior was the accepted service rifle. It is estimated that a minimum of two weeks of intensive training with much time devoted to live fire will be required to achieve the desired level of familiarity. Training procedures applicable to the training program are described in FM 23-31 for the standard grenade launcher, and in FM 23-9 for the rifle attachment launcher.

In reviewing the applicability of training procedures prescribed in the field manuals for standard launchers or rifle attachments, care must be taken to insure that prescribed methods and procedures are applicable to the new or modified weapon. Training procedures should be changed as required to develop the full potential of the new system.

For instance, should the new weapon have a salvo capability, methods for firing in the salvo will have to be determined. Questions to be answered include those concerning firing position, loading procedures, malfunction and stoppage reduction procedures and sighting techniques. Hastily developed and ill-suited training methods can cause bias against a new weapon. There may be requirements for actually testing training levels empirically to determine when performance levels achieve the learning plateau. Measures useful to measure familiarity are hit probability, time between trigger pulls, and time to reload.

One group of eight soldiers should be selected but not trained. This group will comprise the sample of partially trained soldiers. This group should be given training equivalent to that normally given during AIT. This special group will perform subtests (2) through (5) and will use launchers that have been zeroed by other personnel. This group will be tested at the conclusion of the schedule shown below.

(8) Scheduling Procedures. Each of the subtests described in Appendix II is a complete test entity and should be run in the prescribed order after the zeroing (Subtest 1) is completed. Figure 4 below shows the required rotation procedure. Each test soldier should complete each subtest once. One cardinal rule should be observed: each firing by a candidate weapon system during each subtest must be followed by the alternate candidate weapon. Therefore, in the small groups selected for particular subtests, each small group should contain an equal number of competing weapon types, which are fired alternately until the entire group has completed the test.

The recommended procedure is to assign four pairs of weapon systems, one test weapon and one candidate weapon in each pair, to each firing group or order. Using the schedule below, each pair should fire each subtest once. Pair 1 should fire in subtest 2 first, followed by pair 2, and so on. The same procedure should be followed for each group of eight firers.

SUBTESTS

| 2 | 3 | 4 | 5 |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 2 | 3 | 4 | 1 |
| 3 | 4 | 1 | 2 |
| 4 | 1 | 2 | 3 |

SCHEDULE FOR FOUR PAIRS
OF GRENADE LAUNCHER
WEAPON SYSTEMS

FIGURE 4

At the conclusion of this test, the special group of soldiers who have had only familiarity training will perform the subtests.

c. Technical Objective 3.

(1) Introduction. This objective of the methodology study is concerned with critical factors in weapon system evaluation, which cannot be quantitatively analyzed. The objective is stated below:

> Attempt to isolate those factors which are subjective, involving judgement and experience and are not amenable to measurement from those which are, and establish the relative importance as contributing to effectiveness. The use of interim or "breadboard" facilities is desirable to determine the feasibility of this testing methodology, and will utilize movable structures, basic electro-mechanical devices and instrumentation. Existing computer or programmer capability will be used when available for supporting the study and determining permanent requirements.

The development of an instrumented facility (Objective 4) was not included as a requirement for this phase of the methodology; consequently, a field experiment has not been run comparing two grenade launcher systems. This is not a serious shortcoming for the single purpose weapon system since the 3 rifle experiments were conducted and techniques were evolved which reduced subjectively in Infantry weapons testing. Most of these techniques are directly applicable to other single purpose small arms weapons systems such as the machine gun and the grenade launcher.

The Small Arms test facilities are capable of evaluating system accuracy, responsiveness, and sustainability; data collected on these facilities can contribute to the reliability and durability data base. Consequently, an automated grenade launcher test facility should produce a similar capability. Other factors such as portability and compatibility have been recognized. The recommendation, as it was for other Small Arms weapon systems, is made to test these characteristics on other facilities such as the Combat Equipment Test Facilities (CETF).

Three areas remain as critical subjective factors, at least to some extent, in grenade launcher weapon system evaluation. For the single purpose weapon, these are suppression, which is a human factors characteristic, and the use of multiple measures of effectiveness in describing weapon performance; for the combination weapon, there is the problem of determining optimum means of employing candidate combination systems so that a fair evaluation can be made. These three factors are discussed in the following paragraphs.

(2) Human Factors. Findings concerning human factors such as stress, suppression, and motivation, which were recognized as subjective factors during the small arms phase, have been delineated and the recommendations for incorporating motivation and stress into the test program in a realistic manner are identical to that recommended in Volume I. Suppression was not reduced in terms of its subjectivity, but an assumption was made that suppression was a function of enemy firepower. As long as exposure parameters and complexity of operations were equal for the candidate weapons, suppression would affect all candidate systems in a like manner. Since suppression is not likely to be a weapon discriminator, it is not necessary to attempt to duplicate the suppression effect on our test soldiers.

Under conditions where candidate weapons use different caliber projectiles, the impact or signature of the projectile (shock wave, bullet strike) will vary between weapons. The psychological impact of this phenomenon on enemy troops is unknown. The decision maker can only take this factor into account subjectively in the decision process of selecting the superior candidate weapon. Current studies being conducted for the Advance Research Project Agency may shed some light on this subject. For the present, at least, this aspect of suppression remains constant.

(3) Weighting of Multiple Measures of Effectiveness (MOE). On the realistic, combat-action-oriented test facilities, the method of weighting or using multiple MOE was accomplished by the selection of a scenario dependent combat measure, number of targets hit. Under simulated combat conditions with realistic target exposure times, tactical scenarios, and target actions, the number of target hits was assumed to be related to the number of combat casualties. Hence, measures like hit probability, time to first hit, and hits per pound were automatically incorporated to the proper degree or weight in the primary measure. Since the grenade launcher would never be carried into combat and employed as the primary Infantry weapon, it is unrealistic to construct a simulated combat test facility for grenades only. Actual combat would be conducted in such a manner that simulated combat without small arms weapons becomes unrealistic by definition. The current small arms facilities are not compatible with the grenade launcher so this deficiency cannot be overcome by testing launchers on the existing facilities. The remaining choice open to the tester is to construct a grenade test facility, which requires the grenadier to perform realistic combat tasks, but which uses a set of measures of performance. The facility recommended under Objective 4, and described in paragraph 5, is

such a facility. The evaluation technique for analyzing test data is described in Appendix III; The technique reflects the subjective determination of the importance of each of the categories of MOE.

(4) Combination Weapon Evaluation. The evaluation of the combination weapon is an extremely complex task and could easily be the subject of an entirely new methodology study. The problem of evaluating two weapons of entirely different capabilities on the same chasis brings up a new set of problems not envisioned in the formative stages of the methodology study.

The factors that must be considered include interface between the man and each of the weapons and the interaction between the two weapons. The former can be easily treated by simply evaluating the individual man weapon systems as if the weapon were two single purpose weapons. This method yields an adequate analysis of performance for each weapon type and examines problems that may arise if the weapons interfere with each other. The difficulty occurs when an attempt is made to evaluate two candidate combination weapon systems. Problems occur with firing doctrine (i.e., at what range should the soldier select the launcher), the threat, and the ammunition mix. For example, assume that the M203 is the current inventory weapon and for mountainous open terrain, such as Korea, the weapon system weight is 23 pounds including 11 pounds of weapon, 7 pounds of 5.56 ammunition in 12 magazines and 5 pounds of 40-mm grenades (.5 lb ea). This mix of ammunition was found to be optimum for the terrain and expected enemy threat. It is important to note that a change in threat most probably would require a change in mix and a change in firing doctrine. For example, the optimum mix would not necessarily be the same for an insurgent type enemy force as for a mechanized enemy or an unsophisticated enemy capable of utilizing mass assaults. As the terrain changes, the mix will likely change again. The same is true for firing doctrine. Each of these factors affect weapon system effectiveness. Assume that a new candidate weapon is received for test and evaluation. This is a SPIW rifle with a 30-mm grenade launcher. How is a comparative test to be conducted? The optimum family of ammunition mixes for the new weapon system may be very much different from the M203. Assuming like mixes may introduce a very serious source of bias. The optimum mix is meaningless unless the user selects the optimum combination of weapon/ammunition/doctrine for each combat situation, which again may not be the same for both weapons. Consequently, side by side comparisons against varying threats under varying terrain conditions with identical firing doctrine could very well lead to a long, expensive, and inaccurate evaluation.

Two major methodological problems are present. A method of determining the best mix for a given set of conditions for a new weapon system must be found. Second, a means of comparing the operational performance of the candidate systems must be developed. This latter problem includes the determination of firing doctrine. This step is further complicated by the fact that operational test facilities do not exist in which the two weapons can be employed during the tactical situation.

The example described above indicates some of the complexities that have arisen with the development of the combination weapon, a weapon type that was not foreseen during the methodology study formulation period. The complexities include hardware and instrumentation problems as well as the deeper envolvement of the service test with firing and user doctrine.

Since no facilities exist which are capable of evaluating the various decision nodes and trade offs for the combination weapon system, there are no data on which to base recommendations for solving these methodological problems. However, a method of evaluating the combination weapon, based on experience in small arms evaluation, is discussed in paragraph 7, Recommendations for Future Study. A method of trading off rifle and grenade launcher effectiveness is described which uses a model borrowed from the field of economics. The model has been used to determine optimum output of a system using various mixes of input variables. The model describes the theoretical problem extremely well in terms of isolethality curves for a weapon system and in terms of mixing various numbers of grenade rounds and rifle rounds to achieve a given level of effectiveness. The mix that achieves the maximum effectiveness with minimum weight is considered the optimum mix for a given set of conditions.

Further, a computer simulation model is proposed as a vehicle for analyzing performance of the system as a function of the independent performance of each individual weapon of the dual purpose chasis. The model, if developed, would permit evaluation of total system performance as a function of firing doctrine, ammunition mix, terrain, and enemy threat. Performance for each candidate weapon system could be estimated as a function of these four variables. The output would be an estimate of the optimum mix, the optimum doctrine for specific threats and environments, and an estimate of operational performance under these conditions.

(5) Determination of Relative Importance of Subjective Factors. The three sets of subjective factors are human factors, weighting measures of effectiveness, and evaluation of the dual purpose weapons. The single purpose weapon represents a relatively simple test concept. With the construction of a test facility and the production of test data, a sensitivity analysis can be used as a means of determining the relative weight of the multiple measures of effectiveness. At the same time, some human factors variables can be analyzed which will assist in defining the usefulness of the measures. In these areas, subjectiveness can be severely reduced. Only suppression will remain as a subjective factor.

For the combination weapon, the number of subjective factors at present is great. These include such problems as selection of MOE, ammunition mix, firing doctrine, enemy threat, and terrain. All of the factors are interrelated and hence cannot be ranked in order of importance. Paragraph 7 describes two procedures which can be used to reduce subjectivity in evaluating combination weapon system performance. The initial method is a computer simulation. The simulation is a more economical means of evaluating the impact of these variables than the second mehtod, which is the construction of a test facility capable of incorporating all of these factors. The initial computer simulation analysis could be used to answer the question of whether a test facility should be built at all and, if so, what characteristics should the facility have.

d. Technical Objective 4.

Objective 4 is related to the development of a grenade launcher facility. It is stated as follows:

> As a final objective, the foregoing results are eventually intended for application to automated test facilities which will permit imposition of programmed field operational tests while recording and analyzing test data, and displaying results with a minimum of maintenance and technical support.

Fulfillment of this objective is not required for the grenade launcher phase of the methodology study, since this phase was added to the study after the study was formulated. Consequently, no test facility, either breadboard or production, has been completed.

However, the development of the small arms miss distance indicator provided the methodology for the development of an impact scoring system suitable for scoring the practice grenade for the M79/M203 launchers. The system is portable and can be set up on any suitable terrain. The sensor and signal conditioner output is compatible with the ADP equipment used with the small arms ranges. The system, described in detail in Appendix I, consists of an array of sensors which are positioned around a target or set of targets and several round count microphones at the firing line. The round count and scoring microphones are interchangeable; there are 18 signal conditioning circuits available at the present time limiting the total inputs to that number. The number may be increased to 64 with additional signal conditioning circuits since there are 64 microphone inputs on the ADP system. To reach this number, 46 additional signal conditioning circuits will have to be constructed.

The computer programs for editing the microphone inputs into usable pairs of event times and the programs to determine the time differences and compute the impact points are written and are available. An accuracy test has been conducted which shows that the average error in predicting the point of impact of a grenade round is 3 inches; the maximum error is 6 inches. This accuracy analysis appears in Appendix IV.

Paragraph 5, Range Concepts, describes a recommended test facility. Schematics are provided showing recommended microphone arrays for the targets required by the subtests. Flow diagrams are provided showing the software design for the test facility.

The test facility is simple in concept, easy to set up and maintain. Its major shortcoming is its inability to score high explosive (HE) grenades. Many attempts have been made to score HE, but the results lack reliability. Difficulty appears to be caused by one or two factors. The sensors may be triggering on the high velocity seismic wave which reaches the microphone before the acoustic noise from the blast. The other possible cause may be the supersonic shockwaves eminating from the explosion and from the supersonic fragments being ejected by the charge. More research needs to be accomplished before the precise problem can be isolated. This recommendation for further work appears in Paragraph 7.

5. RANGE CONCEPTS. This section describes an improved test facility necessary for the conduct of the recommended subtests. The facility contains six target installations, a zeroing panel and five firing positions (See Figure 5). Each firing position is equipped with a round count microphone which is connected to the APDE. The microphones may be moved as desired to alternate firing positions. Alternate firing positions may be required on some tests and on future methodology tests to provide data evaluating performance as a function of range, where more variation in the firing ranges is required.

Each of the target positions, except for the window, is equipped with a set of sensors to measure point of impact of the grenade. The sensors feed the data directly to the ADPE. The time of arrival of the acoustic signature of the grenade is used to compute the impact point. The window target, which is the only vertical target (i.e., where the round impacts on a vertical surface rather than a horizontal surface) is scored visually. The impact point is observed by the data collection NCO and the miss distance from the window opening is "read" directly from the subdued grid painted on the wooden frame. Electronic scoring can be used by using a set of wooden panels. Figures 6 and 7 show the target configuration. A contact microphone at the base of each panel permits the miss distance to be read directly by the ADPE. The contact microphone senses the sound of the grenade impacting against the wooden frame.

The signal conditioning for the round count sensors and the microphones is identical to the circuit currently being used with the grenade impact scoring system. A schematic for this circuit appears in Appendix I.

The computer programs required to support this test facility concept with its recommended subtests are described in the following six pages. The pages contain a single flow diagram which describes the required target action for each of the targets, the inputs from the test officer required by computer, sensor control instructions and data output.

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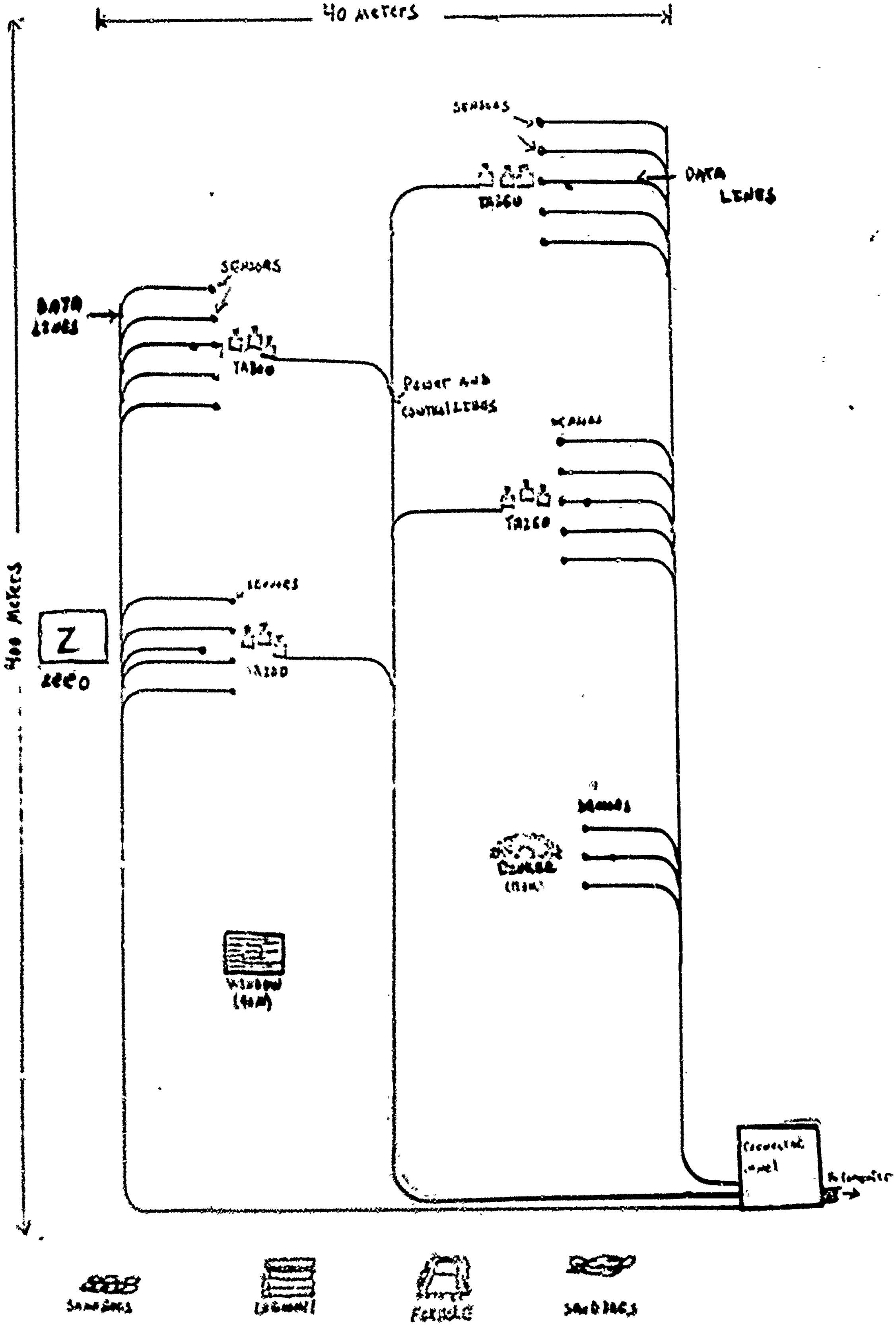
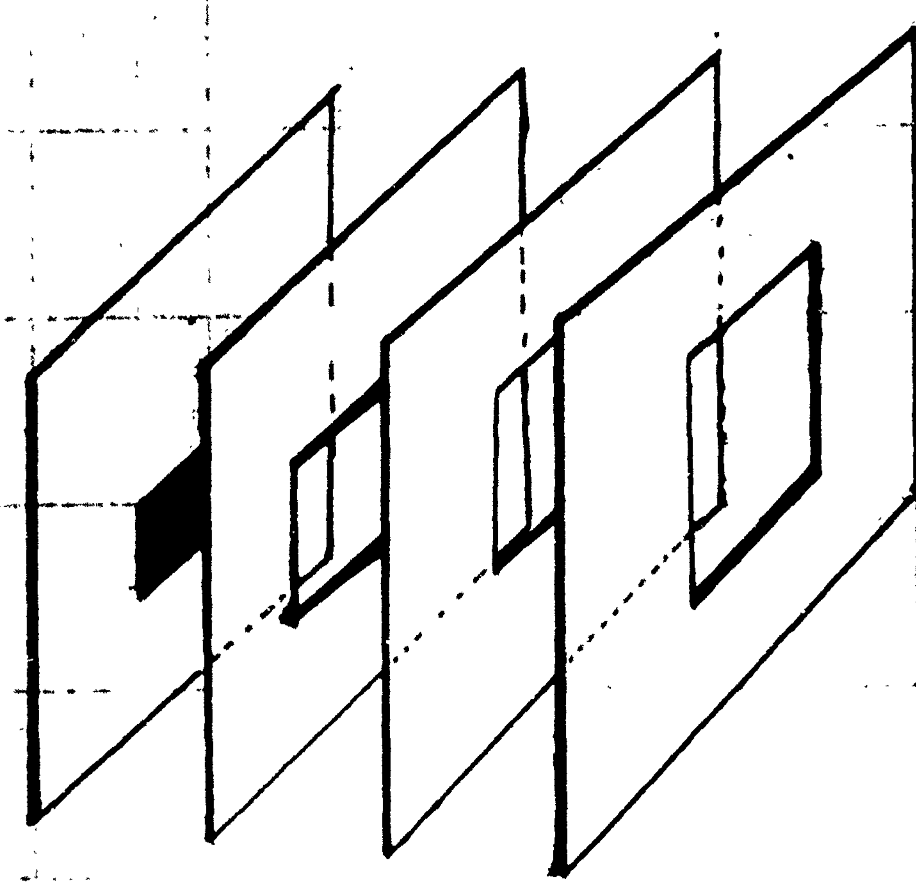


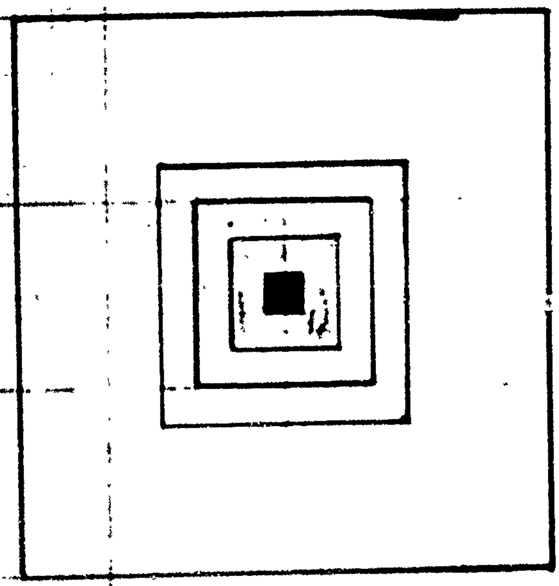

PROPOSES TEST FACILITY
FIGURE 5



MISS DISTANCE SCORING PANEL

EXPLODED VIEW

FIGURE 6

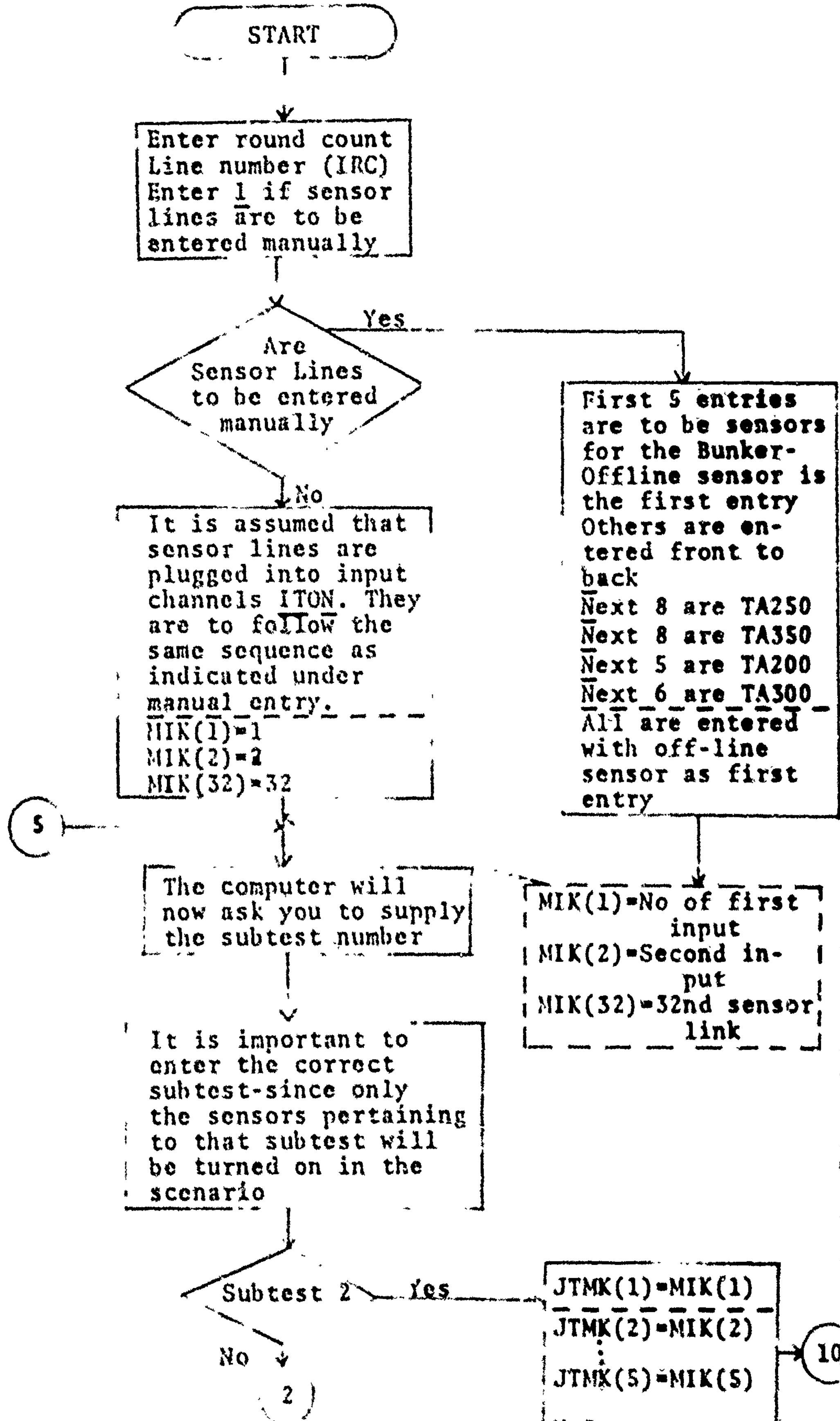


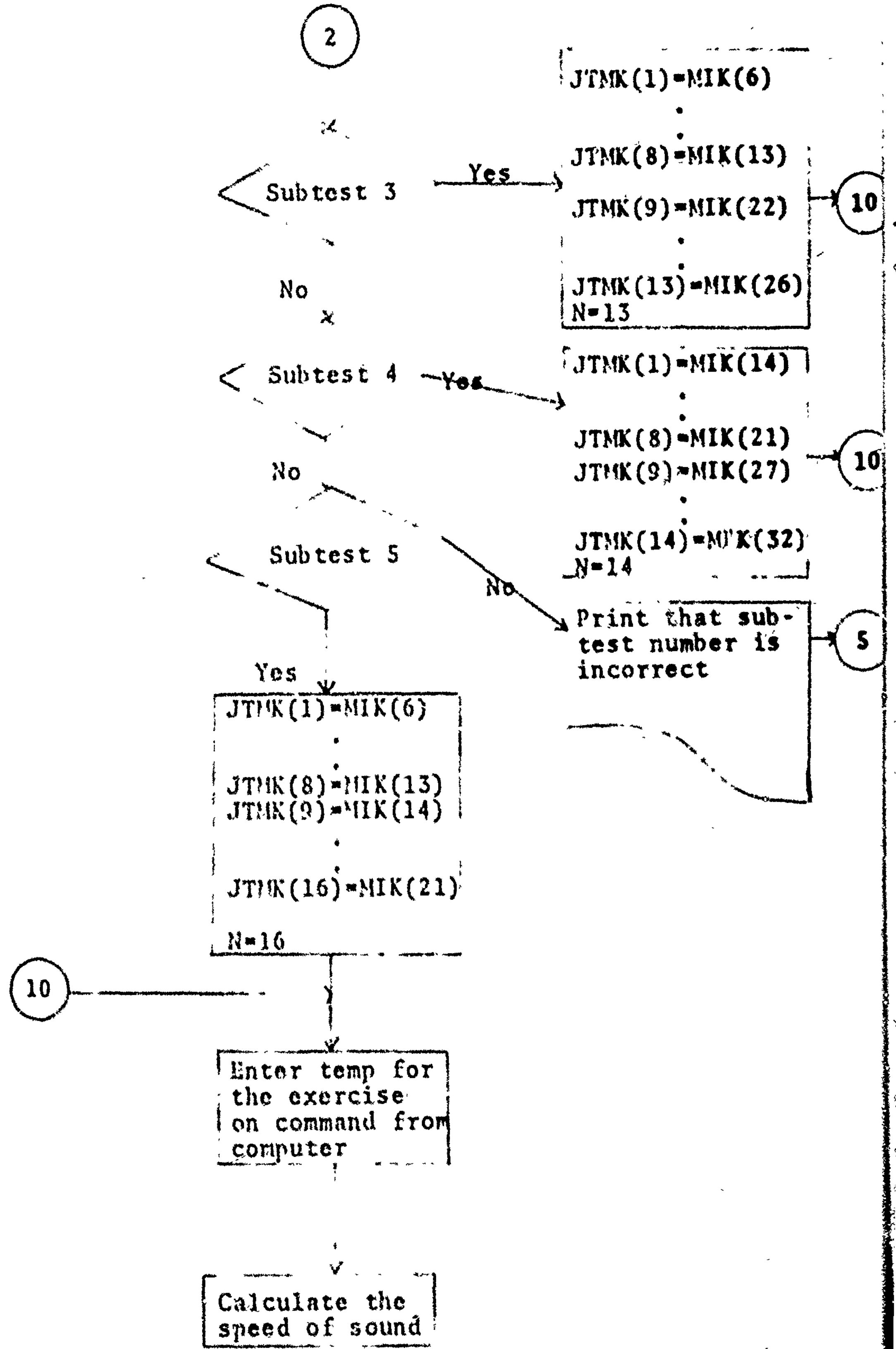
MISS DISTANCE SCORING

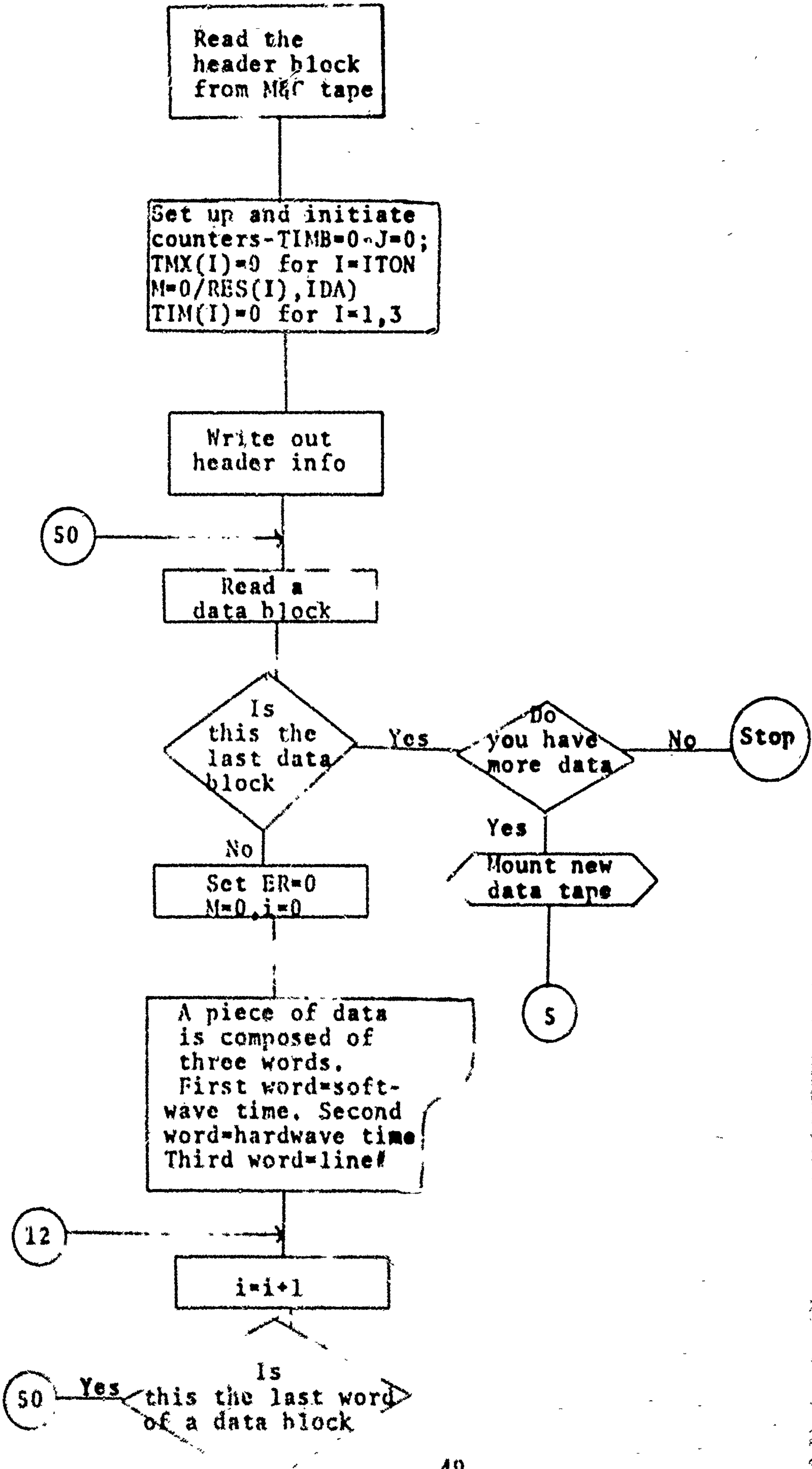
TARGET

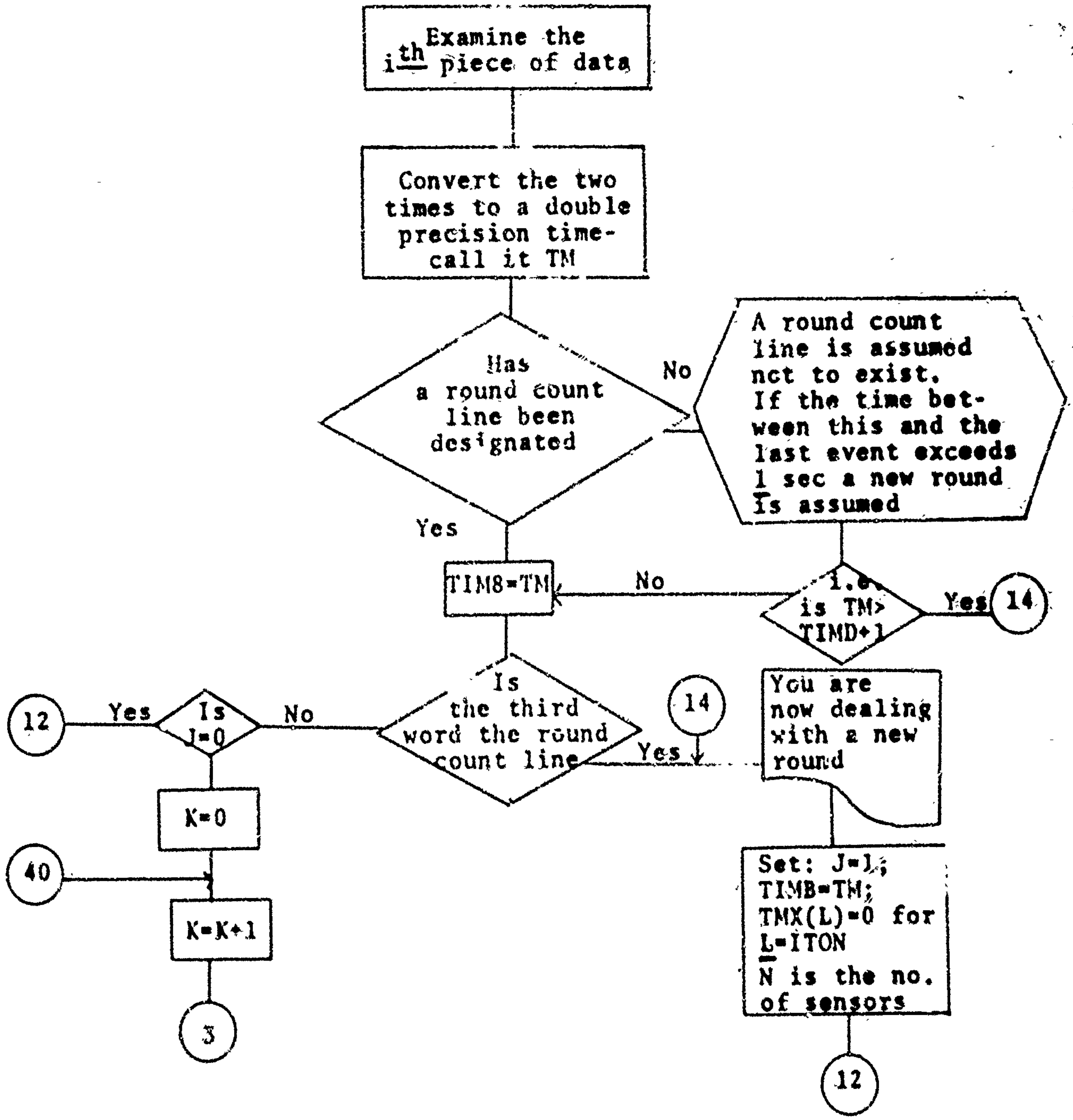
FRONT VIEW

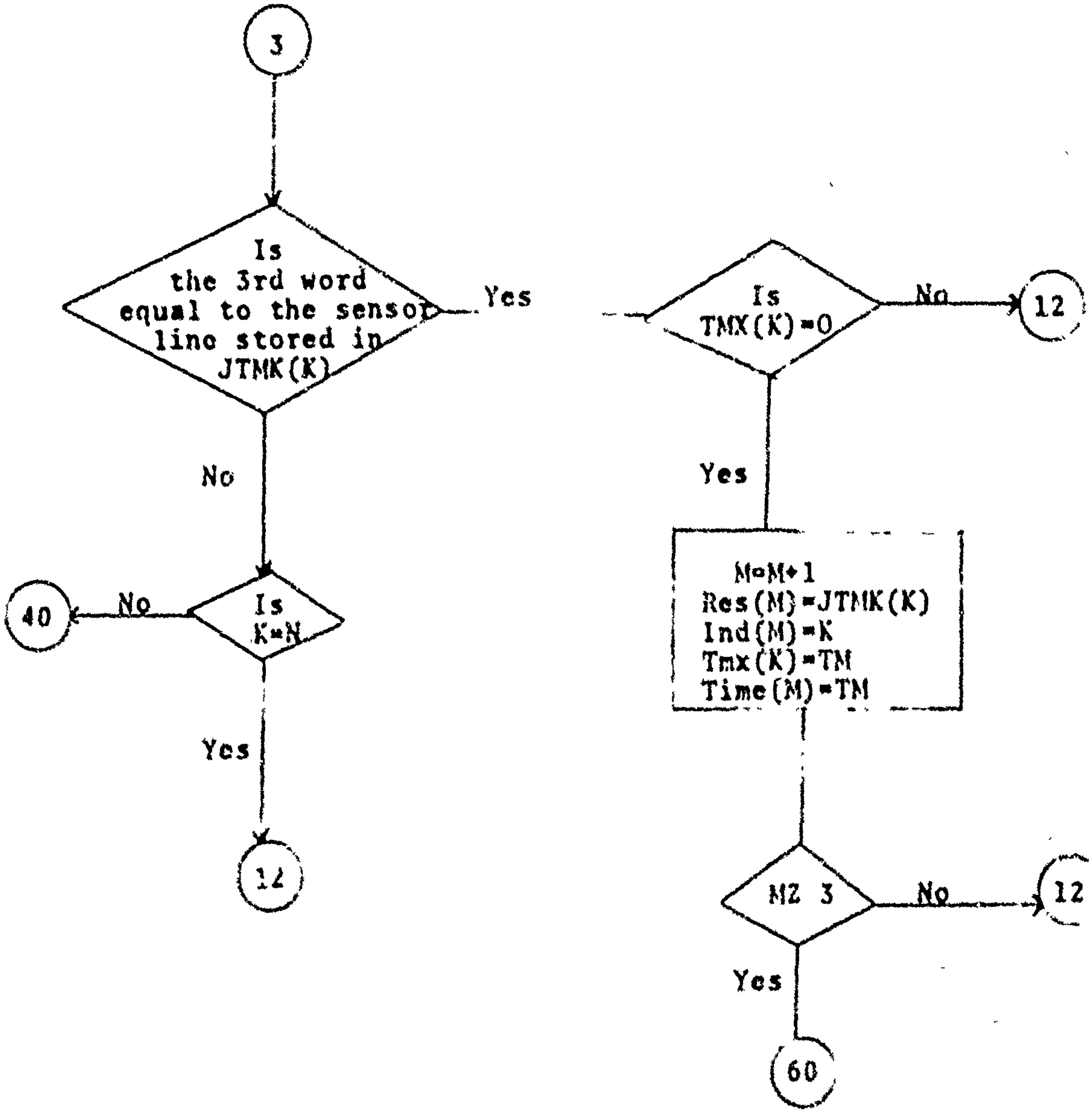
FIGURE 7

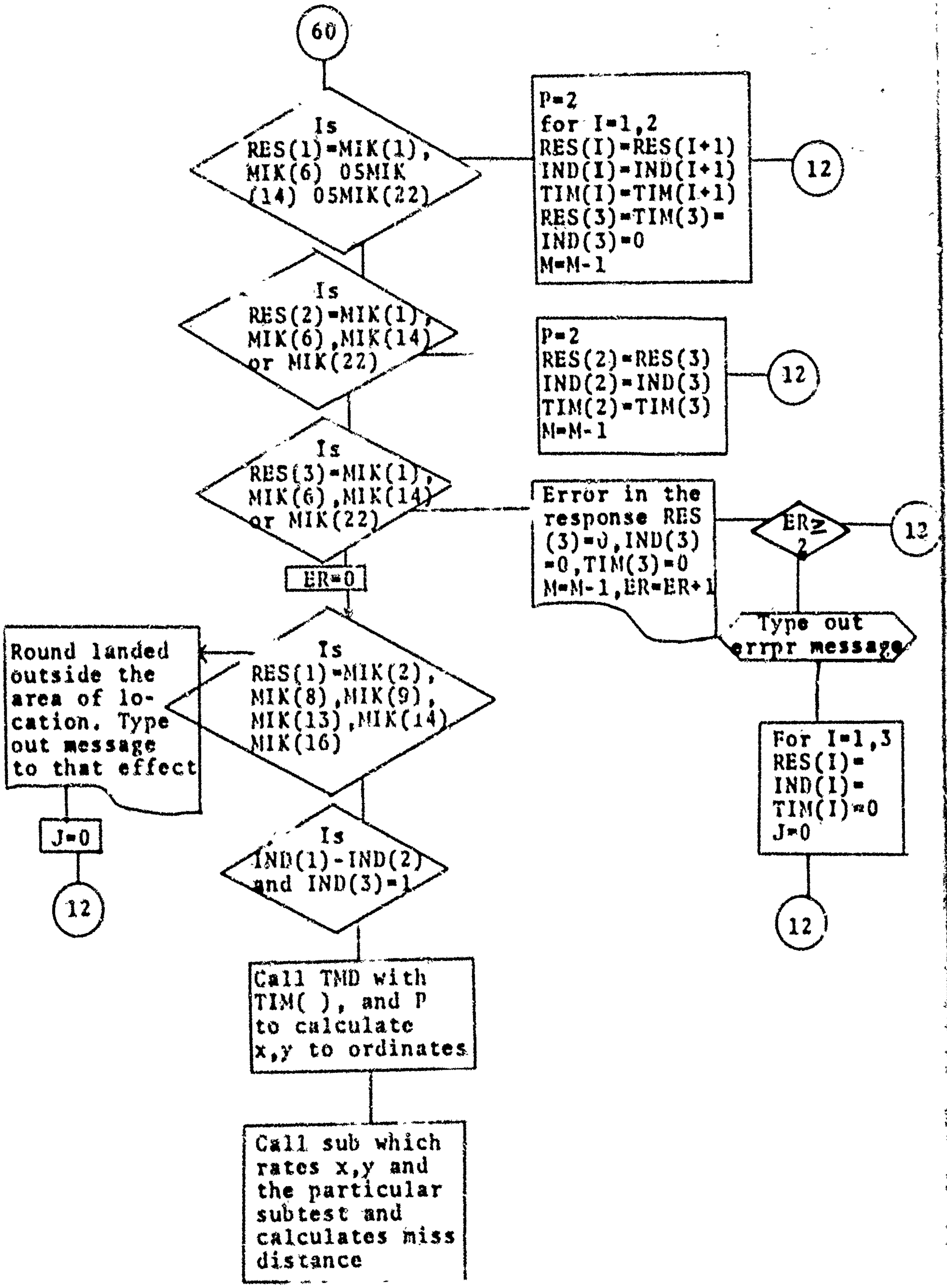

START
Enter round count Line number (IRC) Enter 1 if sensor lines are to be entered manually
Are Sensor Lines to be entered manually
Yes
No
First 5 entries are to be sensors for the Bunker-Offline sensor is the first entry Others are entered front to back
Next 8 are TA250
Next 8 are TA350
Next 5 are TA200
Next 6 are TA300
All are entered with off-line sensor as first entry
It is assumed that sensor lines are plugged into input channels ITON. They are to follow the same sequence as indicated under manual entry.
MIK(1)=1
MIK(2)=2
MIK(32)=32
MIK(1)=No of first input
MIK(2)=Second input
MIK(32)=32nd sensor link
5
The computer will now ask you to supply the subtest number
It is important to enter the correct subtest-since only the sensors pertaining to that subtest will be turned on in the scenario
Subtest 2
Yes
No
2
JTMK(1)=MIK(1)
JTMK(2)=MIK(2)
JTMK(5)=MIK(5)
N=5
10


2
Subtest 3
Yes
JTMK(1)=MIK(6)
JTMK(8)=MIK(13)
JTMK(9)=MIK(22)
JTMK(13)=MIK(26)
N=13
10
No
Subtest 4
Yes
JTMK(1)=MIK(14)
JTMK(8)=MIK(21)
JTMK(9)=MIK(27)
JTMK(14)=MIK(32)
N=14
10
No
Subtest 5
No
Print that subtest number is incorrect
5
Yes
JTMK(1)=MIK(6)
JTMK(8)=MIK(13)
JTMK(9)=MIK(14)
JTMK(16)=MIK(21)
N=16
10
Enter temp for the exercise on command from computer
Calculate the speed of sound


Read the header block from M&C tape
Set up and initiate counters-TIMB=0-J=0; TMX(I)=0 for I=ITON M=0/RES(I),IDA) TIM(I)=0 for I=1,3
Write out header info
50
Read a data block
Is this the last data block
Yes
Do you have more data
No
Stop
Yes
Mount new data tape
5
No
Set ER=0 M=0, i=0
A piece of data is composed of three words. First word=soft-wave time. Second word=hardwave time Third word=line#
12
i=i+1
50
Yes
Is this the last word of a data block


Examine the ith piece of data
Convert the two times to a double precision time-call it TM
Has a round count line been designated
No
A round count line is assumed nct to exist. If the time between this and the last event exceeds 1 sec a new round is assumed
Yes
TIM8=TM
No
i.e. is TM> TIMD+1
Yes
14
Is the third word the round count line
Yes
14
You are now dealing with a new round
No
Is J=0
Yes
12
K=0
40
K=K+1
3
Set: J=1; TIMB=TM; TMX(L)=0 for L=ITON
N is the no. of sensors
12


3
Is the 3rd word equal to the sensor line stored in JTMK(K)
Yes
No
Is K=N
No
40
Yes
12
Is TMX(K)=0
No
12
Yes
M=M+1
Res(M)=JTMK(K)
Ind(M)=K
Tmx(K)=TM
Time(M)=TM
MZ 3
No
12
Yes
60


60
Is RES(1)=MIK(1), MIK(6) 05MIK (14) 05MIK(22)
P=2
for I=1,2
RES(I)=RES(I+1)
IND(I)=IND(I+1)
TIM(I)=TIM(I+1)
RES(3)=TIM(3)=
IND(3)=0
M=M-1
12
Is RES(2)=MIK(1), MIK(6),MIK(14) or MIK(22)
P=2
RES(2)=RES(3)
IND(2)=IND(3)
TIM(2)=TIM(3)
M=M-1
12
Is RES(3)=MIK(1), MIK(6),MIK(14) or MIK(22)
Error in the response RES (3)=0,IND(3) =0,TIM(3)=0 M=M-1,ER=ER+1
ER≥ 2
12
Type out errpr message
For I=1,3
RES(I)=
IND(I)=
TIM(I)=0
J=0
12
ER=0
Is RES(1)=MIK(2), MIK(8),MIK(9), MIK(13),MIK(14) MIK(16)
Round landed outside the area of lo- cation. Type out message to that effect
J=0
12
Is IND(1)-IND(2) and IND(3)=1
Call TMD with TIM( ), and P to calculate x,y to ordinates
Call sub which rates x,y and the particular subtest and calculates miss distance

6. INTEGRATED TEST AND ANALYSIS METHODOLOGY. This section briefly describes the test and analysis procedure for testing the single purpose grenade launcher. Using the procedures for sampling, determination of sample size, training, weapon assignment, and scheduling recommended under Objective 2 above, the five subtests should be run. All test soldiers should fire in Subtest 1, zeroing the weapon, initially. After completion of the first subtest, the remaining subtests should be accomplished in the order prescribed in paragraph 4.b.(8), Scheduling.

The function of the integrated test and evaluation procedure is to utilize the output for all subtests in an integrated analysis designed to select the superior weapon system. All trials for each weapon system will be combined initially as a function of subtest. The superior weapon will be determined in the 2-way classification analysis.

The plan initially uses an accuracy analysis testing for interaction between weapon performance and subtest. The outcome of the initial analysis determines the next step. The flow diagram, Figure 8 outlines the basic steps involved in the accuracy analysis. After the accuracy analysis the sustainability analysis is employed followed finally by the responsiveness analysis. The entire procedure is presented in detail in Appendix III, Evaluation Procedure. The evaluation method for the single purpose grenade launcher and the grenade component of the combination weapon is recommended in Appendix III. Evaluation of the rifle component should also be undertaken to insure no degradation in rifle performance due to the addition of the grenade launcher. The analytical procedure for evaluating the rifle component is identical to that prescribed for the quickfire facility. The rifle should be tested under three conditions:

With launcher loaded

With launcher unloaded

With launcher firing intermittently

If significant differences occur under these three conditions, further rifle tests as prescribed for the defense and attack facilities should be undertaken to determine the full extent of the degradation.

Evaluation of the combination weapon system presents the test officer with a new set of unknowns. This problem is discussed in paragraph 7.c, which describes an approach for evaluating combination weapon systems.

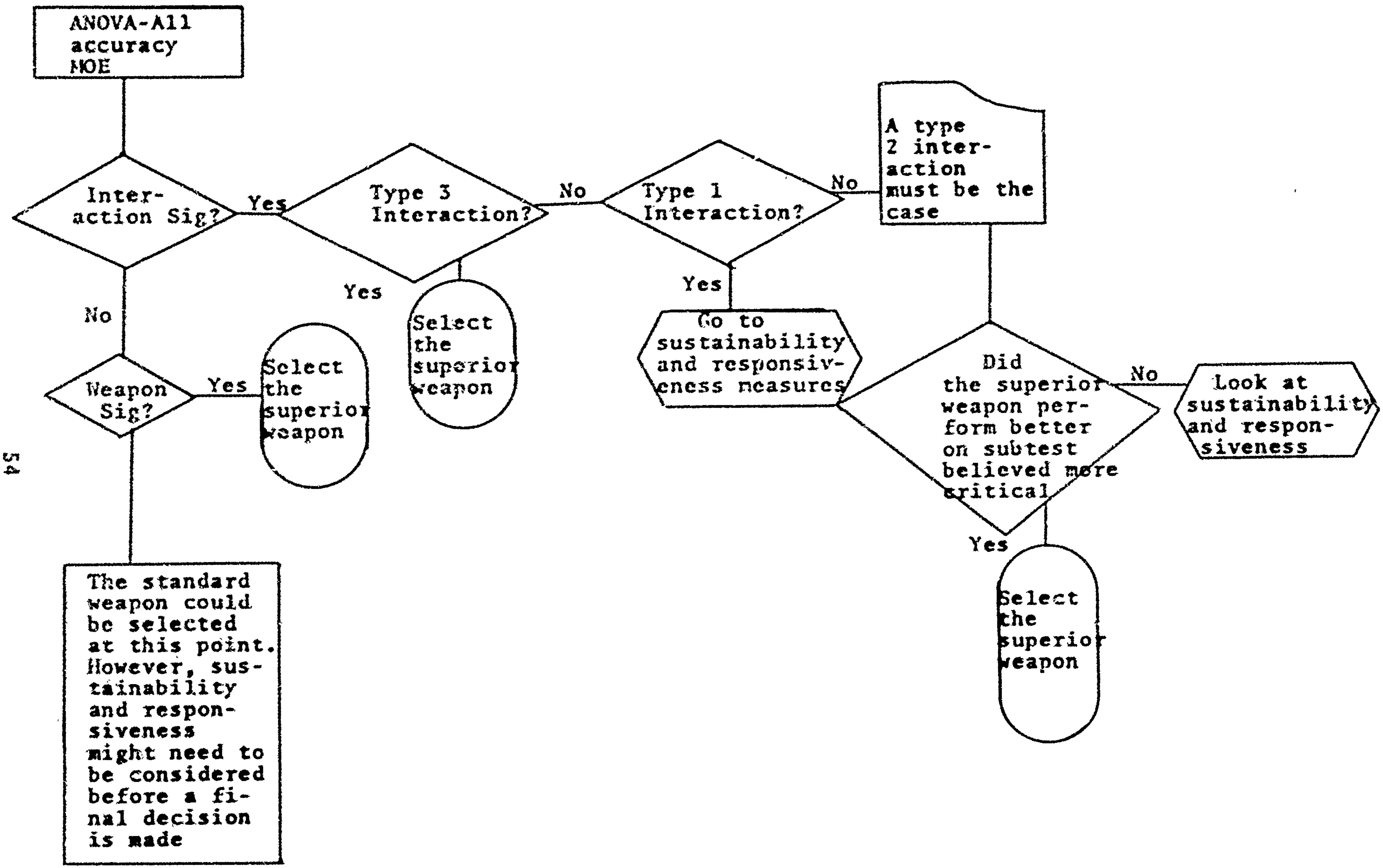

ANOVA-All accuracy MOE
Inter-action Sig?
Yes
No
Type 3 Interaction?
Yes
Select the superior weapon
No
Type 1 Interaction?
Yes
Go to sustainability and responsiveness measures
No
A type 2 interaction must be the case
Did the superior weapon perform better on subtest believed more critical
Yes
Select the superior weapon
No
Look at sustainability and responsiveness
Weapon Sig?
Yes
Select the superior weapon
The standard weapon could be selected at this point. However, sustainability and responsiveness might need to be considered before a final decision is made

Figure 8

## 7. RECOMMENDATIONS FOR FURTHER IMPROVEMENTS IN TEST METHODOLOGY.

a. Introduction. Further improvements in grenade launcher methodology can be achieved in two areas of testing. The first is the need to score the high explosive grenade. Many service tests of ammunition and launchers will require the use of the HE round. Feasibility tests of new caliber sizes will almost certainly require the testing with an HE projectile, since the practice grenade normally follows the development of the HE grenade. The second area in which improvements are feasible is in testing the dual purpose weapon system. The current method of testing the dual purpose weapon is simply composed of testing one capability at a time on separate facilities. This technique is adequate for testing the capability of the single weapon; however, the weapon system will be used in combat as a combined weapon system. Testing one component at a time ignores the interaction between the two weapon systems. It ignores precisely that area of performance for which the system was designed. This section contains a discussion of the problems inherent in testing the dual purpose weapon and presents a method for evaluating total system performance objectively.

b. High Explosive Grenade Scoring System. Several tests were made using the time difference scoring system with HE grenade rounds. The results were not consistent. In some cases, extremely short time differences were measured which indicated that the high speed seismic signature of the round reached the sensors before the acoustic signature. In other cases, large time differences were measured indicating possible response to echoes from nearby objects on the range. In still other cases, time differences of approximately the right magnitude were measured but, after calculation of the x,y coordinate of the impact, there was an inconsistent error in the measurement of several feet. Experience of the technicians and engineers who participated in the development of the practice grenade scoring system believe that a scoring system is feasible for HE. Research that is within the Infantry Boards present capability is required. Experiments must be run with various types of low pass electronic filters to screen out noise caused by the supersonic projectiles emitted from the HE round upon impact. Further, filtering in the extremely low range (seismic energy) may be required. In addition, various techniques of shock mounting or suspending the microphones should be studied to isolate the sensor from the seismic energy of the explosion.

Test equipment for both of these tasks is available as are the electronic parts. The testing should be done by a qualified electronic engineer with experience in field test instrumentation development. A hardened grenade test facility should be considered by Infantry Board personnel if a scoring system for HE grenade is developed. Target mechanisms, data lines, and sensors must be hardened to minimize damage. The hardening requirement will increase the work required to set up temporary test facilities.

c. Evaluation of the Dual Purpose Weapon. As stated under Objective 3 above, the evaluation of performance of dual purpose weapons systems is much more complex than the evaluation of single purpose weapons. System performance in terms of enemy casualties is dependent on the number and types of ammunition available to the gunner, the enemy (insurgent, armored), the terrain, and the firing doctrine under which the soldier is trained. Basically, the problem is to determine the optimum makeup for each competing weapon system prior to the performance comparisons. Bias may be introduced if the optimum configuration for one weapon system is simply transferred to another. The following paragraphs contain a description of a model which is designed to determine optimum mix of ammunition for any given set of combat conditions. The model should permit a fair evaluation of two competing combination weapon systems.

(1) Isoeffectiveness Model. Consider a combat situation resulting in the destruction of $A_1$ enemy targets. Given a system such as the M203 that will allow the soldier to fire both 5.56 ammunition and 40-mm grenades: How many magazines of 5.56 and how many rounds of 40-mm should the soldier enter into combat with? $A_1$ targets could have been destroyed with $Y_1$ magazines of 5.56, or $A_1$ targets could have been destroyed with $X_1$ rounds of 40-mm, or $A_1$ targets could have been destroyed with various combinations of Y and X rounds. An isoeffectiveness curve could be drawn showing all possible (efficient) combinations of 5.56 and 40-mm capable of producing $A_1$ casualties. (Fig 9)

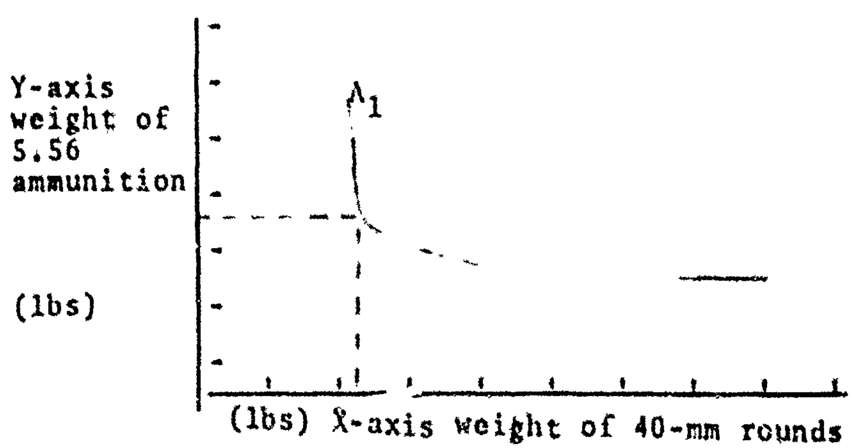


Figure 9

Similarly isokill curves could be drawn depicting $A_2$, $A_3$, --$A_n$ target kills.

Under the assumption that more of something is desired to less than something, the soldier will carry as much ammunition into combat as possible. The limiting factors are the amount of weight and the bulk of what is carried. For a given amount of weight it is desired to have the soldier be effective as possible. The basic load of ammunition may be expressed as:

$$T_W = X.WT_X + Y.WT_Y$$

Where $T_W$ = Total weight

X = number of 40-mm rounds carried

$WT_X$ = weight of 1 40-mm round

Y = number of 5.56 rounds carried

WT = weight of 1 5.56 magazine

This is an equation of a straight line whose slope is $WT_Y/WT_X$, and respective Y and X intercepts of $T_W/WT_Y$ and $T_W/WT_X$.

The point of tangency between this equation, the isoweight curve, and the highest isoeffectiveness curve (Am) would indicate the proper mix of 40-mm and 5.56 (See Figure 10).

Survey information shows that the average rifleman in Vietnam carries into combat approximately 20 magazines of 5.56. This equates to approximately 14 pounds. The basic M-16 rifle weighs approximately 8 pounds. Hence the Infantry rifleman in Vietnam carries into combat approximately 22 pounds of weight directly associated with firepower capability.

The M-79 grenadier carries approximately 35 rounds of 40-mm. This equates to around 17 pounds of ammunition weight. The M-79 weighs approximately 6 pounds. Hence the grenadier in Vietnam carries with him approximately 23 pounds of weight associated with firepower capability.

The M-203 weighs approximately 11 pounds. Due to the distribution of weight it could be assumed that the soldier would carry with him approximately 12 pounds of ammunition composed of some mixture of 5.56 and 40-mm. This means that for the same amount of weight the soldier could carry either 24 rounds of 40-mm or 17 magazines of 5.56.

The isoweight curve would be:

$$12 = XWT_x = YWT_y$$

$$= (X)\ (.5) + (Y)\ (.7)$$

$$y = 17 - .7X$$

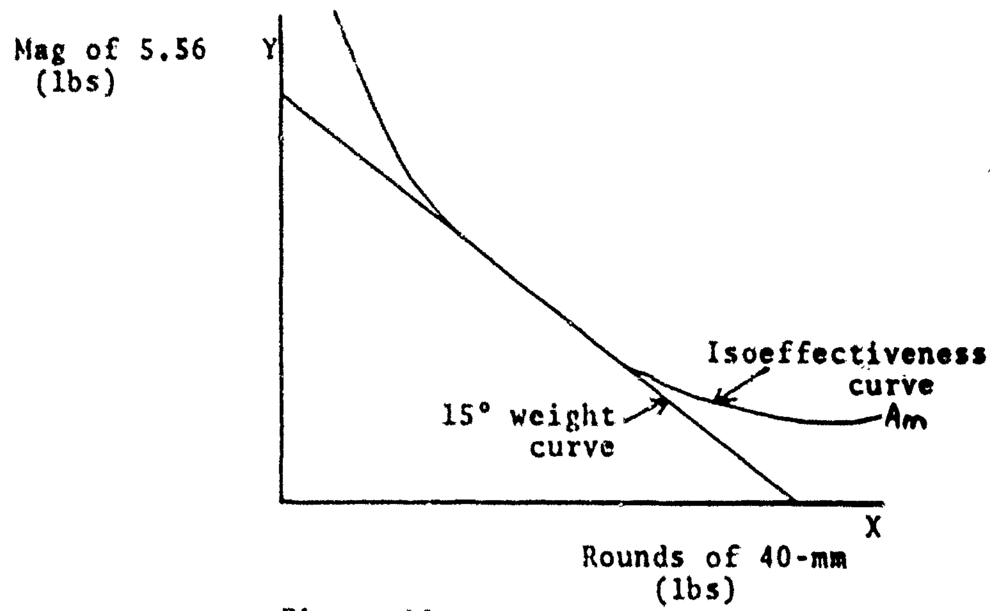



Figure 10
Isoweight Curve Isoeffectiveness Curve

The effectiveness curves appear to be very difficult to estimate. One method of estimating these curves would be to supply a soldier with an unlimited number of 5.56 magazines and 40-mm rounds. These rounds would be used to engage realistic combat situation targets. The soldier could choose any combination of 5.56 and 40-mm that he desired. At the end of an exercise the number of casualties (targets hit) could be obtained as well as the number of 5.56 magazines and 40-mm that were used. If this exercise is repeated often enough, curves could be generated depicting various combinations of 5.56 and 40-mm that yields the same number of casualties against specific types of enemy forces in specific environments. The raw data would probably make for very irregular isoeffectiveness curves. These curves would have to be smoothed to estimate average soldier performance.

Figure 11 shows an example where $A_4$, $A_3$, $A_2$, $A_1$. If these were actual isoeffectiveness curves the graph indicates that the 12 pounds in weight should be divided into approximately 13 magazines of 5.56 and 6 rounds of 40-mm and would result in almost $A_4$ casualties.

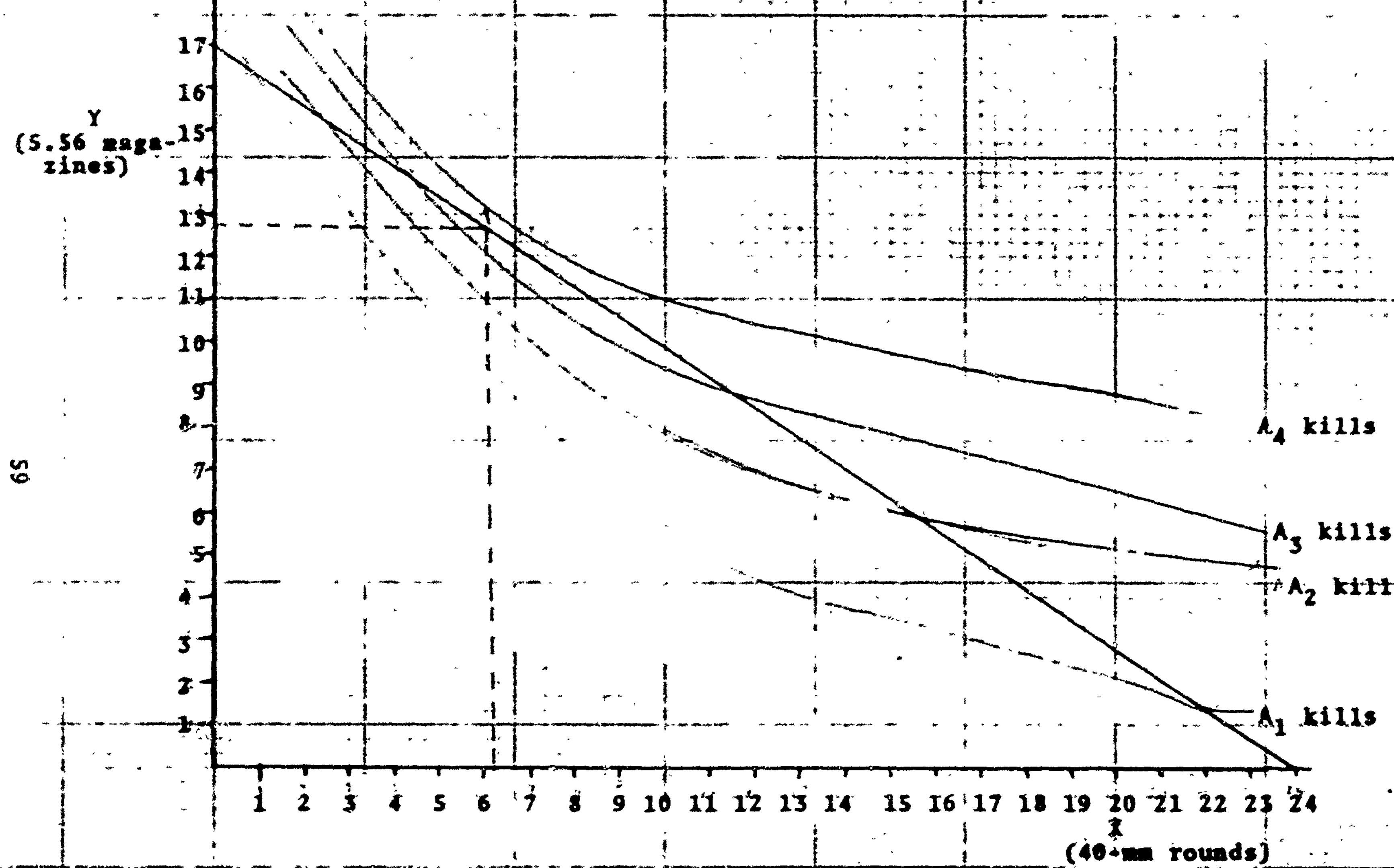

Y
(5.56 maga-
zines)
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
X
(40-mm rounds)
$A_4$ kills
$A_3$ kills
$A_2$ kills
$A_1$ kills

Figure 11

(2) Construction and Use of the Model. The model would be basically a computer simulation of the attack test facility. The primary difference between the actual attack facility and the simulated attack facility is the fact that grenades may be used on the simulated facility. The technique for developing the model is to simulate the rifle engagements actually observed on the facility in the model. Input parameters for the rifle are:

Target exposure time

Hit probability curves

Time to first round

Time between trigger pulls

Time to change magazines

Movement time

Malfunction probability curves

Time to clear malfunctions

Each of these values would be measured on the existing facility using the rifle component only. Grenade launcher effectiveness would be tested on a grenade facility. The parameters measured on a grenade facility and used as input to the simulation model are:

Miss distance curves

Lethal radius

Time to reload

Time between trigger pulls

Malfunction probability curves

Time to clear malfunctions

Upon insertion of the inputs for each component of each competing combination weapon, the model would be exercised to determine weapon superiority (See Figure 12).

| | | | | | | |
|---|---|---|---|---|---|---|
| MEASURED INPUTS | = | RIFLE MOE | + | GRENADE LAUNCHER MOE | + | OPTIMUM MIX OF AMMUNITION |
| VARIABLE INPUTS | = | FIRING INSTRUCTIONS | + | WEAPON SYSTEM WEIGHT | | |
| ATTACK SIMULATION | | | | | | |
| STATISTICAL ANALYSIS | | | | | | |
| ESTIMATE PERFORMANCE CURVES (Number of Enemy Casualties) | | | | | | |

Simulation Model

Figure 12

(3) Validation of the Model. When used as a direct simulation of the attack facility, validation is not too important, because of the direct relationship between the actual range and the simulated range. They are essentially carbon copies of each other. However, if the model is to be used in an extended form such as increasing the attacking force from a fire team to a squad or two squads, adding a base of fire element to the maneuver element, increasing the strength of the enemy force, or introducing the two-sided fire fight, some validation of the original simulation should be undertaken. This validation will be used to gain an improved understanding of the model. Stated in another way, if the model is a direct copy of reality, validation is not too important; if the model is to be used as an extension of reality, that is, as a base for examining situations not actually measured, validation should be undertaken to insure that the base is sound enough to support the extensions. Small errors in the direct simulation may be compounded into larger errors if extensions are made without a thorough knowledge of the basic parameters of the model.

The validation will require an expansion of the attack facility to permit use of the grenade launcher. Projectile impact scoring must be added and the existing round count system must be made compatible with launcher. The actual number of targets hit would be compared to the number of targets hit using the simulation model with each test using identical basic loads, mixes, and firing doctrine.

With these basic inputs it is possible to evaluate in the simulation the performance of the combined weapon system. The initial trials using the model should be devoted to firing doctrine to determine when the soldier should elect to use the grenade launcher. The total number of targets hit would be the measure of effectiveness. Sample doctrines that could be tested are:

(1) Fire a 3-round salvo upon initiation of the attack and sets of 3 rounds at 100-meter intervals until the assault line is reached.

(2) Fire the launcher whenever two or more targets are visible at one time.

(3) Expend all grenade rounds early in the attack (i.e. before reaching the 200-meter phase line).

The results of this analysis would be an indication of the most effective manner in which to employ the dual purpose system. The manner may be quite different for each candidate weapon system.

The next phase is to compare candidate weapon system performance with each weapon operating under optimum firing doctrine. Several target presentation scenarios can be evaluated. A complete picture of weapon performance in the attack situation can be produced using the number of enemy casualties as the primary measure.

The entire process could be duplicated with the defense facility using the same set of MOE. The ammunition weight constraint and mix constraint can be relaxed to some extent in such combat actions as deliberate defense where stockpiling of ammunition is a normal procedure. If differences occur between the test facility and the model during validation, adjustments must be made to the model until each testing method produces the same results. At this point, the model can be expanded with more confidence to new situations which cannot be duplicated on the physical facility, but which can be used to gather a more complete picture of weapon performance.

## APPENDIX I. DESCRIPTION OF PRESENT SCORING SYSTEM

1. Introduction. A scoring system has been developed which is capable of scoring the impact of 40-mm practice grenades to within an accuracy of 6 inches. The accuracy evaluation of the system appears in Appendix IV.

The hardware system is capable of accommodating 18 microphone inputs. Each microphone/signal conditioner can be used as an impact sensor or round count sensor. Normally, the sensors would be carefully deployed approximately 30 feet apart in a straight line as shown in Figure I-1. When the small detonation occurs at impact, its shock wave at each sensor is sensed and measured as the microphone response pulses are conditioned and sent to the ADPE. Figure I-2 is a block diagram of the signal conditioner and ADPE. The data messages are logged onto magnetic tape for subsequent processing. Figure I-3 is a schematic of the signal conditioning circuit used on each of the 18 channels.

2. Hardware Description. The signal conditioning circuits are centrally located with the ADPE in the computer van. Each signal conditioning channel is composed of basically two circuits: an active bandpass filter and level detector. The center frequency ($f_o$) of the active bandpass filter is 450Hz, and the gain at $f_o$ is -12. At 75Hz and 825Hz (bandwidth of 750Hz), the gain is down 3db. The expected outputs from a microphone (250Hz-650Hz) are amplified and any noise on the input cables outside the passband of the filter is alternated.

The output of the filter is fed to a level detector. This signal is compared with a preset threshold level; a signal with amplitude exceeding this reference will give an output which can be used as an input to the California Avionics I-550 Microphone Signal Conditioner. All channels have a common reference.

The ADPE consists of a PDP-15/30 computer especially configured to accept 256 data inputs directly into the core. Data acquisition time is 3-4 microseconds per input and time resolution equals .8 nanoseconds. A detailed description of the ADPE can be found in the Defense Experiment I Report, USAIB, 22 November 1971.

3. Data Collection and Data Handling Programs. A complete set of programs is available for reducing the impact scoring data. The program requires the ambient outdoor temperature as input prior to performing the analysis. The program sorts the data words for complete sets

pertaining to the impact of a single round. It then computes point of impact and prints the answer. Subsequent programs are available for computing mean spread, extreme spread and average offset or miss distance. Figure I-4 is a flow diagram of the present system. A copy of the computer program is included as Figure I-5.

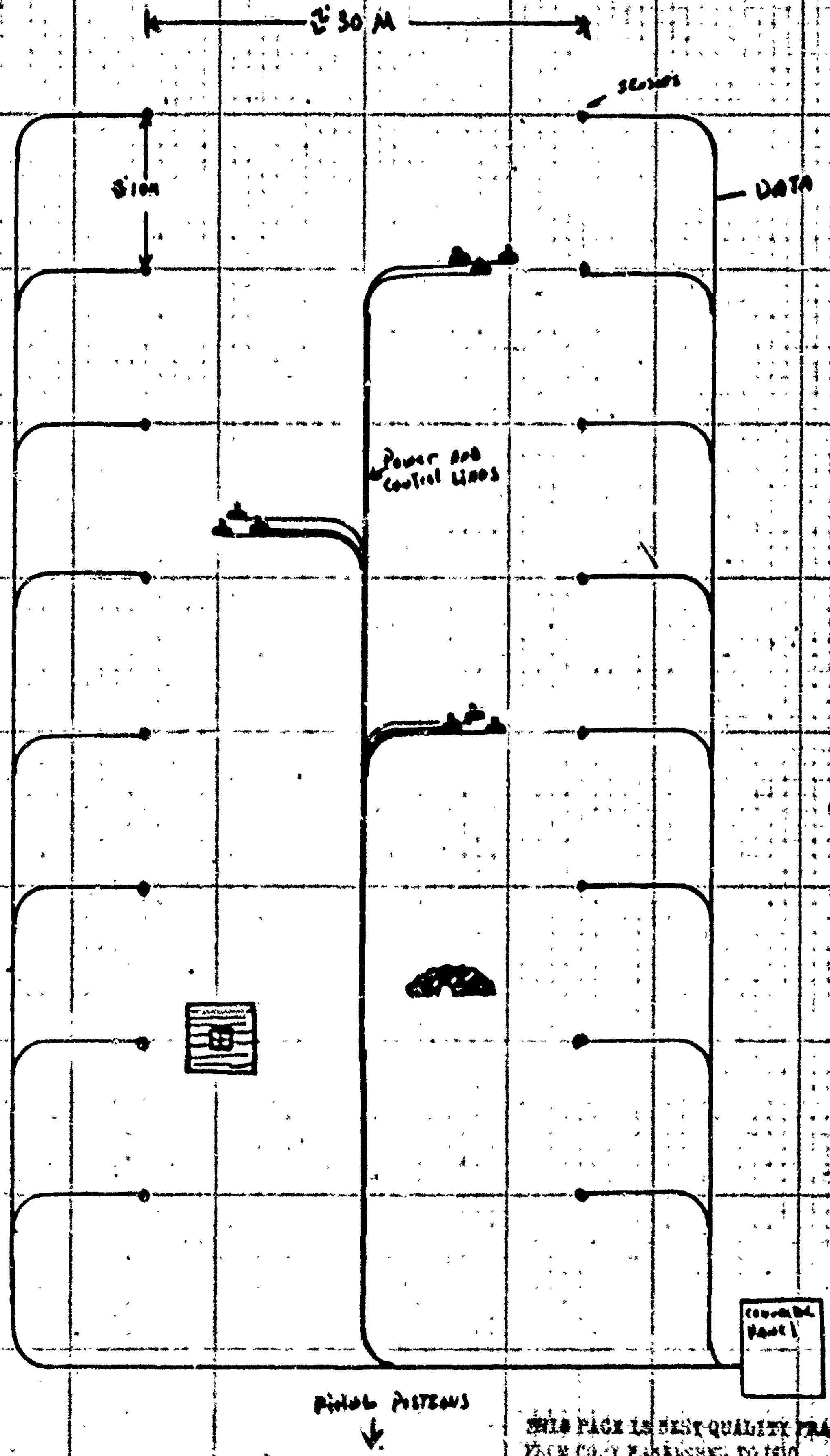



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Figure I-1

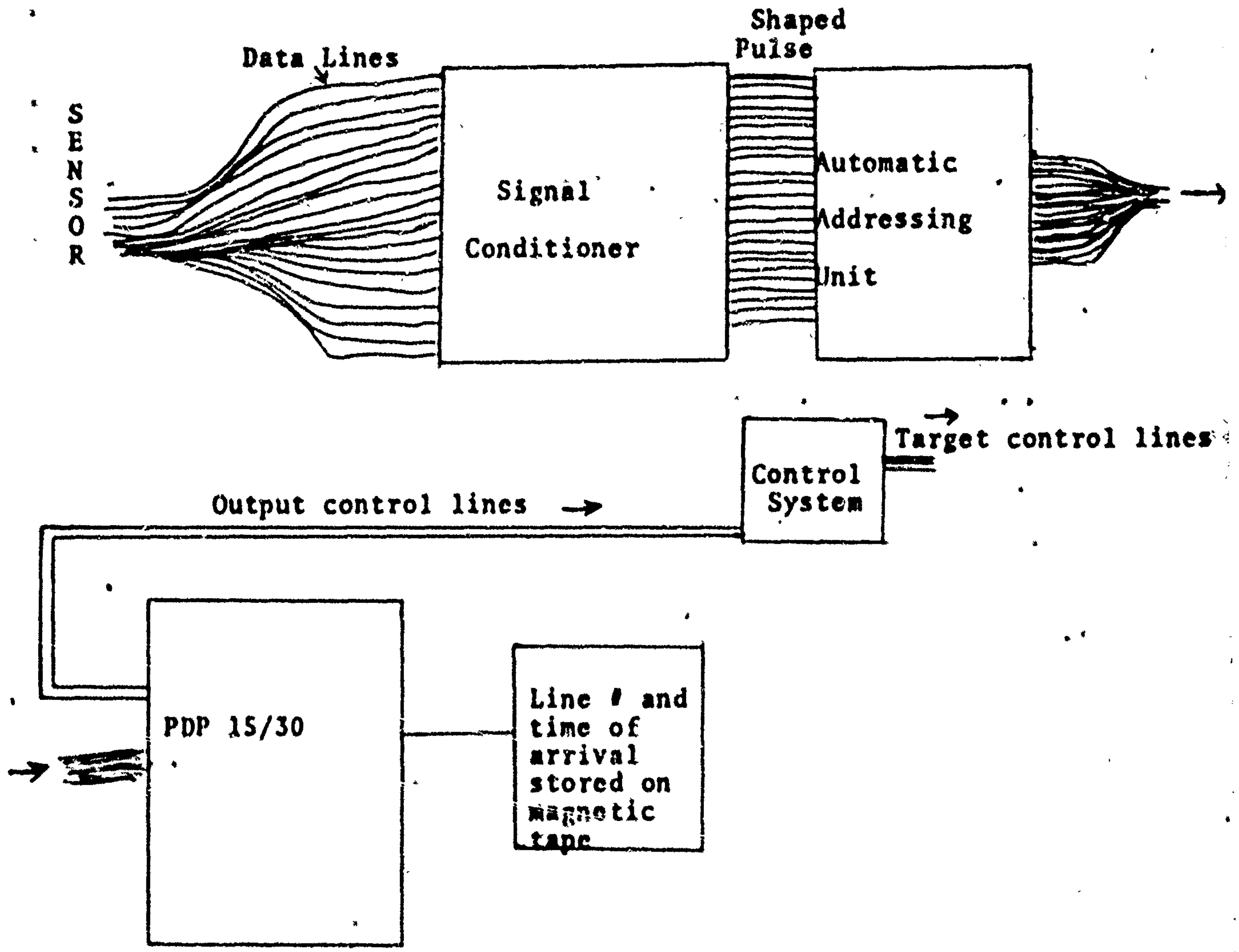

Data Lines
SENSOR
Signal Conditioner
Shaped Pulse
Automatic Addressing Unit
Target control lines
Control System
Output control lines
PDP 15/30
Line # and time of arrival stored on magnetic tape

Figure I-2

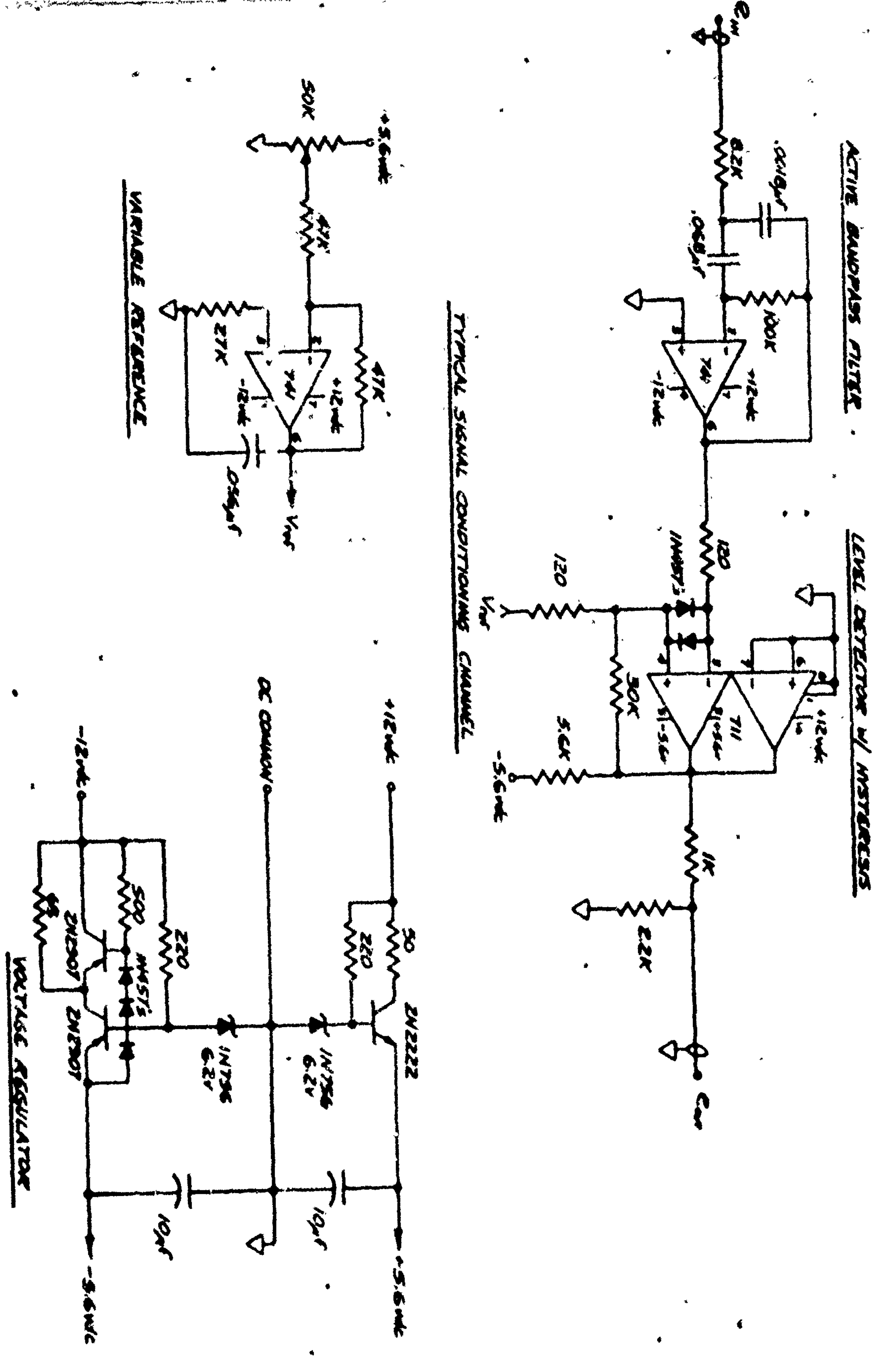
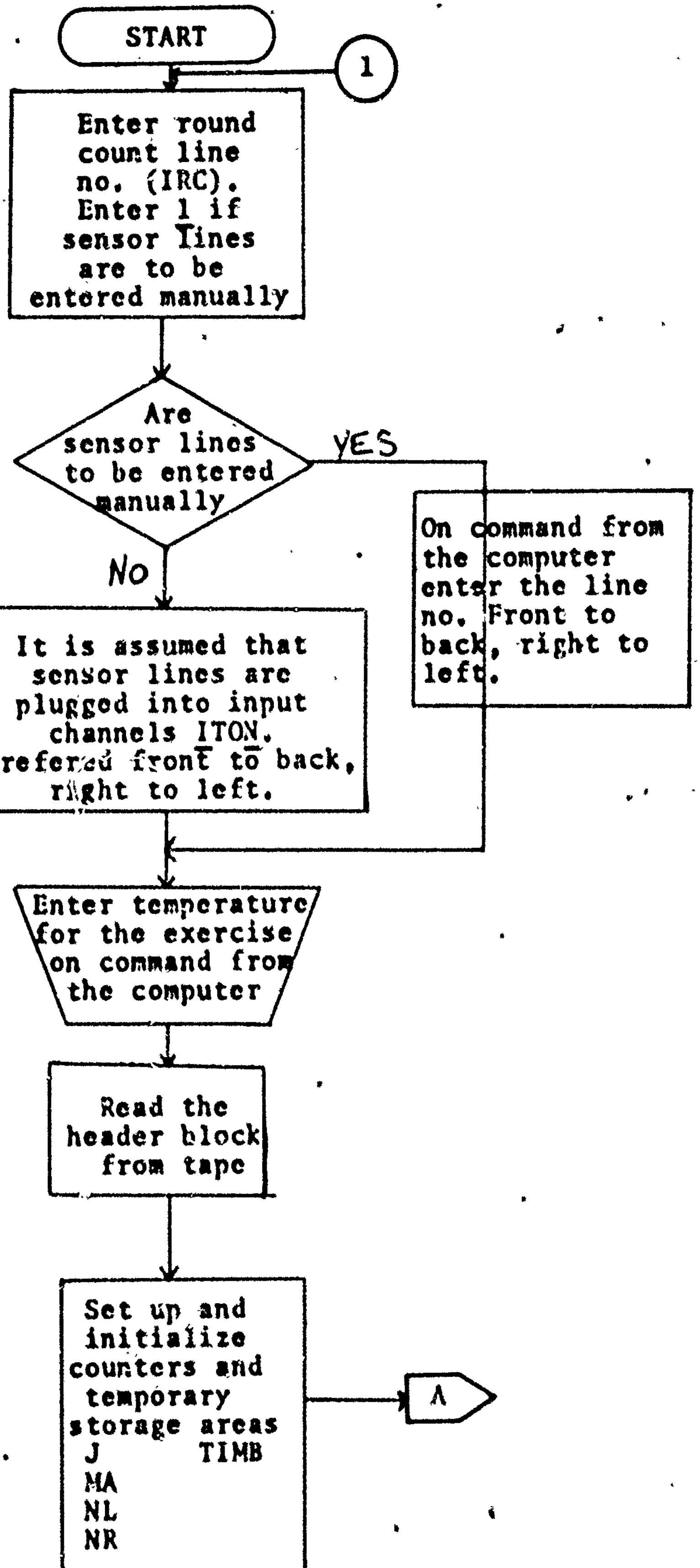

ACTIVE BANDPASS FILTER
LEVEL DETECTOR w/ HYSTERESIS
TYPICAL SIGNAL CONDITIONING CHANNEL
VARIABLE REFERENCE
VOLTAGE REGULATOR

Figure I-3




Data Handling Program Flow Diagram
Figure I-4

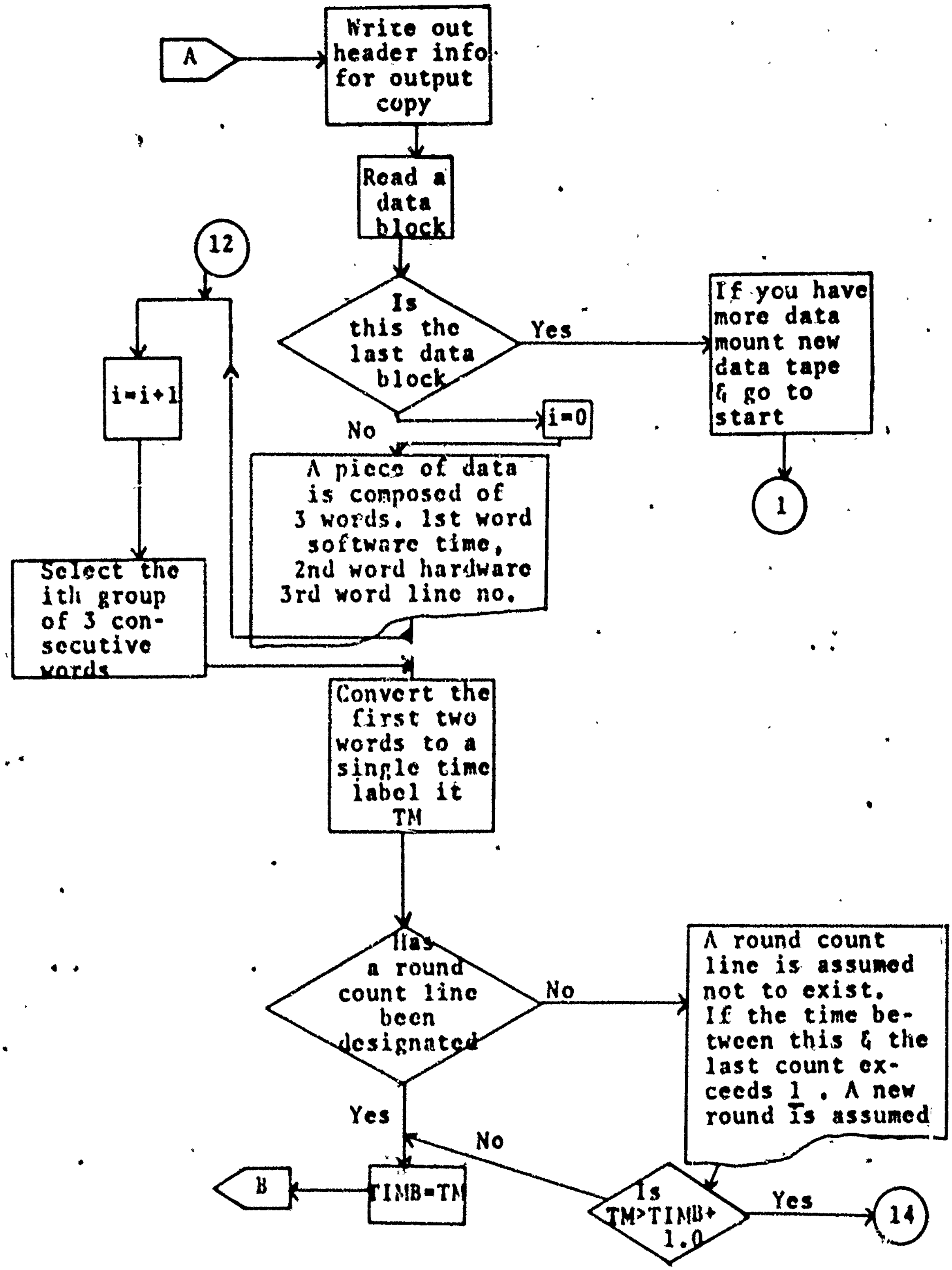



Figure I-4 (Con't)

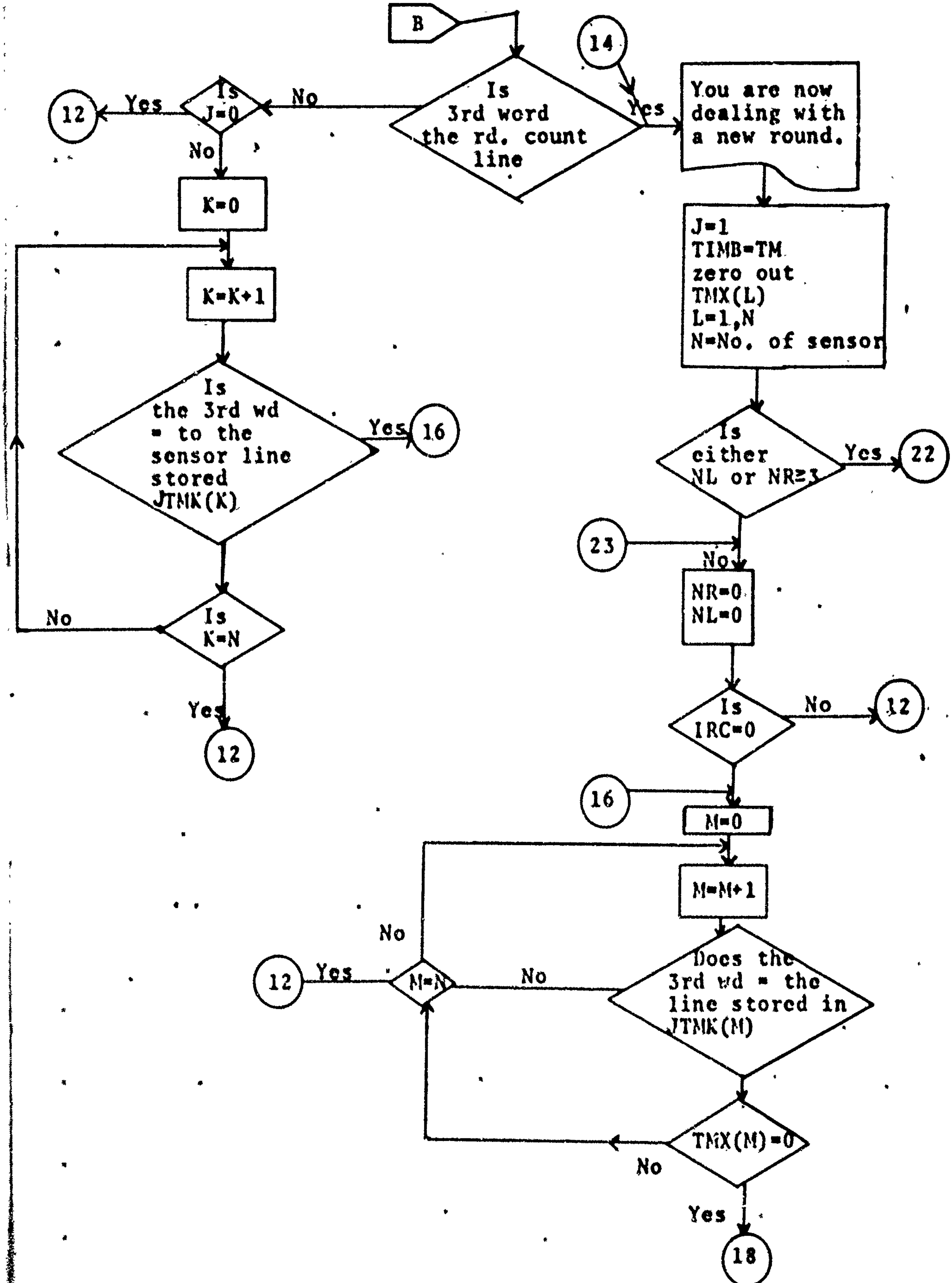



Figure I-4 (Con't)

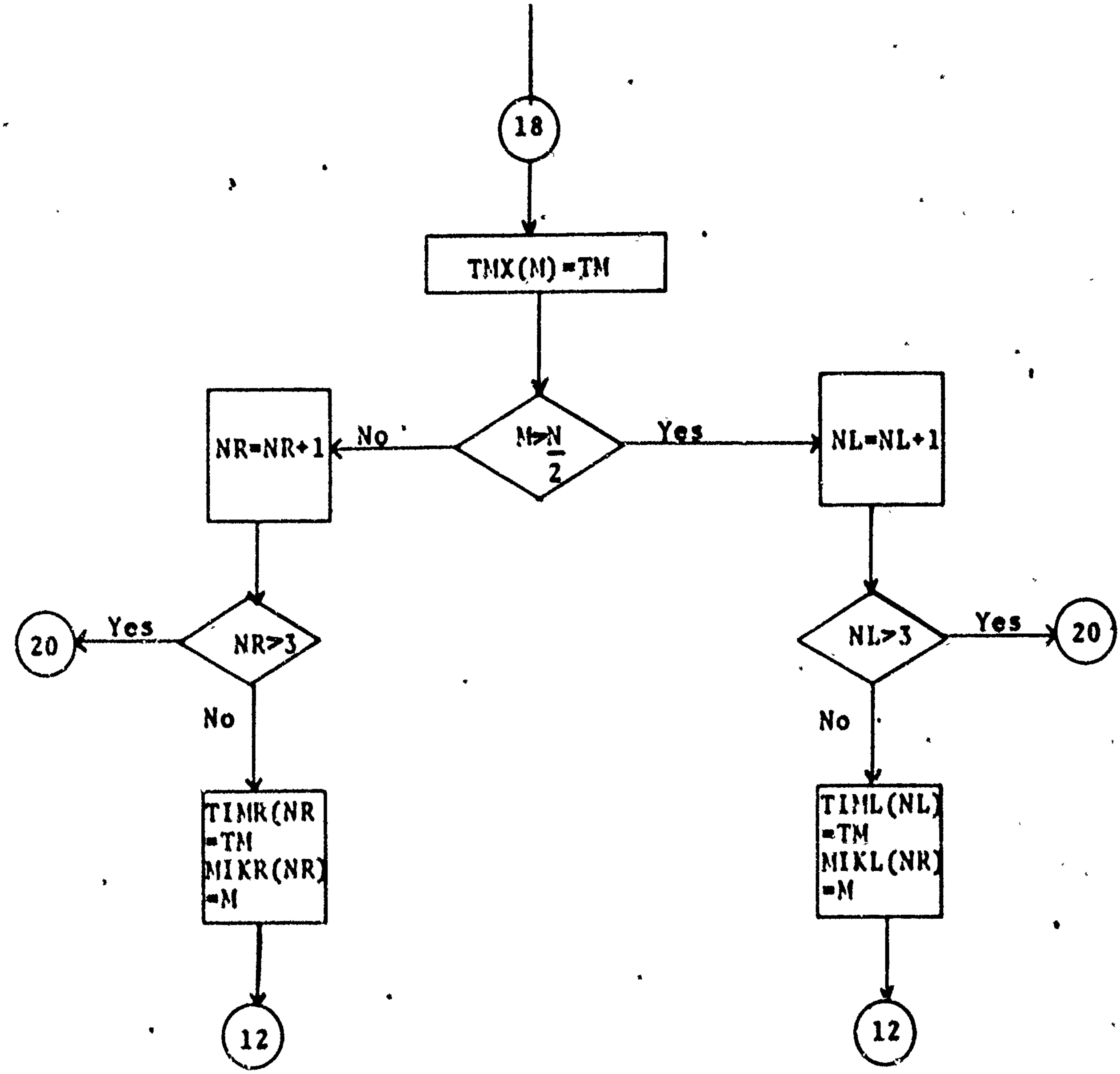



Figure I-4 (Con't)

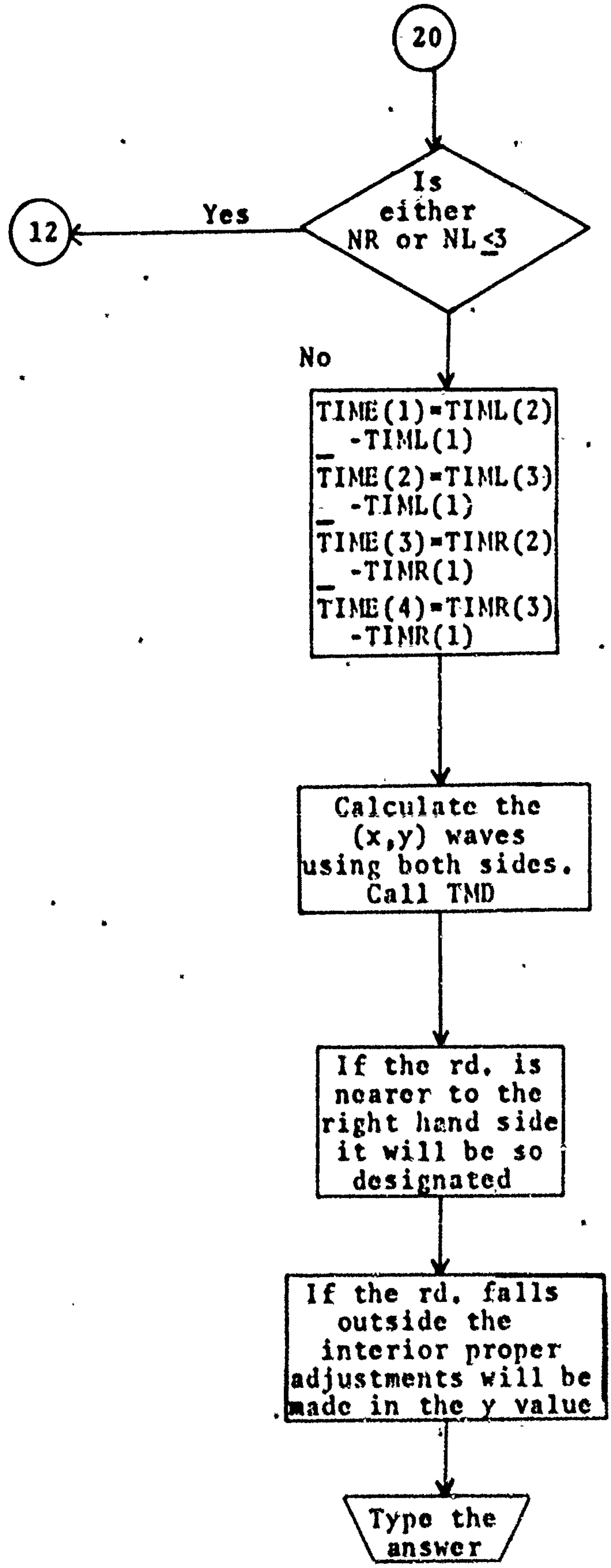



Figure I-4 (Con't)

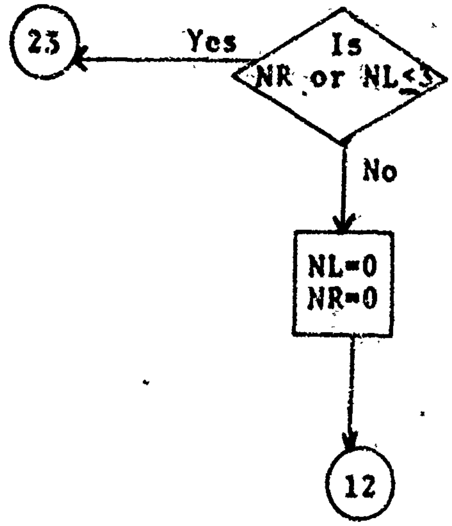



Figure I-4 (Con't)

```
      DOUBLE PRECISION TM,ST,HT,TIME,TDY,TICL,TIM
      DIMENSION IX(248),FILEN(2),JTMK(16),TIMR(4),TIML(4),TIME(4)
      DIMENSION TMK(16),MIKR(8),MIKL(8)
      DATA FILEN(2)/4H DAT/,SIDR/1HR/,SIDL/1HL/
 1    WRITE(4,2)
 2    FORMAT(20HMOUNT FILE TAPE ON 1:/16H ENTER FILE NAME)
      READ(4,3)FILEN(1)
 3    FORMAT(A5)
      CALL FSTAT(2,FILEN,N)
      IF(N.EQ.0)GO TO 1
      CALL SEEK (2,FILEN)
      WRITE(4,4)
 4    FORMAT(55H TYPE ROUND COUNT IN I3 AND A 1 FOR MANUAL MIKE INPUT IN
     XCOLUMN 5  )
      READ(4,5)IRC,MMI
 5    FORMAT(I3,1X,I1)
      IF(MMI.EQ.1)GO TO 7
      DO 6 I=1,16
      JTMK(I)=I
 6    CONTINUE
      GO TO 10
 7    WRITE(4,8)
 8    FORMAT(23H TYPE MIKE LINE NUMBERS 16I3)
      READ(4,9)(JTMK(I),I=1,16)
 9    FORMAT(16I3)
 10   WRITE(4,41)
 41   FORMAT(19H ENTER TEMP IN F6.2)
      READ(4,42)TEMP
 42   FORMAT(F6.2)
      C=(.55556*TEMP)-17.77778
      VS=(1.08743)*(SQRT(1.+C/273.16))
      READ(2)IX
      CALL JMPR(IX)
      J=0
      MA=0
      ML=0
      MR=0
      TIME=0.0
      WRITE(4,43)
 43   FORMAT(33H ROUND TIME DIFF2-1  TIME DIFF3-1,
     X   L-R  Y-LEFT  Y-LEFT  Y-RIGHT  Y-RIGHT  )
 11   READ(2)IX
      IF((IX(1).EQ.(-1)).AND.(IX(26).EQ.(-1)))GO TO 1
      DO 12 I=1,247,3
      ST=IX(I)
      HT=IX(I+1)
      ST=ST*0.196608D0
      HT=HT*2.75D-6
      IF(HT.LT.0.0D0)ST=ST+0.196608D0
      TM=HT+ST
```

I-5

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Grenade Impact Scoring Program.

Figure I-5

```
      IF((IPC.EQ.0).AND.(TM.GT.TIMP+1.0))GO TO 14
      TIMP=TM
      IF(IY(I+2).EQ.IPC)GO TO 14
      IF(J.EQ.0)GO TO 12
      DO 13 K=1,16
      IF(IY(I+2).EQ.JTUK(K))GO TO 16
13    CONTINUE
      GO TO 12
14    J=1
      TIMB=TM
      DO 15 L=1,16
      TMY(L)=0.0
15    CONTINUE
      IF((NL.GE.3).OR.(NR.GE.3))GO TO 22
23    NL=0
      NR=0
      IF(IPC.EQ.0)GO TO 16
      GO TO 12
16    DO 17 M=1,16
      IF((IY(I+2).EQ.JTUK(M)).AND.(TMY(M).EQ.0.0))GO TO 18
17    CONTINUE
      GO TO 12
18    TMY(M)=TM
      IF(M.GT.8)GO TO 19
      NR=NR+1
      IF(NR.GT.3)GO TO 20
      TIMR(NR)=TM
      MIKR(NR)=M
      GO TO 12
19    NL=NL+1
      IF(NL.GT.3)GO TO 20
      TIML(NL)=TM
      MIKL(NL)=M
      GO TO 12
20    IF((NR.LE.3).OR.(NL.LE.3))GO TO 12
22    TIME(1)=TIML(2)-TIML(1)
      TIME(2)=TIML(3)-TIML(1)
      TIME(3)=TIMR(2)-TIMR(1)
      TIME(4)=TIMR(3)-TIMR(1)
      CALL TMD(TIME(1),TIME(2),VS,X1,Y1)
      CALL TMD(TIME(3),TIME(4),VS,X2,Y2)
      Y1=90.0-Y1
      Y3=30*(MIKL(1)-1)
      Y4=3.*(MIKR(1)-2)
      TIMX=TIME(1)
      TIMY=TIME(2)
      IF(TIMR(1).LT.TIML(1))TIMX=TIME(3)
      IF(TIMR(1).LT.TIML(1))TIMY=TIME(4)
      SID=SIDL
      IF(TIMX.EQ.TIME(3))SID=SIDR
      NA=NA+1
      IF(MIKR(2).GT.MIKR(1))X2=90.0-X2
      IF(MIKL(2).GT.MIKL(1))Y1=90.0-X1
      Y1=Y1+Y3
      Y2=Y2+Y4
      WRITE(6,21)NA,TIMX,TIMY,SID,X1,Y1,X2,Y2
21
```

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**Figure I-5 (Con't)**

```
 1    FORMAT(2X,I2,2(3X,F11.8),3X,A1,1X,3(2X,F6.2),3X,F6.2)
      J=0
      IF((NR.LE.3).OR.(NL.LE.3))GO TO 23
      NL=0
      NR=0
 12   CONTINUE
      GO TO 11
      STOP
      END

PIPBF V9A
```

Figure I-5 (Con't)



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## APPENDIX II. SUBTESTS FOR EVALUATION OF GRENADE LAUNCHER WEAPON SYSTEMS

This appendix contains a description of the grenade launcher evaluation subtests. These subtests are to be conducted using the grenade impact scoring system (for the practice grenade), which can be installed on any suitable terrain. To function properly, the terrain should be relatively flat with an open area approximately 400x100 meters. The grass should be very short to facilitate recovery of dud rounds.

This test facility is suitable for examining weapon performance (limiting this examination to the practice grenade, M382 or M407 only), weapon interface problems such as ease of loading or sight alignment, and for testing the compatibility of ancillary equipment with grenade launchers.

At the start of the first subtest, the weapons are zeroed using procedures described in FM 23-31 or other applicable publications. Procedures described under Objective 2, Section 4, should be followed for selecting sample size and composition, scheduling, and training.

Treatment of the output is dependent on the test type and test objective. Recommended analyses for most types of service tests appear in Appendix III. The recommended test facility consists of four firing points and seven sets of targets. The facility should be similar to the design shown in Figure II-1. The resulting data will provide hit probability and mean miss distance curves for the entire spectrum of ranges. These curves may be used for weapon system performance evaluation directly in the case of the single purpose weapon or as inputs to the evaluation model for combination weapons. A summary of the major test parameters appears in Table II-1.

One feature is mandatory if a sustainability analysis is desired: All E type silhouettes should be mounted on target pop-up mechanisms and the exposure time controlled. After the grenadier is in position and ready to fire, targets should be raised for a specified exposure time of 20 seconds. This is enough time for the grenadier to expend the 4 rounds available for each engagement yet places some realistic pressure on the individual. The time constraint should be used only for the simulated troops-in-open targets. The acquisition, aiming and firing should be rushed. The round count impact scoring systems will provide the necessary data for the analysis.

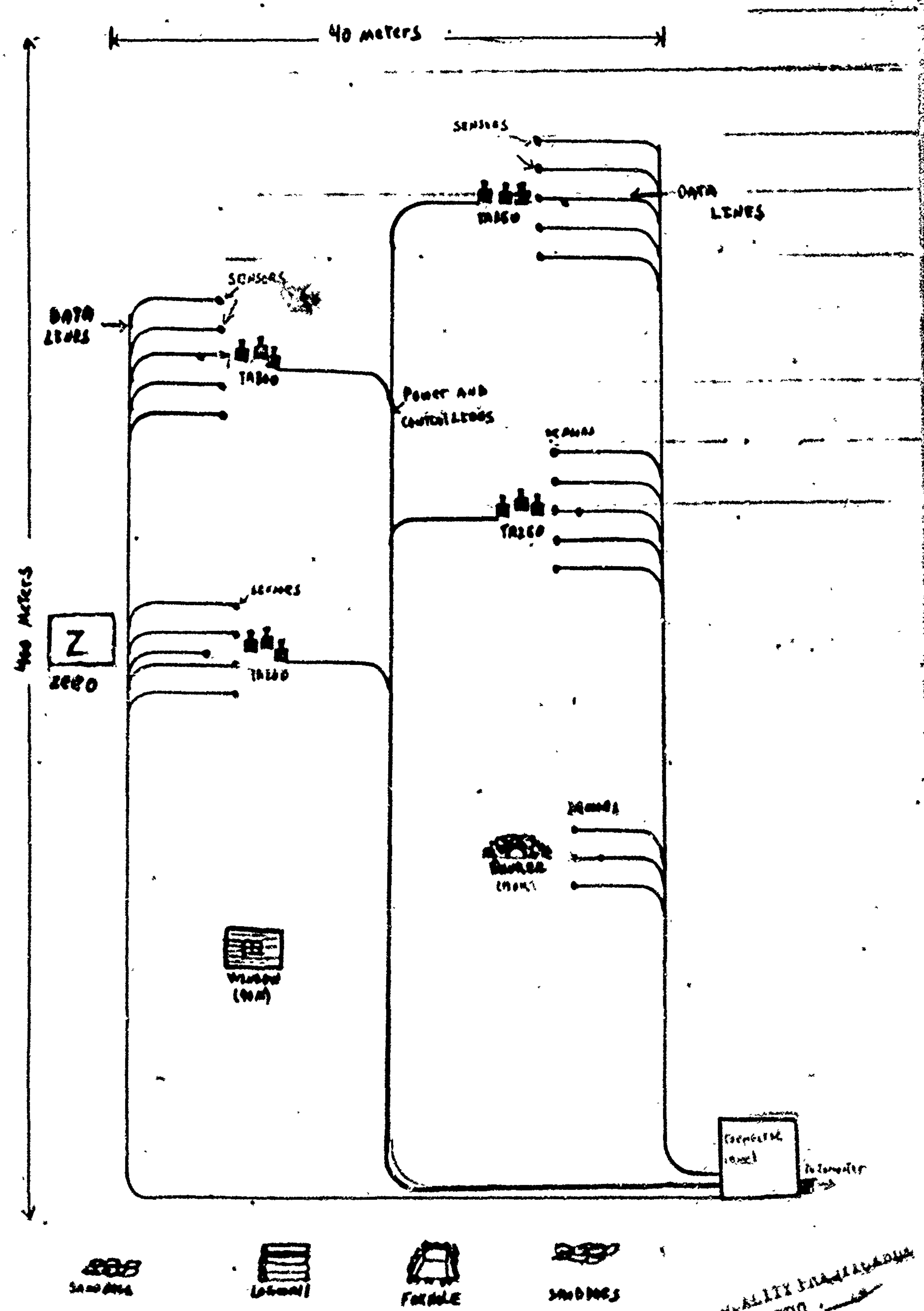

Figure II-1

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Subtests 1 through 4 are designed to evaluate performance of the hand-held grenade launchers. Subtest 5 is designed to evaluate the automatic grenade launcher.

Each group of test soldiers should participate in each subtest as outlined in paragraph 4.b.(8)., Scheduling. After all groups of grenadiers complete the test, a final group of non-grenadiers, Infantry riflemen, should participate in each subtest.

| Subtest | Firing Station | Target Type | Range | Exposure Time |
|---|---|---|---|---|
| 1 | 1-zero prone | Single E Silhouette(1) | 200 | - |
| 2 | 2-standing kneeling | Window Bunker | 90 130 | - - |
| 3 | 1-prone | E Silhouette (3) | 200 250 | 20 Sec 20 Sec |
| 4 | Foxhole | E Silhouette (3) | 300 350 | 20 Sec 20 Sec |

Major Test Parameters

Table II-1

Subtest 1. Weapon Zeroing Task

Each test soldier will zero his weapons using four practice rounds. The zeroing procedure will be accomplished from firing point 1 and the 200-meter target should be raised to provide an aiming point. The miss distance of each round will be measured so that all first, second, third, and fourth rounds may be averaged and compared across weapons to determine ease of obtaining weapon zero. This measure ma be indicative of possible interface problems. The firing point should be equipped with sand bags to provide firing support. The 200-meter target should be clearly visible with good background contrast.

Subtest 2. Combat in Cities

This subtest attempts to permit the grenadier to duplicate the specific tasks that would be required if he were engaged in combat in cities. Firing point 2 will be used and consists of an upright wall or log which can be used as a shield by the grenadier. Two fixed targets at 90 and 130 meters will be used. Target 90 will consist of a single wall with an open window frame. Hits (s[illegible] through the window) will be recorded manually by round and added to the data base in the computer. Near misses which hit the wall may be estimated. Estimation is facilitated by having a grid painted on the wall.

Target 130 will consist of a low mound (2 to 3 feet high) with a small window (1x2 feet) at its base. Miss distance from the bunker will be measured automatically and hits will be recorded manually as above.

Each gunner will fire 4 rounds at each target. All four rounds will be expended at Target 90 before Target 130 is engaged. The first two rounds in each case will be fired from the standing supported position; the last two rounds will be fired from the kneeling supported position. The primary measures are average miss distance and hit probability, as described for single purpose grenade launchers in paragraph 4 of this report. In the case of the open window target, a special hit probability should be computed. The measure will consist of the number of rounds passing through the window divided by the total rounds fired. All other tests use the definition found in the reference mentioned above.

Subtest 3. Troops in Open From Prone Firing Position

Firing point 1 will be used to engage simulated troops in the open at two ranges, 200 and 250 meters. Each target array will consist of 3 targets and near miss distance will be measured from the center of the base of the middle target.

Four rounds will be fired at each target beginning with Target 250. All four rounds will be fired at one target before switching to the next target.

The exposure time is to be limited to 20 seconds in order to obtain from this test a realistic rate of fire. This measure, time between trigger pulls, will provide the basis for determining whether an inherent difference in the rate of expenditure of rounds exists and will form the data base for the sustainability analysis.

Subtest 4. Troops in Open From Foxhole Position

This subtest is accomplished with the grenadier firing from a prepared foxhole at simulated troops in the open at extreme ranges. Two target arrays of three targets each are used. The targets at 300 meters will be engaged initially with four rounds. The grenadier will then switch to the group of targets at 350 meters for the last four rounds.

Subtest 5. Grenade Launcher in the Indirect Fire Role

This subtest will be used for the evaluation of the automatic grenade launcher or the hand-held launcher in the indirect fire role.

Figure II-2 shows the range configuration. Two scoring areas are to be used which contain three personnel, E-type silhouettes. A single firing position is used for the automatic launcher; four adjacent kneeling positions are required for the hand-held launchers. These kneeling positions may be set up just behind firing points 1-4, thus utilizing the round count systems at each of those positions. Simply relocate the sensor from its normal position directly in front of each firing position to a position directly in front of the respective kneeling position.

The target areas are the 250 and 350 areas described above and shown on the figure. At the command of the squad leader, the grenade launcher crew or the grenadiers will fire a salvo at the near area, adjust to fire a salvo at the far array, and readjust to fire a third salvo at the near area. This sequence will be repeated 4 times for each set of firers. The target control scenario is adjusted to permit measurement of time to shift fire.

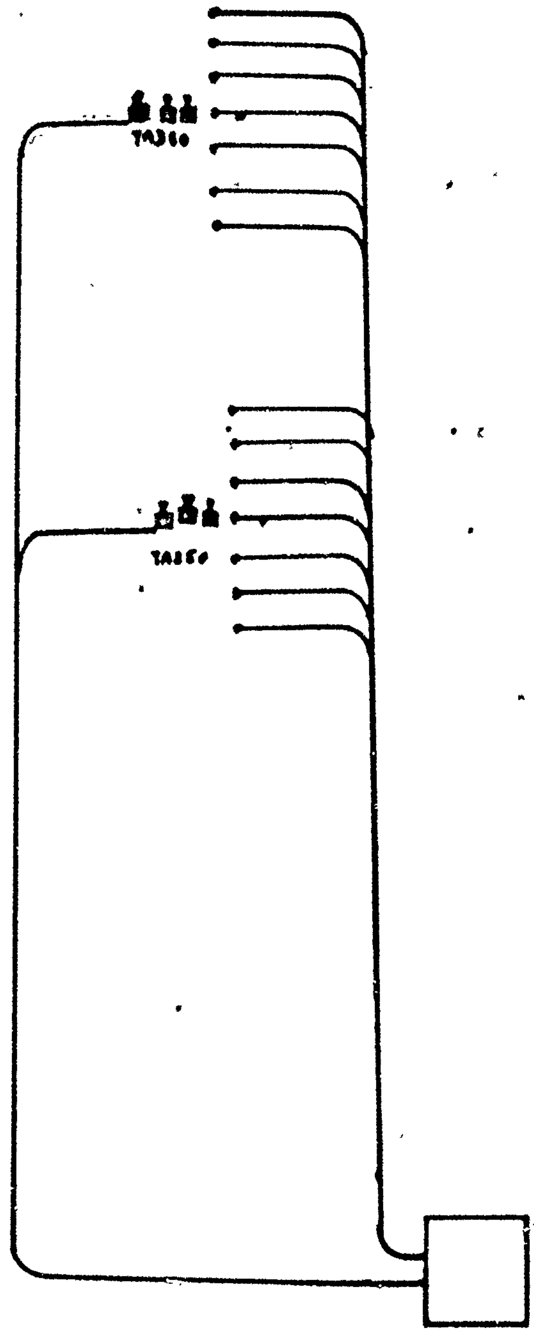


Figure II-2

APPENDIX III. EVALUATION PROCEDURE

The initial analysis is based on accuracy measures followed by sustainability measures (if different rounds are used) and by responsiveness measures. As described under Objective 3, the accuracy measures are the primary measures of effectiveness.

The general procedure is to run a two-way classification analysis of variance on the accuracy measure of effectiveness (Figure III-1) for all subtests combined. The weapon-x-subtest interaction is the first place for the evaluator to direct his attention. If this interaction is significant as indicated by the associated F-value, the source of this significance has to be determined. Only then can this significance be placed in proper perspective.

If the F-value for interaction is significant the cell means should be graphed for the competing weapon systems. The type of interaction existing is determined by comparing the resultant graph with the graphs in Figure III-1. The categories for the differing types of interactions that might exist are labeled, for convenience, as Type 1, Type 2, and Type 3. The graph of the items under test may not initially appear to be either one of the three types of interactions, but a relabeling of subtest, if necessary, will reveal that the interaction can be closely approximated by one of the three types.

A Type 3 interaction is considered to exist when the F-value for interaction is significant, but the F-value for weapons is not. This implies that the weapon systems do not perform consistently over the subtest, but that no one weapon performs well enough to be classified as overall superior. If one weapon excells in subtest that are believed more representative of the combat role played by the grenade launcher then this weapon should be selected. However, if no such determination can be made the MOE representative of sustainability and responsiveness have to be analyzed.

A Type 2 interaction is considered to exist when the F-value for interaction is significant, as well as the F-value for weapons. This type of interaction has to be distinguished from a Type 1 which satisfies the same criteria. The distinction is made by examination of the graph. A Type 2 implies that some crossover effects exist when the cell means are connected with lines, i.e., one weapon may be equal to or inferior in one subtest and superior in another subtest. The fact that one weapon is overall superior distinguishes a Type 2 interaction from a Type 3. If the subtests in which the overall superior weapon falls short are considered more critical than the other subtest then effort should be directed toward sustainability and responsiveness. The problem of inferiority in critical subtest could exist and will have to be dealt with when it occurs. Other MOE can be analyzed, but the problem does not go away and it might be necessary to run the particular subtest over if the problem is believed to be sufficiently important.

A Type 1 interaction exists when one weapon maintains overall superiority and the significant interaction is merely caused by cell mean graphs that are non-parallel. If this type of interaction exists then the superior weapon will be selected with no other analysis required other than informational analysis.

Given that interaction is not significant the F-value associated with weapons is examined. If this F-value is significant then select the superior weapon and restrict further analysis to informational analysis. If the weapon F-value is not significant then go to the sustainability analysis and later to responsiveness analysis if no decision can be made based on sustainability.

The analysis procedure for sustainability, if applicable, parallels the analysis of accuracy measures. The responsiveness measures are likewise treated by the same procedure, but a 25-percent improvement (or some other specified level of improvement) is sought before any decisions are to be made. If the specified percent of improvement is not found, the standard weapon or test item is retained.

In addition to the procedure above, performance curves should be drawn by range for each weapon system. These curves provide insights that might not be evident from a rigid numerical analysis procedure. They also provide the basis for informational analysis and aid in designing future test of similar items.

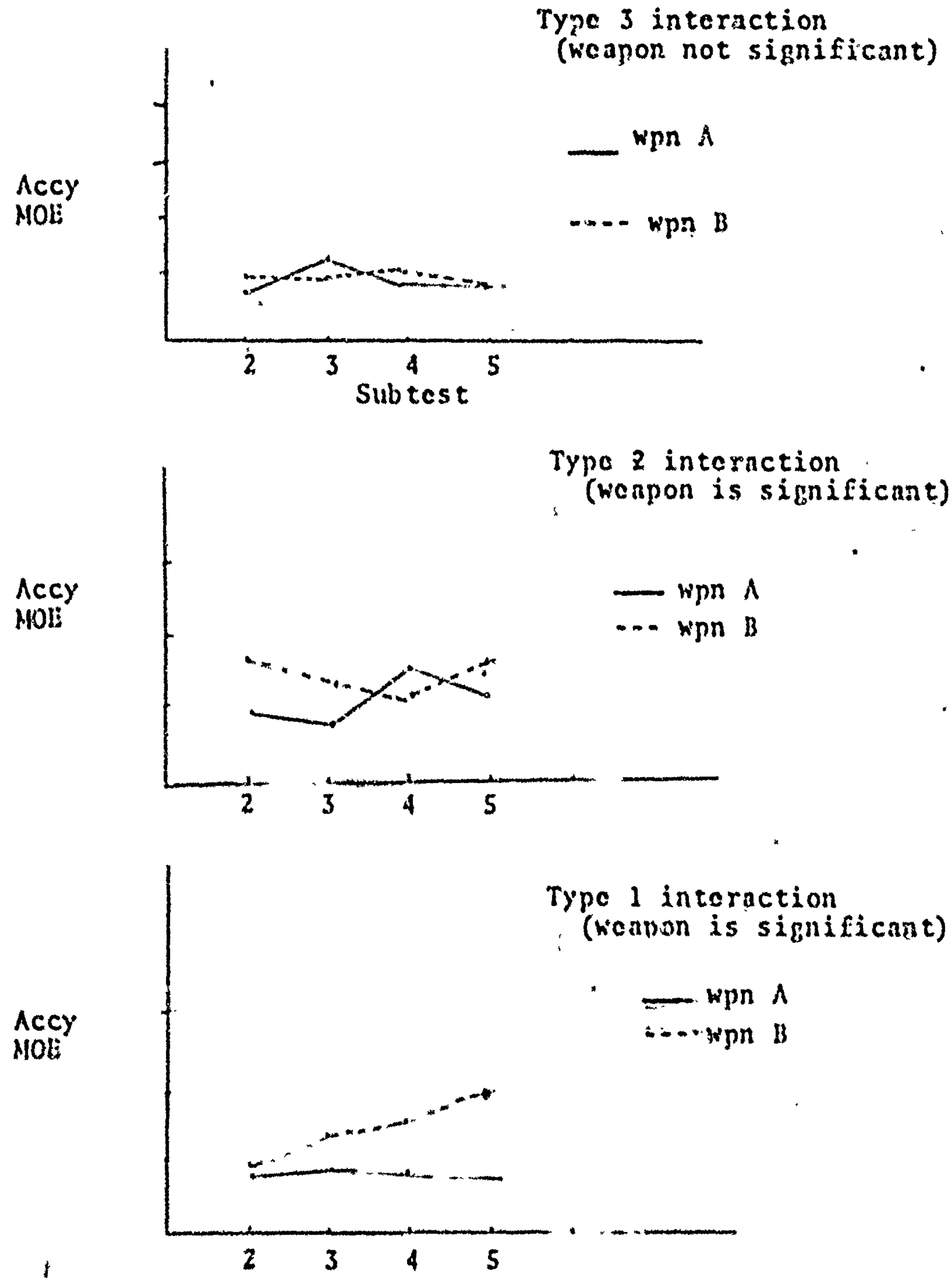

Type 3 interaction
(weapon not significant)
wpn A
wpn B
Accy
MOE
2
3
4
5
Subtest
Type 2 interaction
(weapon is significant)
Accy
MOE
wpn A
wpn B
2
3
4
5
Type 1 interaction
(weapon is significant)
wpn A
wpn B
Accy
MOE
2
3
4
5

Figure III-1

## APPENDIX IV. IMPACT SCORING SYSTEM EVALUATION TECHNICAL MEMORANDUM

1. Introduction. Two technical memoranda have been written which are related to grenade launcher test instrumentation. The first, A Proposed Time Difference System For Scoring Near Misses, was written in support of the development of a small arms miss distance indicator. However, the mathematics for the small arms system are identical to those used in the impact scoring system. This technical memorandum appears in Volume I, Appendix VII.

The second technical memorandum was produced to document the scoring capability of the impact scoring system. The TM appears in the following section beginning on the next page.

This test was conducted in May 1971 on Farnsworth Range. Approximately 16 simulated grenades were used as noise sources. During a later test, actual practice grenades were used and identical results in terms of accuracy of the scoring system were achieved.

2. Accuracy Test. The purpose of this test was to determine the accuracy of an impact scoring system which uses time of arrival of a sound wave at known points to determine point of impact. The array of microphones used is shown below. Three microphones in a straight line representing positions on the X-axis were used. The coordinates in feet for each microphone are shown.

Impact Area

| (0,0) | (30,0) | (60,0) |
|---|---|---|
| Mic 1 | Mic 2 | Mic 3 |

The impact of practice grenades was simulated using small explosives (cherry bomb firecrackers) to generate the noise signal.

In order to make the calculations of impact points, the speed of sound in air at the time of impact must be known or estimated. For this study, these estimates were made in the following manner: detonations were set off so that sound travels the distance between the microphones. For example, for detonations at point A, the time of travel

Mic 1      Mic 2      Mic 3

|←—— 30' A ——→|←—— B 30' ——→|

between microphones 2 and 3 was measured. Similarly, from detonation point B, the time to travel the known distance between microphones 1 and 2 was measured. Table IV-1 shows the 11 speeds of sound measures used for input in the calculations.

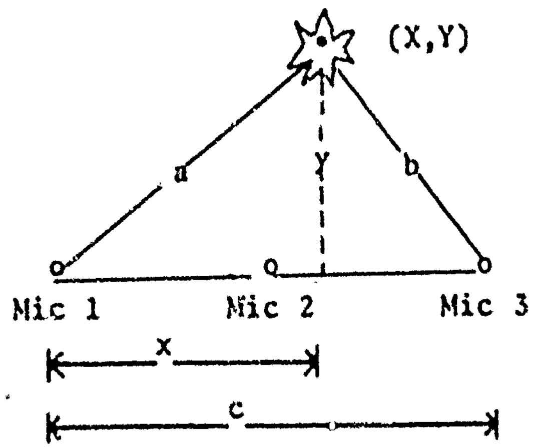
| Position 1 to 2 | Position 2 to 3 |
|---|---|
| 1135.96 | 1133.66 |
| 1138.23 | 1137.21 |
| 1142.22 | 1135.38 |
| 1137.52 | 1136.03 |
| 1141.49 | 1138.40 |
| | 1135.69 |

| | |
|---|---|
| Mean | 1137.44 |
| Variance | .00011 |
| Max Value | 1142.22 |
| Min Value | 1133.66 |

TABLE OF MEASURED SPEED OF SOUND VALUES
(Feet Per Second)

Table IV-1

To check the accuracy of the scoring system, the point of detonation of each test "round" was measured as shown in Table IV-2. With the distance C known (60 feet between Mic 1 and Mic 3) the measured values for a and b were inserted into the formula for the Law of Cosines.




Formula for the Law of Cosines:

$$\frac{b^2 + c^2 - a^2}{2bc} = \text{Cos } A$$

$$Y = b \text{ Sin } A$$

$$X = \sqrt{a^2 - Y^2}$$

Table IV-2

Table IV-2 shows the measured values (a,b) and the resulting X, Y coordinates.

Using mathematical techniques associated with time difference measurement methodology; the X, Y coordinate for each

| MANUALLY MEASURED | | TDMDI MEASURED SPEED OF SOUND = 1137.44 | | |
|---|---|---|---|---|
| X (ft.) | Y (ft.) | X (ft.) | Y (ft.) | d (ft.) |
| 26.43 | 53.14 | 26.36 | 52.54 | .6078 |
| 31.12 | 33.81 | 31.13 | 33.62 | .1903 |
| 30.81 | 6.78 | 30.92 | 6.92 | .1780 |
| 21.87 | 46.27 | 21.95 | 45.99 | .2912 |
| 19.07 | 39.82 | 18.97 | 39.64 | .2059 |
| 19.47 | 29.49 | 19.26 | 29.95 | .5057 |
| 18.06 | 11.75 | 18.09 | 11.96 | .2121 |
| 17.84 | 6.34 | 17.80 | 6.24 | .1071 |
| 38.03 | 30.02 | 38.23 | 30.09 | .2119 |
| 39.08 | 15.78 | 39.16 | 15.68 | .1281 |
| 39.46 | 13.54 | 39.35 | 13.32 | .2460 |
| 39.37 | 7.07 | 39.31 | 7.69 | .6229 |
| 39.47 | 4.17 | 39.49 | 3.92 | .2508 |
| | | | | 13 \| 3.7584 |
| | | | | .2891 |

MANUALLY MEASURED VS HDI CALCULATED IMPACT

COORDINATES USING MEAN SPEED OF SOUND VALUE

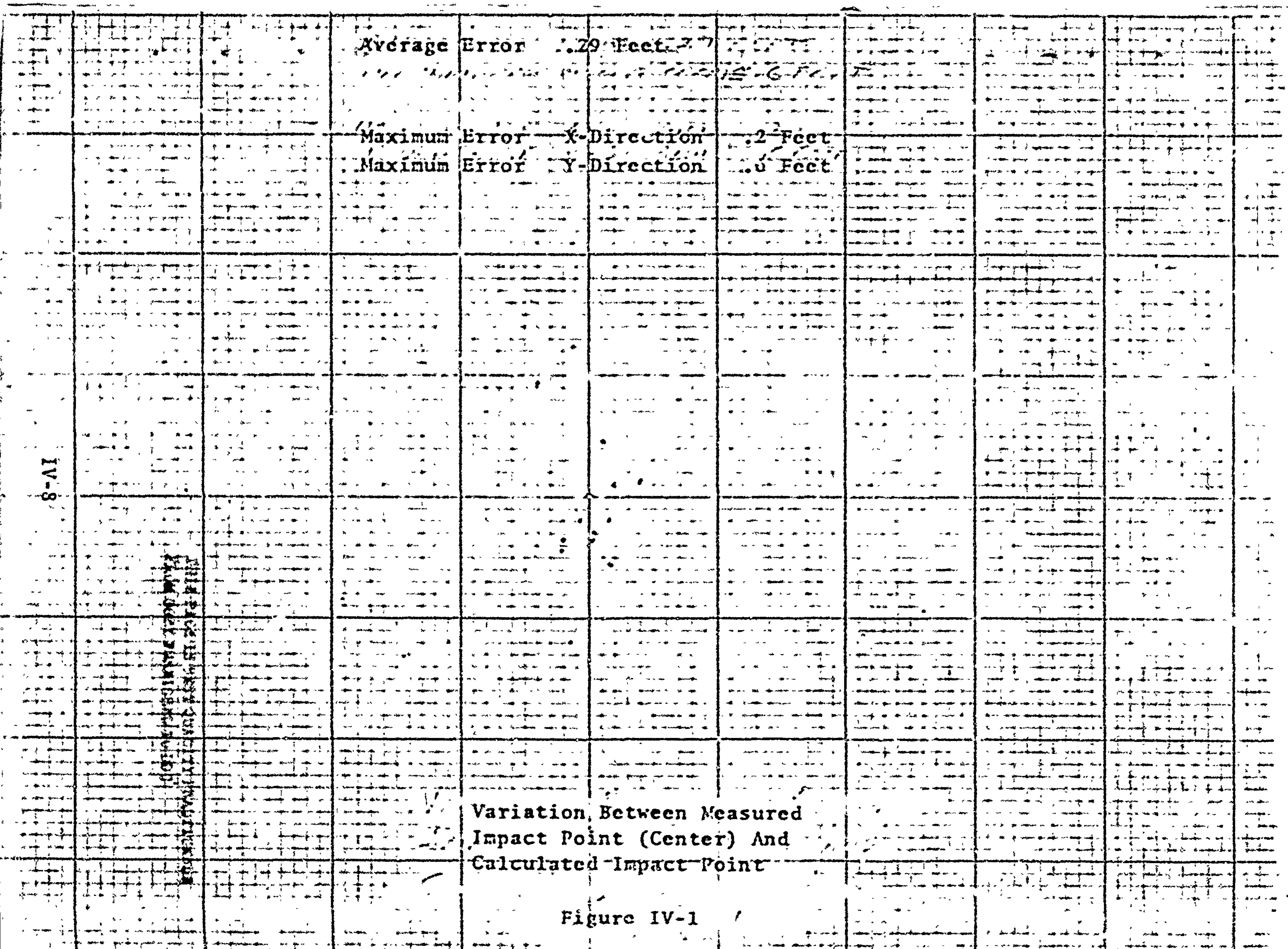
Table IV-3

| TDMDI MEASURED SPEED OF SOUND = 1142.22 | | | TDMDI MEASURED SPEED OF SOUND = 1133.66 | | |
|---|---|---|---|---|---|
| X(ft.) | Y(ft.) | d(ft.) | X(ft.) | Y(ft.) | d(ft.) |
| 26.36 | 52.29 | .8529 | 26.37 | 52.75 | .3945 |
| 31.17 | 33.43 | .3833 | 31.17 | 33.77 | .0640 |
| 30.93 | 6.79 | .1204 | 30.92 | 7.02 | .2640 |
| 21.94 | 45.75 | .5247 | 21.95 | 46.18 | .1204 |
| 18.96 | 39.40 | .4342 | 18.97 | 39.83 | .1004 |
| 19.25 | 29.74 | .3330 | 19.26 | 30.12 | .6496 |
| 18.03 | 11.71 | .0447 | 18.10 | 12.16 | .4119 |
| 17.79 | 5.84 | .5025 | 17.81 | 6.54 | .2023 |
| 38.24 | 29.89 | .2470 | 38.23 | 30.25 | .3047 |
| 39.17 | 15.49 | .3036 | 39.15 | 15.83 | .0860 |
| 39.36 | 13.12 | .4317 | 39.34 | 13.48 | .1341 |
| 39.33 | 7.43 | .3622 | 39.30 | 7.89 | .8130 |
| 39.51 | 3.46 | .7111 | 39.47 | 4.24 | .0700 |
| | | 13 \| 5.2513 | | | 13 \| 3.7489 |
| | | .4039 | | | .2883 |

MANUALLY MEASURED VS MDI CALCULATED COORDINATES

USING EXTREME VALUES FOR SPEED OF SOUND

Table IV-4




Variation Between Measured Impact Point (Center) And Calculated Impact Point

Figure IV-1