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SOME HUMAN FACTORS CONSIDERATIONS IN THE DESIGN OF A COMBAT RIFLE

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This report presents views on some of the human factors considerations in the design of a modern combat rifle.

It draws upon testing and the experience of people at the US Army Human Engineering Laboratory who have been involved in small arms research and developement during the last 25 years.

A figure is included showing a hypothetical combat rifle configuration embodying desirable human factors characteristics.

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INTRODUCTION

The intent of this report is to present some views on the characteristics of a combat rifle for the modern battlefield.

It draws upon the experience of people at the US Army Human Engineering Laboratory who have been involved in small arms research and development over the last 25 years. While considerable hard data exists, there are areas of incomplete data which must rely on the judgment of those people at HEL who have been working on small arms.

The design of an effective combat rifle is, of course, the product of compromise. The major issues of compromise are:

a. Aiming technique. Should a combat rifle be designed primarily for slow, aimed fire or for quickly pointed fire in which the sights are, at best, used as guides without concern for precision?

b. Mode of fire. Should the configuration of a combat rifle be optimized for semiautomatic or fully automatic fire? Imbedded in the concept of fully automatic fire is the question of the need for a burst-limiting device and a muzzle-brake compensator.

c. Caliber. Should the rifle be designed around a large, high energy bullet with its characteristically high recoil impulse, or a small, high velocity, low recoil impulse cartridge that may be somewhat less lethal round for round, but permits the soldier to carry more rounds of ammunition.

The resolution of these highly interrelated issues is not an extremely difficult task once the operational priorities have been identified, since there are ample data to guide the developer in designing a firearm suitable for any particular use. Perhaps the greatest difficulty lies in agreeing on operational priorities within the development community.

DISCUSSION

In addressing the issue of aiming technique, data from past wars have been reviewed.

A survey (1) of Army and Marine combatants from the European and Pacific theatres of World War II and from the Korean War indicates that 80 percent of the rifle fire was pointed rather than aimed when the targets were visible enemy soldiers.

The following quotation from the referenced report nicely summarizes the soldiers' rationale for employing a pointing rather than aiming technique on the battlefield:

"'Aimed fire' implies the use of the rifle sight and, in fact, is the type of fire done on the target range. The major characteristic of this fire is that it is relatively accurate. So accurate, in fact, that improvements in hit probability become very difficult to achieve. Fire at point or visible personnel targets in actual combat, however, is in most cases quite different. Personnel targets, as contrasted with those encountered on the firing range, are often only briefly exposed and fleeting. Even more radically different is the combat stress and, hence, time pressure on the firer. The act of firing, unless he is in an elaborate field fortification, increases his personal vulnerability. In addition, he does not know if the target will be visible for a half second or five seconds. In essence, he is faced with a complicated decision which involves minimizing his own vulnerability and maximizing his probability of hitting the target--his solution is quite simple. In the majority of cases where the infantryman has a visible personnel target, he simply points the rifle and fires--not taking time to use the sights."

US military experience in Viet Nam corroborates the findings from World War II and Korea; and a future war in Europe should be characterized by an extremely high density of fire from tanks, artillery, and both vehicle- and ground-mounted small arms. The result will be an environment where neither shooter nor target will be willing to risk exposure long enough to deliver aimed fire or be a target for very long.

The concluding point to be made concerning pointed- versus aimed-fire is that a weapon whose configuration has been optimized for effective rapid unaimed fire can be readily made to deliver accurate slow aimed fire, but the converse is not necessarily true. This is because such things as a sighting rib, or the optimum butt-stock length are not required for accurate aimed fire but are of vital importance for rapid fire effectiveness. Furthermore, in slow, aimed fire the shooter has more time to compensate for minor configurational shortcomings of the weapons.

In a [illegible] HEL study (2) a slightly modified M1 carbine demonstrated a four-fold increase in hit probability over that of the M16 rifle when used in the quick fire mode. This accuracy was entirely due to the M1's superior configuration, yet it is doubtful that the M1's aimed-fire accuracy is appreciably different from the M16's. If there are differences in aimed fire accuracy, they are probably due to the charactistics of the cartridge rather than the rifle's configuration.

The issue of semiautomatic versus fully automatic fire is a bit more complicated than aimed versus unaimed fire. We know that if a weapon is fired in a short burst of two or three rounds per trigger pull, and the burst dispersion approximates the aiming error, the shooter's hit probability per trigger pull will be greater than firing a single round (6). The difficulty here is that the total number of targets the shooter can hit for a basic load of ammunition may not necessarily be higher.

There are two methods that are usually used to control dispersion. The first is a combination of controlling the rate of fire and the overturning moment of the weapon (determined by the distance the recoil axis is above the shoulder contact point on the buttstock). The second method is by incorporating a muzzle brake compensator into the muzzle of the weapon to divert the exiting propellant gases counter to the direction of the normal recoil induced motion. The maximum achievable compensation through diversion of propellant is effectively limited by the ratio of propellant weight to projectile weight. The closer this ratio is to 1:1, the greater the potential compensation. Effective burst dispersion control by the second means also takes into account the rate of fire and the overturning moment.

The problem with these two methods is that the weapon must be tuned to deliver a dispersion approximately equal to the typical aiming error of 3 to 5 mils. This dispersion is difficult to achieve in a moderate impulse weapon firing a 5.56mm cartridge (1.16 lb/sec impulse) and may not be possible in a 7.62 caliber (high impulse) weapon. Tests conducted with the M14 Rifle (4) (7.62mm) yielded 120-240 mil displacements between the first and third rounds in a typical three-round burst.

Furthermore, the dispersion is very sensitive to firing position and individual differences in shooter physiques. Even though a low impulse weapon (≈.6 to .7 lb/sec) could be fitted with a muzzle brake compensator that would deliver the dispersions required for effective burst fire under some conditions, it would be inferior in others. A weapon, tuned to a good dispersion pattern when firing from the prone position, will very likely have a considerably different dispersion in the standing position or when a different size shooter fires from the same position. In a test conducted by HEL (5), an M16 rifle, equipped with an adjustable muzzle brake compensator, did not increase effectiveness for all shooters in all firing positions. On the average there was at least a 10 mil increase in mean extreme spread when going from the kneeling, supported-firing position to offhand. A compensator tuned as a compromise of these two firing positions is no better than the standard M16 rifle.

Whichever method is used, tests (3) have shown that shooters are capable of obtaining a two- to three-round burst by trigger control 75 percent of the time with no burst control mechanism built into the rifle.

A soldier can fire four three-round bursts in about the same amount of time as he can fire 12 semiautomatic rounds, so that rate of fire does not play a significant role in the choice.

Considering the problems with controlling dispersion in fully automatic fire, and with the casualties that can be produced by each mode of fire with a basic load of ammunition, the semiautomatic mode is the most effective mode of fire. Weapon configuration should be optimized for semiautomatic fire. If the services feel that a fully automatic capability to deliver suppressive fire when ambushed is necessary, then this capability should be created after the weapon has been properly designed for the most accurate semiautomatic shooting.

The issue of caliber is straightforward from the standpoint of human engineering. The small, high velocity calibers like the 5.56mm family have a significantly lower recoil impulse and are, therefore, more controllable when they are fired rapidly in both the semiautomatic and the fully automatic modes. The smaller caliber rifle tends to be lighter, so many more rounds of ammunition may be carried for a given total soldier load.

The following ranges of engagement during World War II and the Korean War are cited from reference 1.

a. The mean maximum range to a visible personnel target in both the day defense and offense was about 375 meters on those occasions (20 percent of the time) when the sights were used to deliver aimed fire. Three quarters of the time the respondents judged these targets to be within 550 meters.

b. The mean minimum range to a visible personnel target in both day offense and defense when the rifle was aimed was 50 meters.

c. The maximum range to a similar target in day defense and offense when the shooter pointed the rifle (80 percent of the time) was 160 meters. The 75 percent mark occurred at 250 meters.

The interaction of range, perceived vulnerability of the shooter, and firing technique in the above data is unclear. It may well be that the reason soldiers pointed their weapons quickly at the closer ranges was because they felt that they were more vulnerable when the enemy was closer, and 80 percent of the time the enemy was indeed closer. The data may actually be more a survey of combat ranges of engagement (80 percent of the engagements occurred at 250 meters or less) rather than a survey of firing technique.

The ranges of engagements and the frequency of engagements that occur at these ranges do not dictate the use of the heavier 7.62 cartridge for the infantry rifle. These ranges are within the capability of a 5.56 cartridge, such as the SS 109, to be satisfactorily effective.

CONCLUSIONS

The conclusion that should be drawn from the existing data is that it is important that a combat rifle be configured to optimize its performance for quick, unaimed (pointed) semiautomatic fire. It should be designed around a cartridge that results in a low recoil impulse (less than 1.2 lb/sec).

Figure 1 shows the general configuration of a weapon designed for rapid, pointed firing. This weapon is capable of accurate, slow, aimed fire when required, and could be equipped with a fully automatic firing mode that could be about as effective as the M16 rifle.

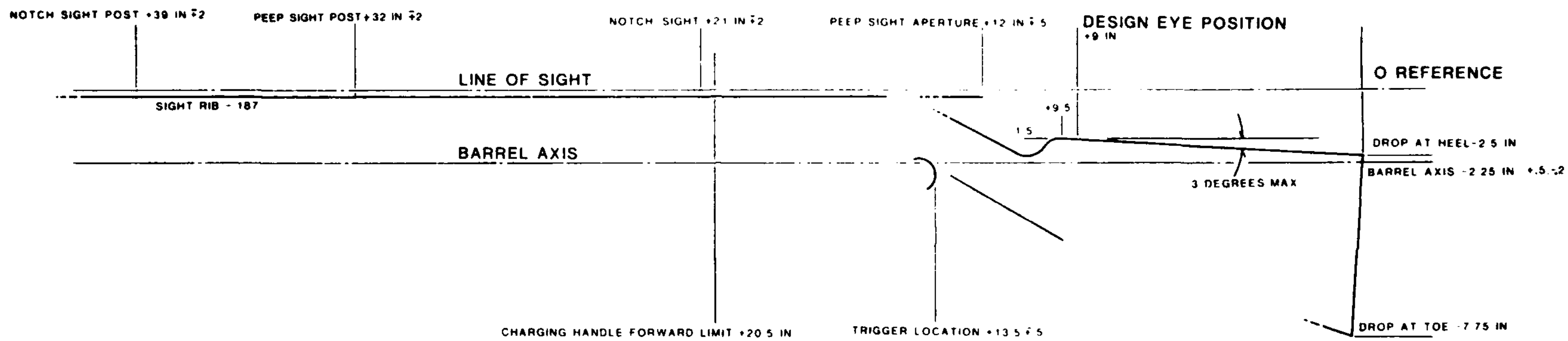

Figure 1. General configuration of a weapon designed for rapid, pointed firing.

In addition to conforming to Figure 1, the rifle should be designed around the following guidelines.

Sights

1. The rifle should have iron sights rather than a reflex collimator sight, telescope, ring or other type sight. Reflex collimator sights, while at first glance appear to offer significant benefits, have never been demonstrated to be better than iron sights, especially in adverse environmental conditions. Their greater cost and inferior ruggedness render these sights undesirable. The fact is, except for long-range sniper fire where a telescope has an advantage, iron sights are still the best choice for a combat rifle.

2. The sight radius should be about 18 inches. While it is true that a longer sight radius is more accurate for aimed fire, the gain is small.

3. A notched rear sight is slightly superior to a peep sight for pointed fire and under low light levels. A notch sight should be as accurate as a peep sight for aimed fire during more usual daylight conditions.

4. The weapon should be designed with a sighting rib between the front and rear sights that is parallel with the rifle's bore and as close to the gunner's line of sight as possible without interfering with his sight picture when delivering aimed fire. A rib design proven to be effective in an HEL test (6) was 3/8-inch wide with 12 equally spaced 1/32-inch wide grooves running longitudinally its full length. The rib extended almost the entire distance of the sight radius. The top edges of the weapon should be parallel with the bore, uncluttered, and free of protrusions.

5. For low levels of ambient light, such as dusk, dawn, or that provided by artillery illumination rounds, the sighting rib should include a white line down the middle (1/32-inch wide) for at least the front half of the rib's length. The first choice for a rear sight should be a notch. An 8mm diameter aperture with a 10mm outside diameter to the metal surround would be nearly as good. The same rear notch can be used during full daylight conditions. An 8mm aperture would be larger than desirable for daylight accuracy so an additional 2.5mm aperture should be provided.

6. The sights should be capable of being zeroed in azimuth and elevation, but there is probably nothing to be gained by providing a rapid windage and range adjustment.

7. The weapon should be designed so that the shooter can place his eye 3 inches (+1/2 inch) behind the rear aperture for peep sights and 12 inches (+2 inches) behind the rear sight for notch sights.

8. Optical sights intended to help determine the range to the target by means of the stadiametric ranging principle have been proven to be no more accurate than a shooter estimating range.

Muzzle Devices

1. Muzzle brake devices that compensate for muzzle climb are of little value for most combat rifles because they must be tuned to a particular shooter and firing position. Muzzle brakes that reduce recoil become more effective as the ratio of projectile weight to propellant weight approaches 1:1. Therefore, a high impulse system such as the M14 has little to gain since the projectile to propellant weight ratio is approximately 3:1. The 5.56mm, M193 cartridge has a ratio of 2:1. An experimental muzzle brake was designed that deflected the propellant gases somewhat more than 90 degrees resulting in an impulse reduction in the M16 rifle from 1.16 lb/sec to 0.77 lb/sec. However, since 1.16 lb/sec is rather low to begin with, the benefits gained here probably contribute little to weapon effectiveness.

2. Noise suppressors (often incorrectly called silencers) are capable of substantial reductions of muzzle noise but have no effect on the "crack" sound caused by the passage of a supersonic projectile through the air. Experiments and combat experience have shown that, although the enemy knows he has been shot at because of the "crack," he cannot tell where the projectile came from because the usual "thump" of the firing noise is absent. The enemy's tendency is to think that the shot came from a direction perpendicular to the shock wave of the projectile. Noise suppressors tend to reduce impulse somewhat and, except for the first round fired, are good flash hiders as well. Flash is sometimes present with the first round because the air in the noise suppressor is rich in oxygen that reacts with the hot, unburned propellant to form a flash. After the first shot, the suppressor fills with oxygen-starved gas, so there is no flash.

Weight and Center of Gravity

The weight of a combat rifle is not critical for portability or accuracy within a reasonable range of 6.5 and 8.5 pounds. The center of gravity can vary in position as well. A heavier, muzzle heavy weapon should be more stable in aiming and exhibit a lower recoil velocity with less of an overturning moment. Tests, however, have not shown this expected difference to result in increased hit probability.

Controls and Other Features

1. Controls such as the safety, fire-mode selector, magazine release, and charging handle should be designed so they are, to the highest degree possible, equally convenient for left- and right-handed shooters.

2. The chamber area of the receiver should be designed so that it is readily accessible for clearing jams and other stoppages.

3. The charging handle must be designed so that sufficient force can be applied to the bolt in both directions to quickly clear jams such as double feeds.

4. The charging handle should be temperature insulated.

5. The stock and receiver should be insulated so they will not burn the shooter's face, and there should be no sharp edges that could harm the shooter.

6. The foregrip should be designed so it does not heat up excessively during sustained, rapid fire. It should also be textured to insure a firm grip.

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