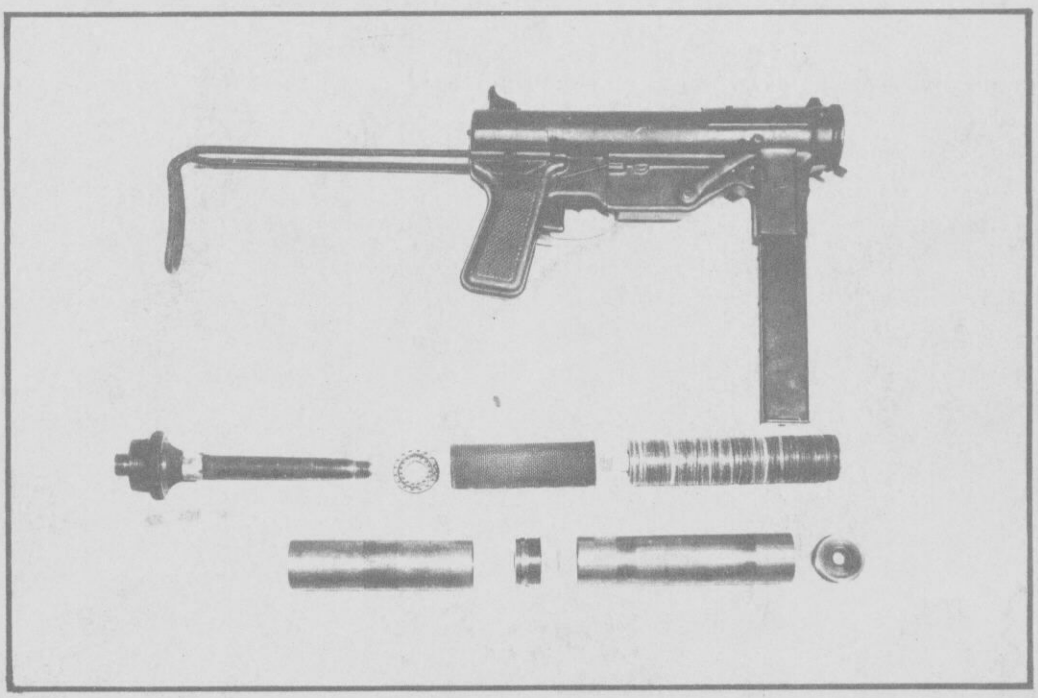
SILENCERS

Patterns and Principles

Vol. 2



FINAL REPORT

Phase III
Acoustic Study Program
(Silencers)

Alexandria Division
American Machine & Foundry Co.

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Introduction

The Alexandria Division of the American Machine & Foundry Company has been actively engaged in the study, design, fabrication, and testing of silent weapons for the past five (5) years.

Our facilities and the major portion of the programs carried out here, has been sponsored by your organization. The establishment of our laboratory was Phase I, in a series of programs for Acoustic Studies of silent weapons systems.

This initial phase consisted of building a laboratory with an acoustic sound room, instrumentation for noise level measurement, a fifty (50) foot range, and a trap for firing weapons up to .30 caliber in size.

Phase II of our Acoustic Study Program was to develop the best acoustical silencers for both the Gustaf 9mm Submachine Gun and the SMLE .303 Enfield Mark 5 Rifle. This work consisted of the review of the program reports carried out by Western Electric Company and the Armour Research Foundation.

After a one (1) year development program we were able to reduce the over-all noise level of both weapons by approximately 30 db's. The Final Report, submitted at the conclusion of this program, discusses in detail our approach to the problems, a step-by-step procedure to solve these problems, and the result of our testing programs.

Phase III of this Acoustic Study Program consisted basically of the development and fabrication of hardware items. All the basic data accumulated to date was utilized in the selection and modification of a wide variety of weapons.

An investigation was made of the problem areas that are inherent in the silencing of weapons, and the solution to these problems are described in the following report and have been incorporated into the modifide weapons.

The following report, therefore, represents the conclusion of Phase III of the Acoustic Study Programs, with out conclusion and recommendations for future development programs on specific weapons.

A. Background

Prior to our initiation into the development of silencers for small caliber weapons, several programs had already been carried out by the Western Electric Company Incorporated, and the Armour Research Foundation of the Illinois Institute of Technology.

Western Electric developed two (2) types of silencers, they are the "muzzle silencer" that attaches to the muzzle of a weapon, and a "barrel silencer" that encapsulates, or encircles, the barrel of a weapon. They also determined that the use of absorption material, such as screen rolls and washers used in these silencers, reduced the noise levels more effectively that the baffle type silencers. The screen roll and washers restrict the flow of the expanding high pressure, high temperature gasses, and presents more surface area of metal for cooling.

The three (3) weapons used by Western Electric in their work were the U.S. M-3, .45 caliber submachine gun, the Hi-Standard Model H.D., .22 caliber pistol, and the U.S. M1, .30 caliber carbine rifle. Using a muzzle and barrel silencer on the .22 and .45 caliber weapons, noise levels were reduced approximately 25 db's, but the velocity of the projectiles also dropped to 750 feet per second. The reduced velocities were due to over venting of the gasses into the barrel silencers.

The results obtained on the M-1 carbine was not as successful in that the velocity of the projectile was well over 1,100 feet per second and produced a sharp sonic crack. However, the muzzle silencer did distort the muzzle blast changing the frequency of the noise, with little or no reduction in the noise level.

Several years later the Armour Research Foundation was authorized to continue investigating silencers for small arms.

The first program consisted of the accumulation and testing of instrumentation for recording and measurement of the noise developed from firing a weapon. The noise was then mixed with various background noise to develop data under different ambient conditions. The data resulting from this program indicated that the high frequency noise developed is the primary noise to be considered for silencer design.

The second program consisted of rating the noise levels developed by silenced weapons with respect to indoor and outdoor ambient conditions. It was found that most silencers reduced the muzzle noise about 20 db's, however, the effect on the over-all noise generated by the weapon varied between 10 and 20 db's. This is obviously due to the noise developed in other areas of the weapon, such as chamber noise, barrel noise, and mechanical noise.

The Armour Research Foundation's work resulted in the silencing of two (2) rifles, and pertinent data that has been beneficial in the design of silent weapons.

B. **Purpose**

The purpose of this program is to apply all of the useful data developed on silenced weapons to date, and select a variety of weapons to be modified.

The weapons selected for this program consisted of 9mm submachine guns, both fixed barrel and telescoping bolt type, bolt action and semiautomatic high powered rifles, side arm revolvers, and semiautomatic pistols.

This program also included investigations into some of the inherent problems which effect the usefulness of a silent weapon. These problem areas are accuracy, malfunctioning, such as a runway gun or chambering problems, and excessive stripping of the bullet jacket.

With the solution of the above problem areas, and the application of the knowledge gained from the previous programs the selected weapons were silenced and tested in the laboratory and in the field.

C. **Weapons Selected**

The weapons chosen for silencing on this program were selected on the basis of their design, construction, availability and would they meet the specific requirements for silencing.

The specific requirements for silencing any weapon with bullet velocities over 1,100 feet per second are as follows:

1. To reduce the high speed of the bullet to approximately 1,000 feet per second, it is essential to bleed off the high pressure gasses as soon as possible. Therefore, access to the chamber area is necessary for drilling bleed holes just forward of the chamber.
2. To reduce the noise generated by the high temperature gasses escaping from the muzzle of the weapon, it is necessary to provide an expansion chamber to capture the gasses flowing through the bleed holes and to cool them. The weapon must have enough material to accept a threaded or brazed on bushing for installing a "barrel silencer," and a "muzzle silencer."
3. The additional weight of a silencer added to a weapon effects the functioning of that weapon and its accuracy. Any weapon selected to accept this additional weight without deflecting the barrel. The weapon should have a fixed barrel, that is, threaded into the receiver, held to the receiver by a threaded collar, or held on the receiver by a slide assembly.

With the above requirements as a guide, the following weapons were selected for this program and are listed by work assignments.

a. Assignment 1 — Two known standards compared
   1. Gustaf Model 45, 9mm SMG
   2. Sten Mark II, 9mm SMG
b. Assignment II — Other 9mm Submachine Guns
   1. Madsen Model 1946, 9mm SMG
   2. U.S. Model M-3, 9mm SMG
c. Assignment III — Telescoping Bolt Action
   1. Beretta Model 12, 9mm SMG
   2. Uzi, 9mm SMG
d. Assignment IV — High Powered Rifles
   1. Springfield Model 1903 A3, .30-06
   2. F.N. Model F.A.L., 7.62 mm
e. Assignment V — Side Arm Weapons
   1. Luger Model 08, 9mm
   2. Beretta Model 1937, 9mm (short .380)
f. Assignment VI — Data Need for Future Designs

Assignments

This section of the Final Report is divided into six (6) assignments, detailing the work accomplished on each group of weapons selected for silencing. These assignments are futher divided to cover each individual weapon. By subdividing each assignment, the information on any specific weapon may be removed from this report for updating technical files on any of the selected weapons.

Assignment 1 — **Two Known Standards Compared (Gustaf and Sten)**

The reason for selecting the Gustaf submachine gun was due to the fact that a majority of the work done in the past was done on this weapon.

The Gustaf is a high quality weapon that has been silenced very effectively, and has been produced in small quantities.

The Sten was selected because it is a relatively inexpensive weapon that has been available as a silenced submachine gun for many years, and is constructed similar to the Gustaf. This weapon will also give us the opportunity to make a comparison between two (2) 9mm submachine guns.

GUSTAF SUBMACHINE GUN

A. **Gustaf, Model 45, 9mm Submachine Gun** (Figure A-1)

In the development of a silencer for the Production Model Gustaf (Fig. A-1) many problems were created which were not anticipated. Some of these problems were alleviated but not fully corrected to satisfy the user, or from the standpoint of economic production.

The problem areas that required this weapon to be included in this program are as follows:

1. **Accuracy**

   What is the major contributor to the inaccuracy of a weapon after it is fitted with a silencer?

2. **Malfunctioning**

   Why does a silenced weapon malfunction more readily than a standard weapon?

Purpose: The purpose of this assignment was to investigate the problems associated with the Gustaf submachine gun, and to product engineer the silencer for economical production.

Procedure: Our approach to solving the problems associated with the Gustaf submachine gun was to start with a standard weapon, and work from the barrel out, doing one step at a time and testing each modification.

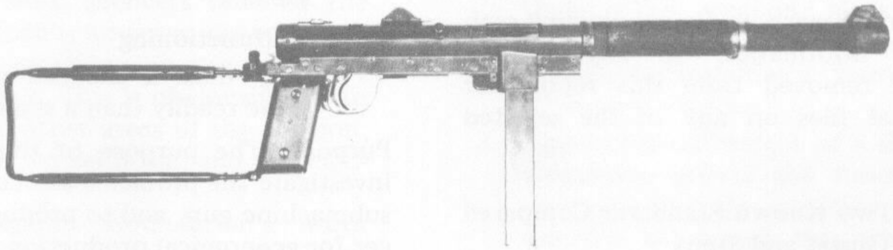
1. **Standard Weapon Test and Evaluation**

   The standard weapon was disassembled and all the component parts were dimensionally checked for misalignment, and for loose fits with mating parts that may cause inaccuracy. The weapon was then reassembled and checked for accuracy on a 40 foot range, using Candian ammunition with an average velocity of 1,300 feet per second. The weapon was disassembled, reassembled, and test fired for accuracy several times, each time checking for loose parts. We found no misalignment, or loose parts, after firing that would cause any inaccuracy. As shown in Fig. A-2, the following results were obtained, an average velocity of 1,300 feet per second, a bullet grouping of 1 inch, and a noise level of 155 db.

2. **Standard and Modified Barrel Evaluation**

   To fully understand what happens to the

Stock "Gustaf"



Production Model Silenced "Gustaf"

FIGURE A-1

accuracy of a silenced weapon, a comparison was made between various barrels and ammunition. It should be noted that when we talk about a modified barrel we mean a standard barrel that has six (6) .086 inch diameter and two (2) .093 inch diameter equally spaced holes drilled around the outside circumference of the barrel. These holes are drilled at an angle of 11° from the center line of the bore, and enter the bore of the barrel just forward of the chamber (see Fig. A-8). This is done to vent the high pressure gasses into an expansion chamber or "barrel silencer." We have found that these eight (8) holes bleed off sufficient gas pressure to reduce the velocity of the projectile to approximately 1,000 feet per second. For this test we used a standard barrel, a modified barrel with one (1) full turn of the rifling in 9.5 inches. We also fabricated a standard barrel and a modified barrel with one (1) full turn of the rifling in 7.45 inches (see Fig. A-3). Each of the above four (4) barrels were tested with commercial Remington ammunition (1,210 feet per second), Canadian ammunition (1,300 feet per second), Canadian underloaded ammunition (925 feet per second), and Remington underloaded ammunition (980 feet per second). As shown in Figure A-2 the best grouping with a standard barrel was with the Remington ammunition in both the standard velocity and the underloaded velocity. It can also be seen that the best grouping obtained was with a standard modified barrel using the Remington ammunition. Using the new barrel with the increased twist rate in both the standard barrel and a modified barrel showed promising results on the indoor 40 foot range, however, on the 100 yard range

GUSTAF ACCURACY TEST

Ammunition	Barrel & Twist	(1) Velocity ft/sec	(2) Rev/Sec	(3) 40' Indoor Group	100 meters Outdoor Group	Noise Level db
Canadian	Standard - 9.5	1300	1705	1"	13"	155
Remington	Standard - 9.5	1210	1528	3/4"	11"	153
Canadian Underload	Standard - 9.5	925	1168	1-3/8"	17"	154
Remington Underload	Standard - 9.5	980	1239	5/8"	15"	152
Canadian	Modified - 9.5	975	1232	3/4"	15	124
Remington	Modified - 9.5	935	1181	5/8"	14-1/2	124
Canadian	Standard - 7.45	1260	2030	7/8"	15"	-
Canadian	Modified - 7.45	1090	1852	7/8"	20"	-

NOTE:
1. Velocity and group is taken on an average of five (5) rounds.
2. Revolutions per second is a calculated figure.
3. No muzzle silencer can was used in any of the above modified barrel tests above.

FIGURE A - 2

Gustaf: (Fast Twist)

Muzzle Velocity	- 1350 fps		Canadian Ammunition
Twist	- 9.5 inches		

@ 1350 fps, 1 Rev/9.5"

$$\frac{1350 \times 12''}{9.5} = 1705 \text{ Rev/Sec.} \qquad \frac{1350 \times 12''}{7.45} = 2174 \text{ Rev/Sec.}$$

Muzzle Velocity - 1210 fps — Remington Ammunition

$$\frac{1210 \times 12''}{9.5} = 1530 \text{ Rev/Sec.} \qquad \frac{1210 \times 12''}{7.45} = 1946 \text{ Rev/Sec.}$$

Theory: Give silenced Canadian Ammunition same rpm as standard (commercial) 9mm ammunition. As we know the Gustaf modified is inaccurate @ 100 yards with Canadian Ammunition. It is believed that 1700 Rev/Sec is too fast for 9mm bullet due to over stabilization.

Twist Should Be:

$$\frac{950 \times 12''}{1530} = 7.45''$$

$$= \text{Twist } 7.5''$$

$$\frac{950 \times 12''}{7.45} = 1530 \text{ Rev/Sec.}$$

FIGURE A - 3

the bullet never hit the target, due in all probability to drift.

3. **Ammunition**

We know that the stripping of the bullet jacket contributes somewhat to the inaccuracy of the weapon, even though we have reduced the stripping to a point that is hardly noticeable on a captured round. It is also a known fact that the reducing velocity of the 117 grain bullet from 1,300 feet per second to 950 feet per second does upset the designed ballistic characteristics of the projectile. It is also known that the Canadian ammunition has a tendency to strip more in a modified weapon than does the Remington ammunition. This is due to the fact that the lead filling on the Canadian ammunition is recessed or concave where the Remington ammunition is flat and even with the base of the projectile. The concave recess allows the pressure to work from the inside towards the outside, applying pressure to expand the diameter of the projectile at its base, this in turn tends to extrude the metal into the pressure relief holes in the barrel causing bullet stripping.

4. **Barrel Deflection**

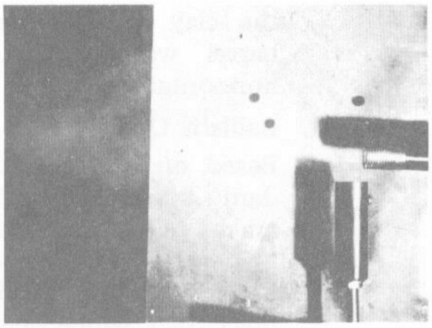
Our next area of interest, because of the varied results above, was to determine if these inaccuracies could be caused by the barrel deflecting either before or after the bullet left the muzzle of the weapon. Tests were made by mounting the weapon in a fixture, using an oscilloscope to trigger a camera to capture the event before and after the bullet left the barrel. Our first attempt was to photograph the barrel with a scale located behind it to check the photograph before and after the event, setting the time delay with the bullet in the barrel and down range. No deflection of the barrel was detected with this setup. We then decided to use a close-up lens to photograph the barrel with a time exposure. In this way, we would get a blurring of the photograph if the barrel moved (see Fig. A-4). Here again, there was no noticeable movement of the barrel. Our last attempt to measure deflection of the barrel, as shown in Fig. A-5, was to set some hard clay on the muzzle end of the barrel, locate a needle point .005 inches and .002 inches above the clay and fired the weapon. Any movement of the barrel would allow the needle point to make an impression in the clay. No noticeable movement of the barrel was detected either vertically or horizontally.

5. **Ballistic Upset**

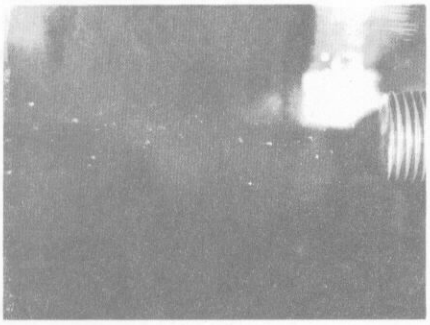
Based on all the above test with the standard barrels, modified barrels, different makes of ammunition with standard velocities and underloaded velocities, and the deflection investigations, we believe that the inaccuracy which occurs when using a modified barrel is primarily an upset in the designed ballistic characteristics of the projectile. It is true that the stripping, however slight, will affect the ballistic characteristics of the projectile, even though the stripping is symmetrically located around the base of the projectile, but it is also true that the reduced velocities and the reduced spin imparted to the projectile would obviously have a greater effect on the flight of the projectile. This is further evidenced by calculating under ideal conditions, the range and vertical drop of a 117 grain bullet at the standard velocity of 1,300 feet per second and 980 feet per second, which is 13 inches at 350 feet and 13 inches at 250 feet, respectively (see Figure A-6). It has been established that the dimensional tolerance used in the manufacture of the Canadian ammunition has been found to be rather loose as compared to the Remington. What we do not know is how accurate is the projectile in weight, balance and uniformity of the jacket, this is evidenced by the comparison between a modified Gustaf which fires a 12-3/4" group at 75 yards with muzzle silencer, and a standard Gustaf that fires a 9" group at 75 yards (see Figure A-10). At this point in determining what affects the accuracy of this weapon the most, it must be noted that all the work discussed above was done without a muzzle silencer, except where specified.

6. **Muzzle and Barrel Silencer**

Our next addition to the modified weapon to reduce the muzzle blast noise level, was the attachment of the muzzle silencer. Prior to testing, the weapon with the silencer attached to the muzzle of the barrel, we reviewed the drawings used to produce the silencers for the Production Model Gustaf (see Figure A-7). These drawings were reviewed for tolerence build up which could cause misalignment and in turn affect the



Gustaf
Bullet In Barrel



Gustaf
Bullet Down Range
Note: Power Residue

Barrel Deflection
Note: Clarity of Threads

FIGURE A-4

accuracy. It can be seen in Figure A-7 that with the present means of manufacturing, a maximum of .121" misalignment of the center line of the muzzle silencer housing with the center line of the bore of the barrel is possible. The tolerance used in fabricating the component parts that make up the silencer assembly are standard machine shop practices. These tolerances could be reduced to minimize the amount of the total misalignment, however, the cost of manufacturing would increase considerably. An assembly procedure has been established in the assembly and packing of the muzzle silencer that has helped to improve the accuracy of this weapon. This assembly method requires the use of an aligning rod, that is packaged with the silenced weapon. All the component parts of the silencer are assembled on the weapon loosely. With the front bushing, and screen washers for packing the muzzle silencer stacked on the aligning rod, the rod is then inserted through the muzzle end of the weapon. Starting at the chamber end, each component is tightened one at a time, working out to the front bushing. It has been established that weapons which are assembled in this manner will shoot a tighter group. Accuracy can also be improved by increasing the inside diameter of the screen washers that are used for packing the muzzle silencer. However, this would increase the annulus spacing between the outside diameter of the bullet and the inside diameter

Deflection Test, Setup

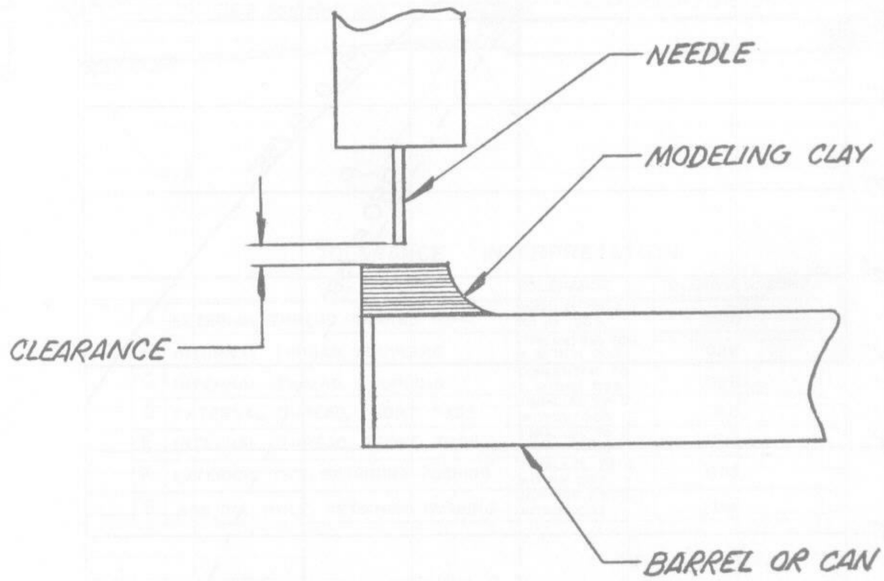


FIGURE A-5

of the screen washers. With this increase in the annulus spacing the noise level of the weapon also increases, we therefore, had to sacrifice some of the accuracy to achieve the noise reduction desired. To reduce the cost of producing a silenced weapon we have investigated the location, size and angle of the gas bleeder holes to be drilled near the chamber. On the Production Model Gustaf, four (4) rows of twelve (12) holes, 3/16 inches diameter, totaling forty eight (48) holes were drilled along the length of the barrel to reduce the velocity of the bullet to 1,000 feet per second. Because of the inconsistency of the velocity of the Canadian ammunition, many of the rounds would exceed 1,130 feet per second resulting in a sharp sonic crack. To reduce the velocity to about 1,000 feet per second and to assure ourselves that none of the rounds would exceed the speed of sound (1130 fps) we drilled four (4) holes, .125" in diameter just forward of the chamber at an angle of 10^{o}. This reduced the average velocity to 980 feet per second, and is used in the Production Model Gustaf today. Based on this approach we investigated the number, location, size, and angles that gas pressure relief holes should be drilled to accomplish the necessary reduction in velocity with a minimum amount of stripping. A series of tests were made to reduce shipping and to establish the optimum location, diameter, and angle of the pressure relief holes drilled in a barrel, see Figure A-8. These modified barrels were tested on a Gustaf weapon using a barrel silencer with a screen roll, a solid center bushing, and a muzzle silencer with the same outside diameter as the barrel silencer. Six (6) barrels were fabricated, each having eight (8) .086" diameter holes drilled in the barrel. These holes were drilled as shown in Figure A-8, at various angles and as a result entered the bore of the barrel at different distances from the chamber area. The smaller diameter holes were used to reduce the stripping of the bullet jacket and the number of holes were increased from six (6) to eight (8) to transfer the volume of gas required to reduce the velocity to approximately 1,000 feet per second. The drawings and data along side each barrel represent

Vertical Bullet Drop

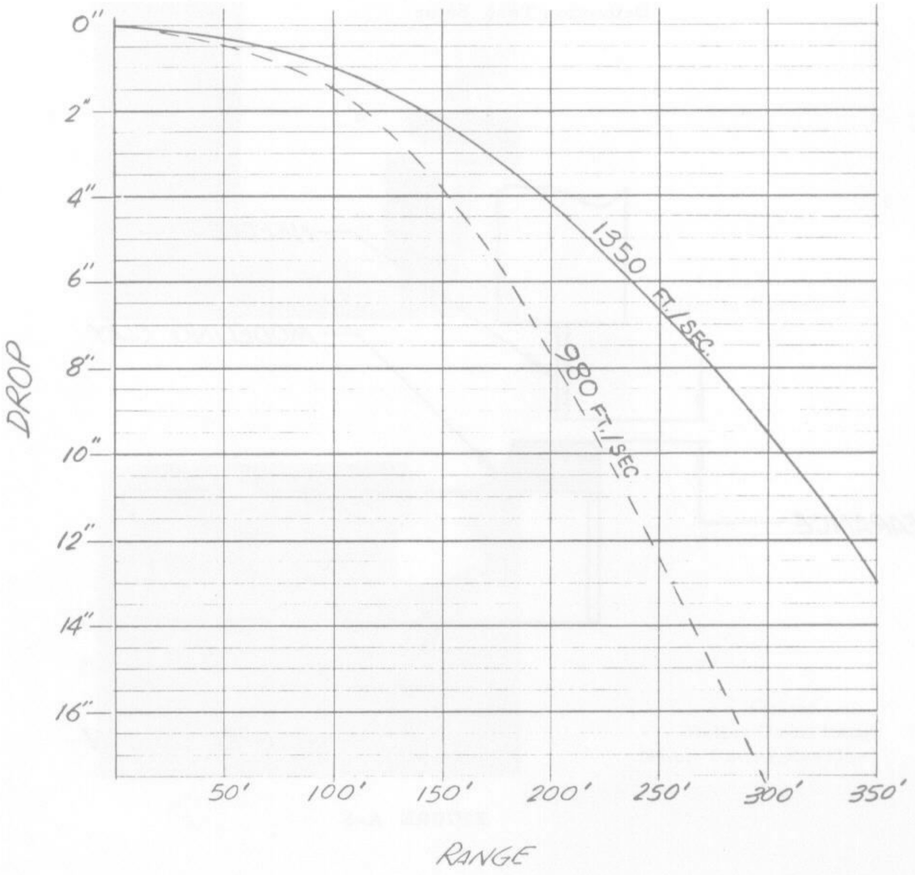


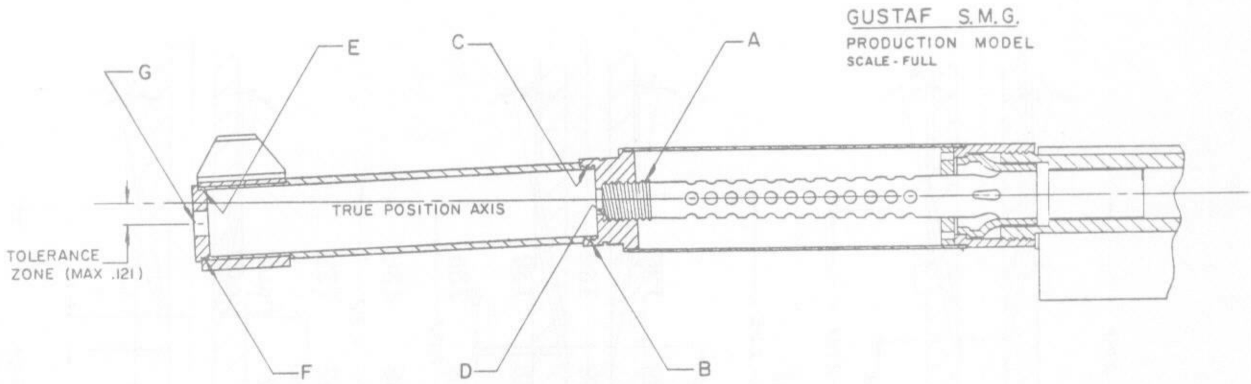
FIGURE A-6

the results of this investigation, with the best results obtained with barrel number six (6). This barrel resulted in an average velocity of 975 feet per second and a noise level of 123-125 db's, with a very slight trace of stripping of the bullet jacket. Using the number six (6) barrel, the new barrel silencer and muzzle silencer of the same diameter was added to the weapon and a series of tests were run to determine what combination of packing would yield the lowest noise level. The results of these tests are shown in Figure A-9, barrel number six (6) yielded the best results with no screen roll in the barrel silencer.

7. **Malfunction**

In the silenced Gustaf Submachine Gun there are two (2) types of malfunctioning. The first malfunction on this weapon was a runaway gun. That is, after the first round was fired the weapon would very often fire a complete magazine or several rounds; the operator would have no control of the number of rounds fired. The other cause for malfunctioning of this weapon was caused by the stripping of the bullet jacket; small chips of metal would collect in the chamber area and would interfere with chambering of the next round.

a. **Runaway Gun** — The Gustaf submachine gun is a blowback operated weapon with a fixed firing pin, that is, a portion of the energy of a fired round is imparted to the bolt of the weapon driving it rearward against a recoil spring with sufficient force to carry the bolt past the sear, allowing the sear to engage the bolt on its return forward motion. When pulling the trigger the sear disengages from the bolt allowing the bolt to be driven forward by the compressed recoil spring. The bolt moves forward picking up a round from the magazine and chambers the round in the chamber and fires, when the chambered round shoulders at the bottom of the chamber. When the



TOLERANCE INTERPRETATION

		TOLERANCE	TOLERANCE ZONE
A	EXTERNAL THREAD, BARREL	PARALLEL TO ℄ WITHIN 003	.028
B	INTERNAL THREAD, COUPLING	CONCENTRIC TO ℄ WITHIN 003	.028
C	INTERNAL THREAD, COUPLING	CONCENTRIC TO ℄ WITHIN 003	.026
D	EXTERNAL THREAD, FRONT TUBE	PARALLEL TO ℄ WITHIN 003	.026
E	INTERNAL THREAD, FRONT TUBE	PARALLEL TO ℄ WITHIN 003	.004
F	EXTERNAL TH'D, RETAINING BUSHING	PARALLEL TO ℄ WITHIN 003	.003
G	405 DIA HOLE, RETAINING BUSHING	LOCATION & SIZE WITHIN 003	.006

FIGURE A-7

weapon is modified the gas pressure is reduced by the bleed holes in the barrel. Therefore, the energy that drives the bolt rearward, is insufficient to drive the bolt back far enough to engage the sear, resulting in a runaway gun. Some weapons can be corrected by cutting off 1-1/2 to 2 coils from the recoil spring, but this should only be done when a new spring can not be made or purchased.

b. **Chambering Problems** — The chambering problems were overcome by the elimination of the stripping of the bullet jacket. At first the excess chips collected in the chamber caused premature firing which resulted in ruptured cartridge cases. It is, therefore, recommended that the firing of single rounds when checking a modified weapon for stripping should be adhered to until the stripping of the bullet jacket has been eliminated or minimized.

B. **Results**

The results of the above tests, evaluations, and modifications are as follows:

1. **Standard Weapon**

The standard Gustaf 9mm submachine gun is a high quality well constructed weapon which has all the requirements for the addition of a silencer. We have found no deflection of the barrel or loosening of parts that would interfere with the accuracy of the weapon, which as shown in Figure A-10, fires a 9 inch group at 75 yards and a 13 inch group at 100 yards, using Canadian ammunition.

2. **Modified Barrel**

Our experiments in the location, size, and angle of the gas pressure relief holes resulted as shown in Barrel No. 6, Fig. A-8, using eight (8) holes drilled as shown, reduces the velocity of the bullet to approximately 980 feet per second with a very minor indication of stripping the bullet jacket. With this approach to reducing the velocity of the bullet, only the gas pressure relief holes at the chamber are needed, doing away with forty eight (48) 3/16" diameter holes drilled along the length of the barrel. After the pressure relief holes are drilled on a standard barrel, only the muzzle has to be threaded to

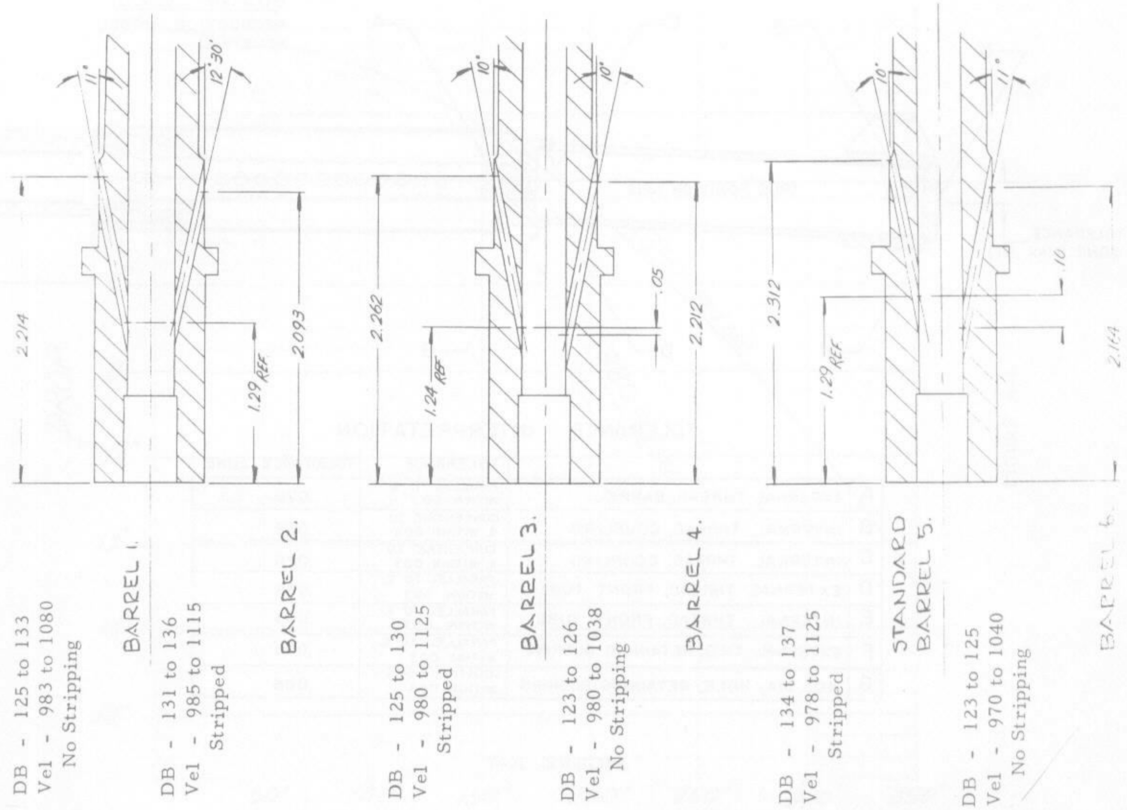


FIGURE A-8

accept the center bushing.

3. **Barrel Silencer**
   The results shown in Figure A-9, eliminates the need for a stainless steel screen roll which weighs 9 ounces and the stainless steel baffel plate, and accomplishes the same reduction in noise level of about 126-127 db's as the Production Model Gustaf.

4. **Muzzle Silencer and Center Bushing**
   The use of the same size tubing to make both the barrel and muzzle silencer gives the weapon a more uniform appearance and also assist in eliminating the screen roll in the barrel silencer, in that it increases the volume into which the high pressure gasses can be vented into through the vent holes in the center bushing.

5. **Accuracy**
   The effects of a silencer on the accuracy of this weapon, as shown in Figure A-10, is a 12-3/4" group at 225 feet and is not bad when compared with an underloaded round through a standard weapon which is a 15" grouping at 300 feet. Based on the accuracy tests run throughout this program, it is evident that the reduced velocities effect the accuracy of the bullet more then any other modification. It is also our opinion that because this is a submachine gun, the possibilities of aiming the weapon at a target and firing a single shot to hit that target, is not

MUZZLE AND BARREL SILENCER TEST

Test No.	Barrel No.	Packed Muzzle Silencer	Packed/Unpacked Barrel Silencer	No. Holes in Center Bushing	Velocity	Noise Level
1	6	Screen Washers	Screen Roll	None	990	128
2	6	Screen Washers	No Screen Roll	None	1028	126
3	6	Screen Washers	Screen Roll	4	1048	129
4	6	Screen Washers	No Screen Roll	4	983	126
5	6	Screen Washers	Screen Roll	8	1028	126
6	6	Screen Washers	No Screen Roll	8	1008	132

Stand barrel modified with six (6) holes; four (4) .090" diameter and two (2) .125" diameter, @ 10^{o} angle (Barrel No. 6, Figure A-9). Muzzle and barrel silencer same outside diameter.

FIGURE A - 9

Experimental Model

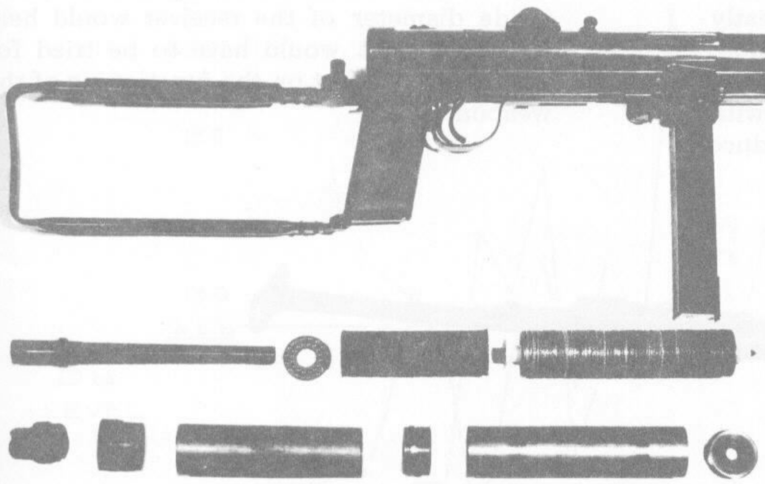
Name: Submachine Gun
Make: Carl Gustaf Model 1945
Description Unmodified: Standard
Operation: Blowback, full automatic
Size: Length 32" Width 8" Thick 2 - 1/2"
Weight: 8 lbs. w/o magazine
Other: Stock extended - no magazine

Type:
Caliber 9mm Parabellum
Description Modified: Silenced
Operation: Blowback, full automatic
Size: L - 38 - 1/2", W - 8", Thick - 2 - 1/2"
Weight: 10 lbs. 14 oz.
Other: Stock Extended - no magazine

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	1280 fps		Ave - 967 E. V. - 105	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards	-		-	
b) 10 yards	1"		-	
c) 15 yards	2"		2-3/4"	
d) 25 yards	4"		4-1/4"	
e) 50 yards	6-1/2"		9-3/8"	
f) 75 yards	9"		12-3/4"	
g) 100 yards	15"			
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards				
3; Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	90 yards		75 yards	
b) Range of 6" Vertical Drop	70 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	155 db		124 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE A - 10



Experimental Model

FIGURE A-11

what the basic weapon was designed for.

6. **Malfunction**
   When modifying a weapon of this type any change in the operating pressures will upset the designed characteristics of the weapon. The malfunctioning of the weapon can only be corrected by redesigning those components which are affected.

C. **Conclusions**

Reviewing the results of all the work done to date on the Gustaf submachine gun, we feel that the silent weapon produced for this program incorporates all of the best features resulting from these programs.

This weapon, as shown in Figure A-11, is capable of firing over 10,000 rounds of ammunition through its silencer with no increase in its noise level of 127 db, and can be refurbished by a simple cleaning process. It is eleven (11) ounces lighter in weight, and would be more economical to manufacture than the present Production Model Gustaf. The decrease in the accuracy of this weapon is mainly caused by an upset of the ballistics due to the reduced velocities. The increased barrel twist, to increase the spin rate of the projectile, did not help the accuracy at all and would not help without redesigning the projectile for a more stable flight at the lower velocities.

It was also found that the use of an asbestos wrapping around the barrel silencer would help protect the operator from burning his hands, but is not essential if only a few rounds are to be fired, or if the operator is careful.

The use of attachments to the chamber area of this weapon to help reduce the blowback noise is a hindrance to the operation of the weapon and to the operator. It also can not be attached to the weapon without obstructing the line of sight and would affect the accuracy which was one of the problem areas and the main objective of selecting this weapon for evaluation.

The Gustaf submachine gun in its final configuration resulting from this program using the Canadian ammunition, and being operated as a submachine is a very effective weapon.

D. **Recommendations**

After evaluating the results of this program and the amount of work that has been done on the Gustaf, there are only two (2) areas that may be considered for future investigation, they are the packing materials and the reduction of some of the metallic noise.

1. **Muzzle Silencer Packing**
   Some effort should be made to reduce the weight of the material used in the packing of the muzzle silencer and is possible, to reduce the noise level to below 127 db. In some instances, packing arrangements using a few rubber washers or other elastometers have reduced noise levels below 127 db's, but also have effected the accuracy and deteriorate rapidly due to the heat developed. Work in this area may help to reduce the uneven weight distribution of the weapon and may result in lower noise levels.

2. **Metallic Noise Reduction**
   Some work has been done in this area, such as the use of bumper pads, plastic bolts, and sears, but the high impacts involved in the operation of the weapon are too great. Any

reduction in metallic noise by the replacement of component parts would greatly increase the production cost of the weapon. However, there has been some recent improvements in the coating of metal with teflon that ought to be tried to help reduce the metallic clatter. Coating the bolt and inside diameter of the receiver would help somewhat, but would have to be tried for wear and its effect on the functioning of the weapon.

Stock Sten

Modified Sten Mk II-S, Unknown Origin

STEN SUBMACHINE GUN

B. **Sten, Mark II, 9mm Submachine Gun** (Figure B-1)

The Sten Mark II submachine gun was used in this program for two (2) reasons: first, this weapon has been in production since 1940, it is inexpensive and available, second, this weapon, the Sten Mark II-S (Figure B-1), has been silenced, as shown in The World's Submachine Guns Volume I publication. The Sten Mark II-S was also made available to us for comparison to other 9mm submachine guns.

Prior to discussing the work done on the Sten Mark II, we would like to discuss the silenced Sten Mark II-S so as not to confuse any of the data developed on the standard weapon used on this program.

1. **Sten Mark II-S**

The Sten Mark II-S, as received, was inspected and tested as a comparison to the Production Model Gustaf. The following are the results of this comparison. Both the Sten and the Gustaf barrels were modified by drilling four (4) rows of twelve (12) holes

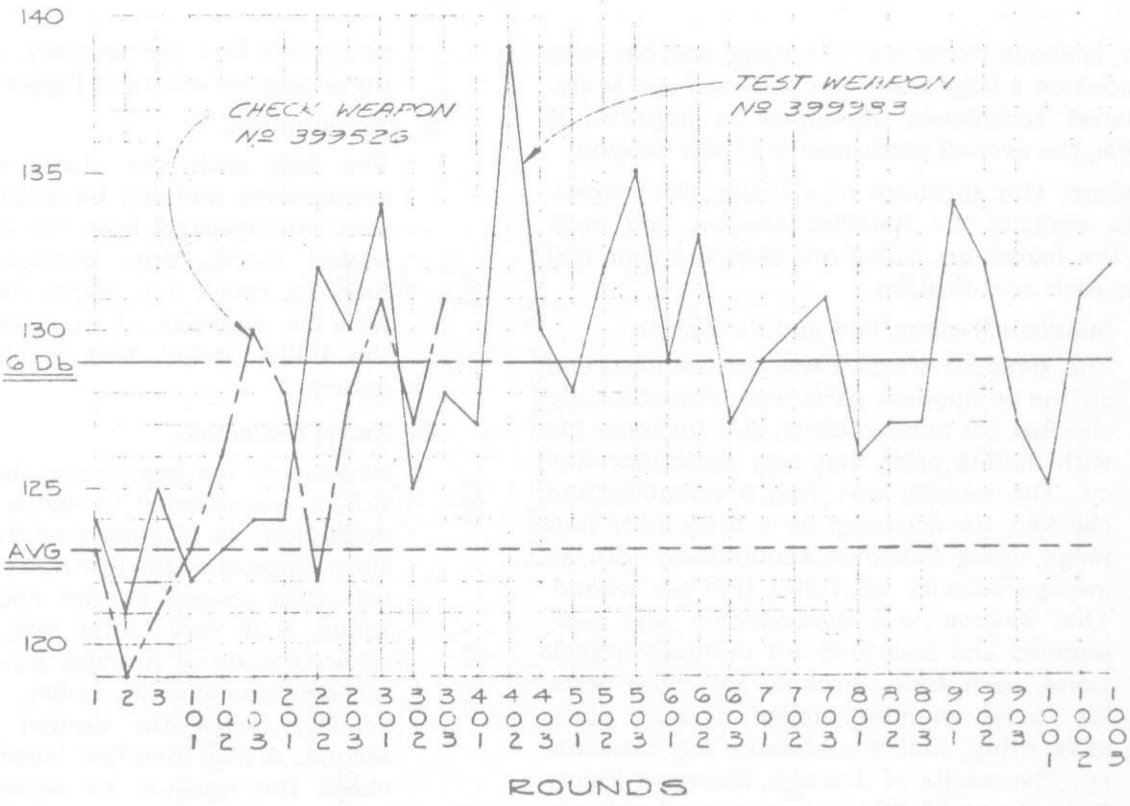


FIGURE B-2

longitudinally along the length of the barrel, ninety (90) degrees to the axis of the bore of the barrel for a total of forty eight (48) holes. The diameter of the holes in the Sten barrel are 1/4 inch in diameter, as compared to the 3/16 inch diameter holes in the Gustaf. It should be noted that an additional four (4) holes were drilled at an angle towards the chamber in the Production Model Gustaf barrel to keep the velocity of the Canadian ammunition below sonic speeds. The velocity of the Canadian ammunition from the Sten was inconsistant, in that several rounds went sonic. This test also proved another fact, in that the diameter and number of holes drilled in the barrel reduces the velocity of the projectile to a certain point, but not sufficiently, to keep all the rounds below sonic speeds. It was also found that the Sten weapon had a modified light recoil spring to prevent a runaway gun. The use of the lighter recoil spring was further evidenced by the fact that the magazine could not be loaded to its full capacity of thirty five (35) rounds. The recoil spring did not have enough force to overcome the pressure on the rounds applied by the magazine spring and to chamber a round in the chamber. The number of rounds had to be reduced to twenty four (24), maximum. This problem was overcome on the Production Model Gustaf by redesigning the recoil spring. A noise level reading was taken on the Sten of 131 db, as compared to the 127 db obtained on the Gustaf. A life test was then performed on the Sten silencer and, between 100 and 200 rounds, the noise level increased and became very erratic, as shown in Figure B-2. The life test, ran on the Gustaf, did not show a rise of 6 db over the 127 db in 10,000 rounds. In comparison, the silenced Sten had some features that do not compare with the silenced Gustaf, but it has been very successful for its intended purpose during World War II.

Purpose: The purpose of selecting the Sten Mark II, 9mm submachine gun for silencing was that this weapon has been widely used since 1940 and has been silenced by many. The Mark II-S, as tested above, is about World War II vintage and has been produced on a large scale. Our endeavor was to use the latest techniques developed to improve, if possible, the over-all performance of this weapon.

Procedure: Our approach to silencing this weapon was to evaluate the standard weapon, and work from the barrel out, doing one step at a time and testing each modification.

1. **Standard Weapon Test and Evaluation**
   The standard weapon was disassembled and all the component parts were dimensionally checked for misalignment, and for loose fits with mating parts that may cause inaccuracy. The weapon was then reassembled and checked for accuracy on a forty (40) foot range, using Canadian ammunition with an average velocity of 1,300 feet per second. The weapon was disassembled and reassembled and test fired for accuracy several times, each time checking for loose parts. We found no misalignment or loose parts, after firing, that would cause any inaccuracy. The results of this test, shown in Figure B-3, averaged 1,280 feet per second, velocity 1-1/8 inch bullet grouping, and 155 db noise level.

2. **Standard and Modified Barrel Evaluation**
   Because of the similarity between the Gustaf and Sten barrels, and the method of attaching the barrels to the receiver, the extensive testing which was performed on the Gustaf was conclusive enough to realize that repeating these tests on another weapon of the same type would not yield any different results. Here again, when we talk about a modified barrel, we mean a standard barrel that has six (6) .086 inch diameter and two (2) .093 inch diameter equally spaced holes drilled at an angle of 11^{o} from the center line of the bore, and enter the bore of the barrel just forward of the chamber. This is done to vent the high pressure gasses into an expansion chamber, or "barrel silencer." We have found that these eight (8) holes bleed off sufficient gas pressure to reduce the velocity of the projectile to approximately 1,000 feet per second. Sufficient tests were performed on the Sten with a standard barrel and a modified barrel to substantiate the previous results obtained on the Gustaf. Each of these barrels were tested with Canadian ammunition (1,300 feet per second) and Canadian underloaded ammunition (980 feet per second). The results of these tests are shown in Figure B-3.

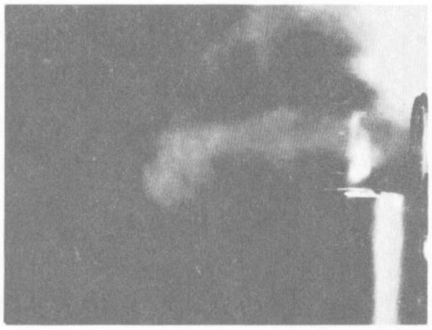
3. **Ammunition**
   The test with the standard commercial ammunition and the Canadian ammunition were not repeated, however, we did capture several rounds fired through the silenced Sten to check for bullet stripping. There were no evidence of excessive stripping of the bullet jacket that would cause inaccuracy.

4. **Barrel Deflection**
   Because of the inaccuracy, shown in Figure B-3, it was decided to check the barrel for deflection, we also checked the bore dimensions because of the low 800 feet per second velocities shown in the above tests. We found that this barrel was worn, which allowed some of the high pressure gasses to escape around the bullet, reducing the velocity below the desired 980 feet per second. A new modified barrel was made to check the weapon for accuracy, velocity, and noise level. As shown in Figure B-3, the new modified barrel averaged a 1-7/8 inch group at 40 feet, velocity at 1003 feet per second, and the noise level 124 db. This barrel was then used to check for barrel deflection. Tests were made by mounting the weapon in a fixture, an oscilloscope was used to trigger a camera to capture the event, before and after the bullet left the barrel. Our first attempt was to photograph the barrel with a scale located behind to check the photograph before and after the event, setting the time delay with the bullet in the barrel and down range. No deflection of the barrel was detected with this setup. We then decided to use a close-up lens to photograph the barrel with a time exposure. In this way, we would get a blurring of the photograph if the barrel moved (see Fig. B-4). Here again, there was no noticeable movement of the barrel. Our last attempt to measure deflection of the barrel, as shown in Figure B-5, was to set some hard clay on the muzzle end of the barrel, locate a needle point .005" and .002" above the clay and fired the weapon. Any movement of the barrel would allow the needle point to make an impression in the clay. No noticeable movement of the barrel was detected either vertically or horizontally.

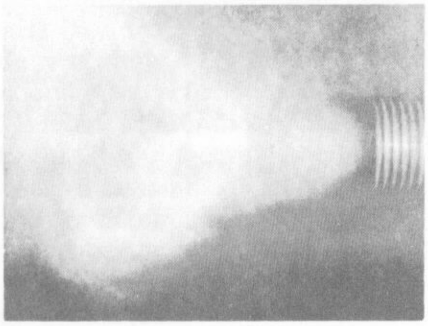
STEN ACCURACY AND SOUND TEST
40 FT. & 330 FT. RANGE

Ammunition	Barrel	Velocity	40' Group	db Level	330' Group
Canadian	Stock	1280	1-1/8"	155	9"
Canadian Underload	Stock	980	1-1/2"	155	16"
Canadian	Modified First Barrel	800	2"	155 w/o silencer	12-3/4"
Candian	New Modified Barrel	1003	1-7/8"	124	

FIGURE B - 3



Sten
Bullet in Barrel
Note: Strobe light lower right



Sten
Bullet Down Range

Barrel Deflection
Note: Clarity of Threads

FIGURE B-4

5. **Ballistic Upset**

From all the previous tests; we have concluded that the prime reason for the inaccuracy of the modified weapons studied on previous programs, and on this program, is the reduced velocity of the projectile. This is evidenced by the tests performed with underloaded ammunition in the standard weapon. It is also true that the stripping of the bullet jacket adds to the inaccuracy, but this has been virtually eliminated with the present method of drilling the pressure relief holes (see Data Sheet, Fig. B-9).

6. **Muzzle and Barrel Silencer**

Several small problems were encountered during the fabrication and adapting the barrel silencer to the Sten. Referring to Figure B-6, the barrel retainer "A" was eliptical and the rear tube of the barrel silencer would not fit over it. The collar had to be cut off and a new collar was brazed on the threaded portion and turned concentric to the threads "G." It was also necessary to turn the diameter "B" concentric to allow the barrel silencer tube to slide up against the sight. The barrel silencer was assembled on this weapon with the muzzle bushing and muzzle silencer tube. The weapon was test fired for accuracy and shot an extremely bad group at forty (40) feet. In checking the weapon for possible causes, it was found that surfaces "C," "D," and "F" had to be faced off parallel with each other and perpendicular to the center line of the bore of the barrel. Material was also removed from the base of the barrel "F" to maintain the proper head spacing. Prior to testing this

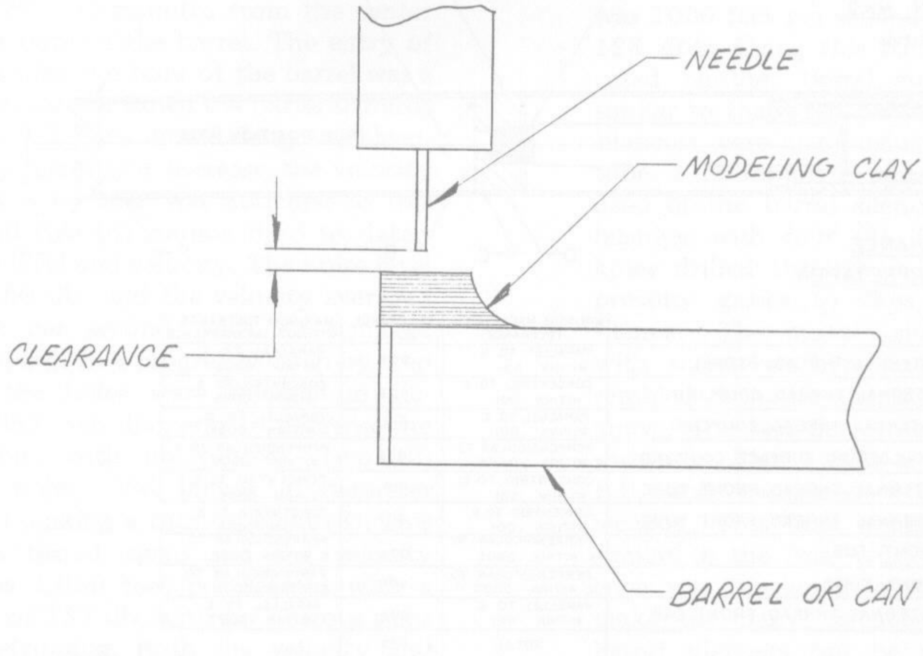
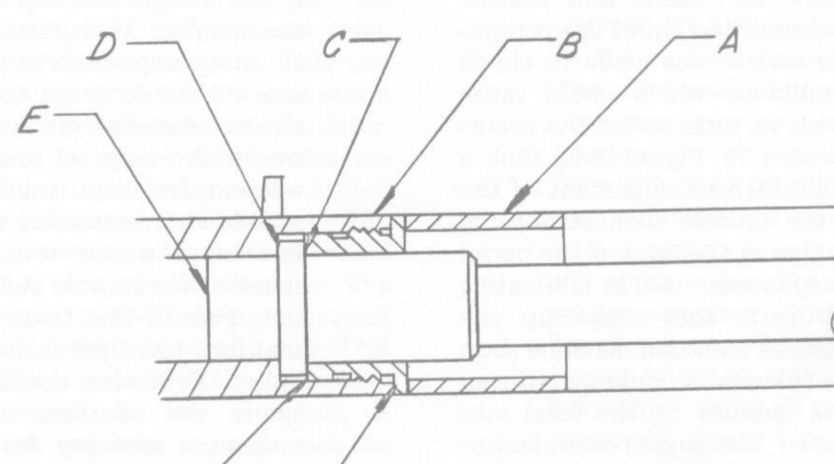
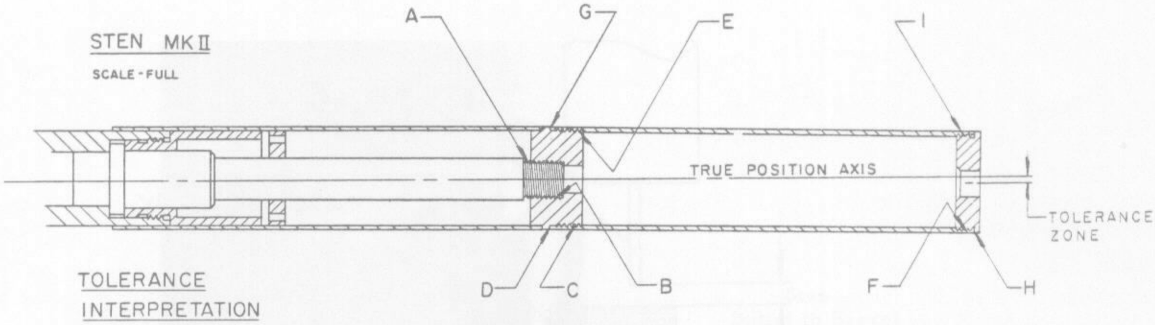


Figure B-5



Silencer Effect On Accuracy

FIGURE B-6



		MINIMUM MACHINABLE TOLERANCE	TOLERANCE ZONE	MAXIMUM TOLERANCE WITHOUT INTERFERENCE
A	EXTERNAL THREAD, BARREL	PARALLEL TO ℄ WITHIN .001	.009	PARALLEL TO ℄ WITHIN .0005
B	INTERNAL THREAD, COUPLING	CONCENTRIC TO ℄ WITHIN .001	.009	CONCENTRIC TO ℄ WITHIN .0005
C	EXTERNAL THREAD, COUPLING	PARALLEL TO ℄ WITHIN .001	.014	PARALLEL TO ℄ WITHIN .0005
D	SHOULDERING SURFACE, COUPLING	PERPENDICULAR TO ℄ WITHIN .0005	.002	PERPENDICULAR TO ℄ WITHIN .0005
E	INTERNAL THREAD, FRONT TUBE	CONCENTRIC TO ℄ WITHIN .001	.014	CONCENTRIC TO ℄ WITHIN .0005
F	INTERNAL THREAD, FRONT TUBE	CONCENTRIC TO ℄ WITHIN .001	.002	CONCENTRIC TO ℄ WITHIN .0005
G	FRONT TUBE	PERPENDICULAR TO ℄ WITHIN .0005	.002	PERPENDICULAR TO ℄ WITHIN .0005
H	FRONT TUBE	PERPENDICULAR TO ℄ WITHIN .0005	.001	PERPENDICULAR TO ℄ WITHIN .0005
I	EXTERNAL THREAD, FRONT CAP	PARALLEL TO ℄ WITHIN .001	.002	PARALLEL TO ℄ WITHIN .0005
		TOTAL	.055	
		INTERFERENCE	.026	

FIGURE B-7

weapon, we reviewed the updated drawings used to fabricate the barrel and muzzle silencer, plus the modification of the component parts. This review was made to check the tolerance build-up which could cause misalignment and, in turn, affect the accuracy. It can be seen in Figure B-7, that a maximum of .026 inch misalignment of the center line of the muzzle silencer housing with the center line of the bore of the barrel is possible. The tolerance used in fabricating the component parts that make up the silencer assembly are standard machine shop practices. These tolerances could be reduced to minimize the amount of the total misalignment, however, the cost of manufacturing would increase considerably. The weapon was reassembled, using the below described procedure, and tested for accruacy, this time firing a one (1) inch group at forty (40) feet. All the component parts of the silencer are assembled on the weapon loosely. Using the aligning rod, the front bushing and screen washers were assembled on the rod. With all the component parts loosely assembled on the weapon, the aligning rod was inserted in the muzzle of the barrel. Starting at the chamber end, each of the component parts were tightened successively out to the end cap at the muzzle end of the weapon. With this method of assembly, all the components are lined up with the axis of the bore of the barrel and all the screen washers are centrally located. It would also be good practice, after firing the weapon for any length of time, to disassemble and reassemble the weapon adding a few more screen washers to take up any space in the muzzle silencer. This will assure the operator that there are no loose washers that are misaligned that could deflect the bullet. Following the above procedures will assure the operator that he will get the maximum accuracy from his silenced weapon. In an effort to increase the accuracy of the Sten submachine gun and applying some of the knowledge gained on the Gustaf, investigations were made into the location and size of the pressure relief holes. To provide a wider range of data on this type of weapon, a new barrel was made and modified somewhat differently then the standard modification as described in Section I of this report. This modification consisted of drilling six (6) .078 inch diameter pressure relief holes, drilled at an angle of 12^{o} - 30 minutes from the center line of the bore of the barrel. The entry of these holes into the bore of the barrel was a quarter inch further down the barrel towards the muzzle end. This should delay the bleeding off the gasses and increase the velocity somewhat. A silencer was attached to this weapon and five (5) rounds fired to determine noise level and velocity. The noise level averaged 150 db, and the velocity averaged 1,220 feet per second, with no signs of bullet stripping. In a progressive step-by-step operation the holes were enlarged in diameter to .086 inch diameter to decrease the velocity, but with no success. Two (2) additional holes .086 inches in diameter were added making a total of eight (8). This barrel was tested again and the velocity dropped to 1,050 feet per second with a noise level of 137 db, with no obvious signs of bullet stripping. Both the velocity and noise levels were high, proving that the pressure relief holes were not located close enough to the chamber to bleed off the high peak pressure gasses. To move these holes closer to the chamber we chambered the barrel .050 inches deeper. This weapon was tested giving the following results, 1,000 feet per second velocity and 127 db noise level, with no signs of bullet stripping. This test gave us the best results on the Sten weapon with this type of modified barrel. To determine that the location of these holes are critical in reducing the velocity of the bullet, we chambered the barrel an additional .030 inches deeper, moving the pressure relief holes .080 inches closer to the chamber. The velocity increased to 1,025 feet per second and the noise level went up to 132 db's. This indicates that the location of these pressure holes, with respect to the chamber, is extremely critical and even more-so with the use of the Canadian ammunition which has a wide spread in its velocity from round to round. Another barrel was made with the pressure relief holes identical to that used on the Gustaf. Eight (8) holes, .086" diameter drilled at an angle of 11^{o} from the center line of the bore of the barrel and entering the barrel at .708 inches forward of the chamber. The test performed with this barrel resulted in velocities of 1,050 feet per second, and a noise level of 130 db. We increased the diameter of two (2) holes to .093 and tested the weapon. The velocity was 1030 feet per second and the noise level 123 db's. Using this barrel, we then fabricated another barrel and muzzle silencer similar to that used on the final Gustaf. The silencers were made using the same diameter tube a baffel plate and a screen roll was used in the barrel silencer, and the center bushing with four (4) .201 inch diameter holes drilled through it to allow the high pressure gasses to flow into the muzzle silencer. The muzzle silencer was packed with screen washers and the silencers assembled with the aligning rod, as described above. The test performed on the weapon, shown in Figure B-8, is detailed in Figure B-9, and compared with an unmodified weapon. This final weapon was made very similar to the final Gustaf, the only difference was the length of the tubing used to make the barrel silencer. If all the fixed barrel silencers can be made in a similar manner, the interchangability of components would make the logistic problems somewhat easier and it would also reduce the manufacturing cost.

7. **Malfunction**

In the silenced Sten, and as was found in the silenced Gustaf, problems were encountered in the normal functioning of the weapon. The first malfunction encountered on the Sten was a runaway gun. This was due to the decrease in the peak pressure developed from the fired round being bleed off, thereby, reducing the energy imparted to the bolt, causing a runaway gun. The other cause of malfunction resulted from the bullet jacket stripping, which left chips to collet in the chamber area, and obstructed the chambering of a new round, causing jamming and premature firing of the round before it was properly seated. Our solution to these problem areas are as follows:

a. **Runaway Gun**

The Sten and Gustaf are blowback operated weapons with a fixed firing pin, that is, a portion of the energy of a fired round is imparted to the bolt of the weapon driving it rearward against a recoil spring with sufficient force to carry the bolt pass the sear allowing the sear to engage the bolt on its return forward motion. When pulling the trigger the sear disengages from the bolt allowing the bolt to be driven forward by the compressed recoil spring. The bolt moves forward picking up a round from the magazine and chambers the round in the chamber and fires, when the chambered round shoulders at the bottom of the chamber. When the weapon is modified the gas pressure is reduced by the bleed holes in the barrel. Therefore, the energy that drives the bolt rearward, is insufficient to drive the bolt rearward far enough to engage the sear, resulting in a runaway gun. Some weapons can be corrected by cutting off 1-1/2 to 2 coils from the recoil spring, but this should only be done when a new spring can not be made or purchased.

b. **Chambering Problems**
Again the chambering problems in the Sten were the same as that encountered with the Gustaf which were overcome by the elimination of the stripping of the bullet jackets. At first, the excess chips collected in the chamber caused premature firing which resulted in ruptured cartridge cases. It is, therefore, recommended that the firing of single rounds when checking a modified weapon for stripping, should be adhered to until the stripping of the bullet jacket has been minimized.

B. **Results**

The results of the above tests, and evaluations of the Mark II-S, standard Sten, and the new silenced Sten are as follows:

1. **Mark II-S Sten (Tested as received)**
This weapon, as received, had many of the faults that were encountered on the first silenced Gustaf. These faults were:

a. The method for reducing the velocity of the projectiles was not sufficient enough when using Canadian ammunition, many of the rounds would go sonic.

b. Recoil springs were either too weak or too strong. The weak recoil springs had insufficient energy to pickup a round from a fully loaded magazine, to chamber and fire it. The number of rounds had to be reduced to make the weaker springs work. The heavy recoil springs would cause runaway guns, due to the decreased gas pressures developed by an expended round. This reduction in gas pressures did not produce sufficient energy to compress the recoil spring and move the bolt far enough to the rear to engage the sear.

c. The life of the Sten Mark II-S silencer was effective only up to 100 - 200 rounds, after which time the sound readings were very erratic. The silencer on the Gustaf maintained a noise level of 127 db plus or minus 6 db's for over 10,000 rounds.

These faults were minor and should not deter from the fact that this weapon was modified some twenty (20) years ago.

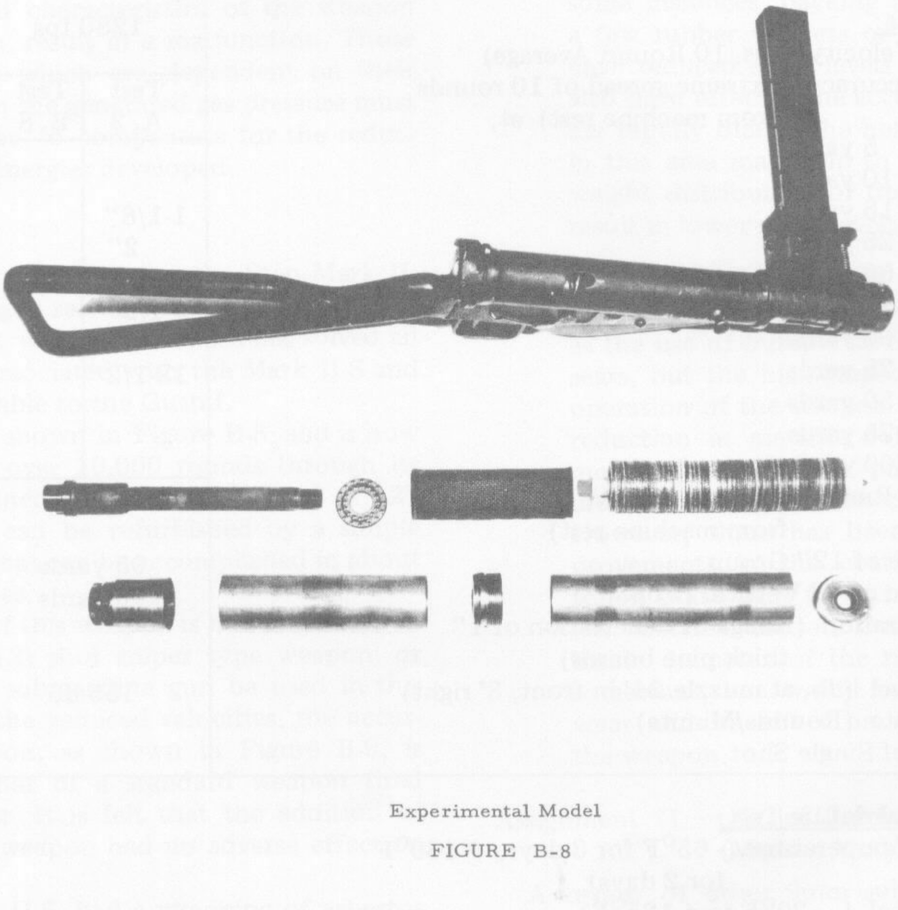
2. **Standard Weapon, Sten Mark II**
This weapon, unlike the Gustaf, is a relatively inexpensive weapon, however, it does have all the desired features necessary for the addition of a silencer. We have found no deflection of the barrel or any loosening of parts that would interfere with the accuracy of the weapon, the test results which are shown in Figure B-9.

3. **Modified Barrel**
Our experiments in the location, size, and angle of the gas pressure relief holes, resulted in using the same modifications to the barrel developed for the Gustaf (Barrel No. 6). This barrel consisted of eight (8) holes drilled as shown, reduced the velocity to 1,060 feet per second, which is a little higher then we would recommend, but was caused by the tight bore dimensions of the barrel stock from which this barrel was made. There was only minor indications of bullet jacket stripping and the accuracy was relatively good.

4. **Barrel Silencer**
Because of the decrease in length of the barrel and silencer required for this weapon, our best noise levels of 127 db's were achieved with the screen roll around the barrel.

5. **Muzzle Silencer and Center Bushing**
The use of the same size tubing to make both the barrel and muzzle silencer gives the weapon a more uniform appearance. It also provides an extra expansion chamber for bleeding gasses from the barrel silencer into the muzzle silencer through the four (4) holes in the center bushing.

6. **Accuracy**
The effect of the silencer added to this



Experimental Model

FIGURE B-8

Experimental Model

Name: Submachine Gun	Type: Automatic
Make: British Sten Model Mark II	Caliber 9mm Parabellum
Description Unmodified: Standard	Description Modified: Silenced
Operation: Blowback, full automatic	Operation: Blowback, full automatic
Size: L - 29-1/2", W - 5", Thick 4"	Size: L - 38-1/2", W - 5", Thick 4"
Weight: 6-1/2 lbs. w/o magazine	Weight: 9 lbs. 12 oz.
Other: w/stock - w/o magazine	Other: w/stock - w/o magazine

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	1280 fps		Ave - 1061 E. V. - 93	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards				
c) 15 yards	1-1/8"		1-1/2"	
d) 25 yards	2"		2-3/8"	
e) 50 yards	4-1/4"		6"	
f) 75 yards	6-1/2"		9"	
g) 100 yards	9"		12-3/4"	
h) 125 yards	12-1/2"			
i) 150 yards				
j) 175 yards				
k) 200 yards				
3. Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	95 yards		100 yards	
b) Range of 6" Vertical Drop	70 yards		65 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	155 db		127 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE B - 9

weapon, as shown in Figure B-9, is a 12-3/4 inch group at 100 yards as compared with the 9 inch group of the standard weapon, and a 15 inch group using underloaded ammunition through a standard weapon at the same ranges. Based on all the accuracy tests performed throughout this program, we feel that the main contributing factor to the inaccuracies of the modified weapon is the reduction in velocity.

7. **Malfunction**

When modifying a weapon of this type any change in the operating pressures will upset the designed characteristics of the weapon and, in turn, result in a malfunction. Those components which are dependent on their motion from the generated gas pressure must be redesigned to compensate for the reduction of the energies developed.

C. **Conclusions**

Reviewing the work done on the Sten Mark II, 9mm submachine gun selected for this program, we feel that the silent weapon produced has solved all of the problems associated with the Mark II-S and is, in fact, comparable to the Gustaf.

This weapon is shown in Figure B-8, and is now capable of firing over 10,000 rounds through its silencer with no increase in its noise level of 127 db. The silencer can be refurbished by a simple cleaning process that can be accomplished in about fifteen (15) minutes.

The accuracy of this weapon is not conducive to one (1) or two (2) shot sniper type weapon, or would any other submachine gun be used in this manner. Due to the reduced velocities, the accuracy of this weapon, as shown in Figure B-9, is comparable to that of a standard weapon fired from a bench rest. It is felt that the addition of a silencer to this weapon had no adverse effect on the accuracy.

The Sten Mark II-S, had a wrapping of asbestos around the barrel silencer covered with a loced piece of canvas. This is used for protecting the operator against burns, however, the weapon is normally held by the magazine and never by the barrel.

The use of attachments to reduce the blowback noises generated at the breech of the weapon could be used, but would be a hinderance to the operation of this weapon. Attachments of this type would also obstruct the sight and would effect the accuracy.

D. **Recommendations**

Because the design features of the Sten are similar to that of the Gustaf, and because the modifications to the Gustaf are similar to those done to the Sten, the results are basically the same. Our recommendations for future work on the Sten would be the same as that suggested for the Gustaf and are as follows.

1. **Muzzle Silencer Packing**

Some effort should be made to reduce the weight of the material used in the packing of the muzzle silencer and, if possible, to reduce the noise level to below 127 db. In some instances, packing arrangements using a few rubber washers or other elastometers have reduced noise levels below 127 db but also have effected the accuracy and deteriorate rapidly due to the heat developed. Work in this area may help to reduce the uneven weight distribution of the weapon and may result in lower noise levels.

2. **Metallic Noise Reduction**

Some work has been done in this area, such as the use of bumper pads, plastic bolts, and sears, but the high impacts involved in the operation of the weapon are too great. Any reduction in metallic noise by the replacement of component parts would greatly increase the production cost of the weapon. However, there has been some recent improvements in the coating of metal with teflon that ought to be tried to help reduce the metallic clatter. Coating the bolt and inside diameter of the receiver would help somewhat, but would have to be tried for wear and its effect on the functioning of the weapon.

Assignment II — **Other 9mm Submachine Guns (Madsen Model 1950, U.S. M-3)**

A review of other 9mm submachine guns was made on the basis of those requirements in Section I of this report.

The two (2) weapons selected for this assignment were the Madsen Model 1950, and the U.S. M-3, 9mm submachine guns.

The reason for selecting the Madsen submachine gun was the fact that this weapon is made up of two (2) half shell metal stampings together by the barrel retainer nut.

The U.S. M-3 was selected for a similar reason, in that it is made up of stampings welded together, and the barrel is held in the receiver by a heavy collar section pinned to the barrel.

Using all the techniques and data developed in Assignment I of this program, these two (2) weapons were evaluated and silenced.

9mm Madsen Model 1950

FIGURE A-1

MADSEN SUBMACHINE GUN

A. Madsen Model 1950, 9mm Submachine Gun

The Madsen, as shown in Figure A-1, is unique in its construction, the receiver is made up of two (2) flat stampings, hinged at the rear. The pistol grip and magazine slide are also made from simple stampings. The barrel is fastened to the receiver by a locking nut which, when unscrewed and moved forward, permits the left side of the receiver to be opened for removing the barrel and exposing all the moving parts.

This weapon was designed for high quantity production, it is relatively inexpensive and proven to be highly reliable.

Purpose: The purpose of this assignment was to develop a silencer for the Madsen 9mm submachine gun using the data, designs, and techniques developed in Assignment I of this program.

Procedure: Our approach to the silencing of the Madsen submachine gun was to start with the standard weapon and proceed in a step-by-step manner to modify this weapon for a silencer.

1. **Standard Weapon Test and Evaluation**

It is interesting to note that at the introduction of the Madsen Model 1950, the weapon was tested by firing over 20,000 rounds through a production model. The entire test was accomplished in two (2) hours and fifteen (15) minutes. Prior to the endurance test above, a barrel was tested by firing 43,000 rounds through it. Before and during the test, accuracy tests were performed by firing 10 rounds single shot. Some of the results are as follows:

Rounds	Dispersion From 0 Vertical	Horizontal
Before Testing	3.3"	5.8"
After 3,520	3.5"	4.7"
After 15,920	2"	4"
After 25,044	6"	5"
After 31,220	4.5"	3"
After 38,090	4"	5"
After 42,930	4.7"	6.5"

The standard weapon was disassembled and the component parts inspected for loose fits or misalignment. The weapon was reassembled and tested for accuracy on a 40 foot range, using Canadian ammunition with an average velocity of 1300 feet per second. We disassembled and reassembled the weapon several times, each time checking for loose parts that could cause inaccuracy. As shown in Figure A-2, the standard weapon had an average velocity of 1290 feet per second, with a 7/8 inch bullet grouping and a noise level of 154 db.

2. **Standard and Modified Barrel Evaluation**

The extensive testing that was performed on the Gustaf and Sten weapons were conclusive enough that repeating these tests for the modified barrels, with increased twist, would not yield any different results on this weapon. However, to prove the results on the new barrel developed for the Gustaf in this program, we fabricated two (2) different barrels for this weapon, as follows:

Barrel No. 1

This barrel was modified in the same manner as that used on the Production Model Gustaf. It consisted of four (4) pressure relief holes .125 inches in diameter, drilled at an angle of 10^{o} from the center line of the bore and eliminated the drilling of the 48 holes. This is done to vent the high pressure gasses into the "barrel silencer" and to reduce the velocity of the bullet.

Barrel No. 2

This barrel was modified in the same manner as barrel No. 6, in Assignment I, of this program. It consisted of six (6) .086 inch diameter and two (2) .093 inch diameter equally spaced holes drilled around the outside circumference of the barrel. These holes are drilled at an angle of 11^{o} from the center line of the bore, and enter the bore of the barrel just forward of the chamber. This is done to vent the high pressure gasses into an expansion chamber or "barrel silencer." We have found that these eight (8) holes bleed off sufficient gas pressure to reduce the velocity of the projectile to approximately 1,000 feet per second, without the need of drilling the four (4) rows of twelve (12) holes each at right angles, to each other along the length o of the barrel. Sufficient tests were performed on the Madsen with a standard barrel and the modified barrels to substantiate the previous results obtained on the Gustaf and Sten. Each of these barrels were tested with Canadian ammunition (1,300 feet per second). The results of these tests are shown in Figure A-2.

3. **Ammunition**

The test with the standard commercial ammunition and the Canadian ammunition were repeated. We captured several rounds fired through the silenced Madsen using barrel No. 6 to check for bullet stripping. There were no evidence of excessive stripping of the bullet jacket that would cause the inaccuracy. However, there was some stripping of the bullet jacket using barrel No. 1.

4. **Barrel Deflection**

Because of the barrel deflection tests performed on the Gustaf and Sten, we did not repeat these tests on the Madsen. The Madsen barrel is attached to the receiver in a similar manner and it is recessed about 1-1/2 inch in the receiver, which provides more bearing support surface than either the Sten or Gustaf.

5. **Ballistic Upset**

From all the previous tests we have concluded that the prime reason for the inaccuracy of the modified weapons studied on other programs and on this program, is due to the reduced velocity of the projectile. This is evidenced by the tests performed with underloaded ammunition in the standard weapon, see Figure A-2. It is also true that the stripping of the bullet jacket adds to the inaccuracy, but this has been virtually eliminated with the present method of drilling the pressure relief holes in barrel No. 6, as described above.

6. **Muzzle and Barrel Silencer**

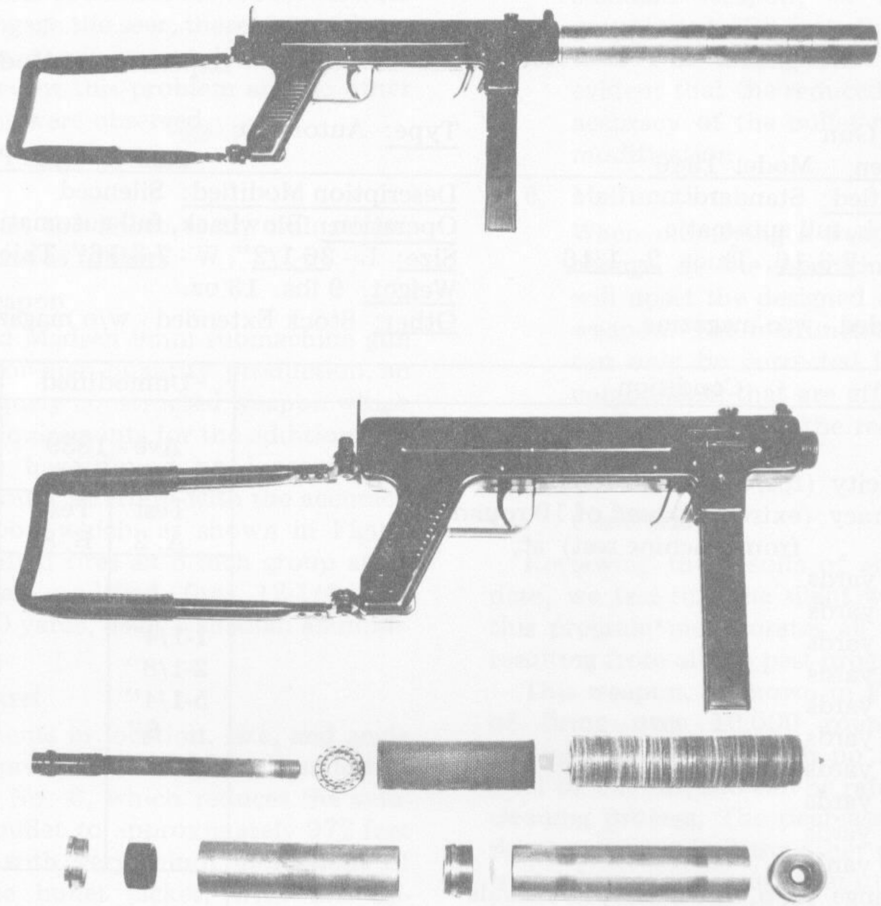
As shown in Figure A-3, a muzzle and barrel silencer was made for this weapon using the same diameter outside tubing. The barrel silencer consisted of a outer tube, a new barrel nut which was machined to fit the inside diameter of the rear tube, a spacer to create a chamber in the rear of the barrel silencer, a barrel ring, and a screen roll with a center bushing that threaded on the muzzle of the barrel. The muzzle silencer consisted of an outer tube which threaded on the center bushing, screen washers and an end cap to retain the washers. This silenced weapon was tested with the two (2) different barrels made for a comparison. The results of these tests are shown in Figure A-2. Using barrel No. 1 and the above silencer, the tests resulted in velocities of 1,070 feet per second, a group size of 1-7/8 inches, and noise levels of 134 db. Using barrel No. 2 and the same silencer, the test resulted in

1950 MADSEN ACCURACY AND SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
Canadian	Stock	1290	7/8 inch	154
Canadian Underload	Stock	937	1-1/8 inch	154
Remington	Stock	1135	3/4 inch	155
Remington Underload	Stock	935	1 inch	153
Canadian *	Modified No. 1 Barrel & Silencer	1070	1-7/8 inch	134
Canadian	Modified No. 1 Barrel & Silencer	1070	1-7/8 inch	127
Canadian	Modified No. 2 Barrel & Silencer	972	1-1/2 inch	126

* Silencer had no bleed holes in center bushing

FIGURE A - 2



Madsen Experimental Model

FIGURE A-3

velocities of 972 feet per second, a group size of 1-1/2 inches, and noise levels of 126 db. Because the velocities and the noise level were high using barrel No. 1, the weapon was disassembled and the silencer modified. This modification consisted of drilling four (4) .201 diameter holes in the center bushing to provide more expansion area for the gasses. The weapon was reassembled using the prescribed assembly procedure. Using an aligning rod all the component parts of the silencer were assembled loosely on the gun, the aligning rod with the front bushing and screen washers for packing the muzzle silencer was then inserted through the muzzle end of the weapon. Starting at the chamber end, each component is tightened one at a time, out to the front bushing. It has been established that weapons which are assembled in this manner will shoot a tighter group. Tests were performed with barrel No. 1 and No. 2 which, as shown in Figure A-2, gave the following results. Barrel No. 1 with silencer gave velocities of 1070 feet per second, group size 1-5/8 inches and noise level of 127 db. Barrel No. 2 with silencer assembled in the same manner gave velocities of 972 feet per second, group size of 1-1/2 inches and a noise level of 126 db. The same results as above, without the addition of the four (4) holes in the center bushing.

7. **Malfunction**

The only malfunction observed in the Madsen after modifications were made to it was again a tendency for the gun to run-away. Due to the bleeding of the high pressure gasses and the strong (original) recoil

Experimental Model

Name: Submachine Gun
Make: Danish Madsen Model 1946
Description Unmodified: Standard
Operation: Blowback, full automatic
Size: L - 38-3/4, W - 7-3/16, Thick 2 - 1/16
Weight: 7 lbs. 2 oz.
Other: Stock extended - w/o magazine

Type: Automatic
Caliber 9mm Parabellum
Description Modified: Silenced
Operation: Blowback, full automatic
Size: L - 36-1/2", W - 7-3/16", Thick - 2 - 1/16"
Weight: 9 lbs. 13 oz.
Other: Stock Extended - w/o magazine

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 1339 E. V. - 77		Ave - 1014 E. V. - 55	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards				
c) 15 yards	1-1/4"		2 - 5/8"	
d) 25 yards	2-1/8"		4-1/4"	
e) 50 yards	5-1/4"		9"	
f) 75 yards	8"		12-1/4"	
g) 100 yards	12-1/4"			
i) 150 yards				
j) 175 yards				
k) 200 yards				
3; Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	100 yards		75 yards	
b) Range of 6" Vertical Drop	75 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	154 db		127 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (-65^{O}F for 3 days, $+160^{O}$F for 2 days)				
2. Operational (-20^{O}F to $+125^{O}$F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE A - 4

spring, the bolt could not move rearward far enough to engage the sear, thereby, causing a runaway gun. Again we modified the recoil spring to prevent this problem and no other modifications were observed.

B. **Results**

The results of all the above tests, evaluations, and modifications are as follows:

1. **Standard Weapon**

   The standard Madsen 9mm submachine gun is designed for high quantity production, an and is a uniquely constructed weapon which has all the requirements for the addition of a silencer. We have found no loosening of parts that would interfere with the accuracy of the weapon which, as shown in Figure A-4, unmodified fires an 8 inch group at 75 yards and as modified fires 12-1/4 inch group at 100 yards, using Canadian ammunition.

2. **Modified Barrel**

   Our experiments in location, size, and angle of the gas pressure relief holes resulted in using barrel No. 6, which reduces the velocity of the bullet to approximately 972 feet per second with very minor indications of stripping the bullet jacket. With this approach to reducing the velocity of the bullet, only the gas pressure relief holes at the chamber were needed. After the pressure relief holes were drilled on a standard barrel, only the muzzle has to be threaded to accept the center bushing.

3. **Barrel Silencer**

   The results, shown in Figure A-2, required the use of a stainless steel screen roll and a stainless steel baffel plate to accomplish a noise level of 127 db's as recorded with the Production Model Gustaf.

4. **Muzzle Silencer and Center Bushing**

   The use of the same size tubing to make the muzzle silencer, gives the weapon a more uniform appearance. It should be noted that a center bushing with four (4) bleed holes was necessary to reduce the noise level to 127 db.

5. **Accuracy**

   The effect of a silencer on the accuracy of this weapon, as shown in Figure A-4, is a 12-1/4 inch group at 225 feet. When compared with an underloaded round through a standard weapon, we recorded a 17 inch grouping at 328 feet. Based on the accuracy tests run throughout this program, it is evident that the reduced velocities effect the accuracy of the bullet more than any other modification.

6. **Malfunction**

   When modifying a weapon of this type any change in the operating pressure involved will upset the designed characteristics of the weapon. The malfunctioning of the weapon can only be corrected by redesigning those components that are affected. In the case of the Madsen, only the recoil spring had to be modified.

C. **Conclusions**

Reviewing the results of all the work done to date, we feel that the silent weapon produced for this program incorporates all of the best features resulting from all the past programs.

This weapon, as shown in Figure A-5, is capable of firing over 10,000 rounds of ammunition through its silencer with no increase in its noise level of 127 db, and can be refurbished by a simple cleaning process. The decrease in the accuracy of this weapon and all the other weapons of this type is mainly caused by an upset of the ballistics due to the reduced velocities.

It was also found that the use of an asbestos wrapping around the barrel silencer would help protect the operator from burning his hands, but is not essential if only a few rounds are to be fired, or if the operator is careful.

The use of attachments to the chamber area of this weapon to help reduce the blowback noise emitting from this area, is a hindrance to the operation of the weapon and to the operator. It also can not be attached to the weapon without obstructing the line of sight and would effect the accuracy which was the main objective of selecting this weapon for evaluation.

The Madsen, Model 1950 submachine gun in its final configuration, resulting from this program, using the Canadian ammunition and being operated as a submachine is a very effective weapon.

D. **Recommendations**

After evaluating the results of this program and the amount of work that has been done on weapons of this type, there are only two (2) areas that may be considered for future investigations, are the packing and the reduction of some of the metallic noise.

Madsen Experimental Model

FIGURE A-5

1. **Muzzle Silencer Packing**
Some effort should be made to reduce the weight of the material used in the packing of the muzzle silencer, and if possible, to reduce the noise level to below 127 db. In some instances, packing arrangements, using a few washers or made of rubber or elastometers, have reduced the noise levels below 127 db's, but also have effected the accuracy and deteriorate rapidly. Work in this area would help to reduce the unbalance in the uneven weight distribution of the weapon and may result in lower noise levels.

2. **Metallic Noise Reduction**
The reduction of the metallic noise generated by the bolt moving in the receiver of this weapon would probably be a very difficult task, due to the construction. Some thought was given to using thin plastic guide rails, however, this would be rather expensive. It is our feeling that there would be no simple solution to the reduction of the metallic noise in this weapon.

9mm M-3 Submachine Gun

FIGURE B-1

U.S. M-3 SUBMACHINE GUN

B. **U.S. M-3, 9mm Submachine Gun**

The U.S. M-3, as shown in Figure B-1, is designed for high quantity production in that except for a few pieces, it is made of sheet metal stampings welded together. The barrel is pinned to a large and heavy bushing that is threaded and screwed into the receiver.

Purpose: The purpose of this assignment was to develop a silencer for the U.S. M-3, 9mm submachine gun using data, designs, and techniques developed in Assignment I of this program.

Procedure: Our approach to the silencing of the U.S. M-3 submachine gun, was to start with the standard weapon and proceed in a step-by-step manner to modify this weapon for a silencer.

1. **Standard Weapon Test and Evaluation**

   The standard weapon, as shown in Figure B-1, was disassembled and the component parts inspected for loose fits or misalignment. The weapon was reassembled and tested for accuracy on a 40 foot range, using Canadian ammunition with an average velocity of 1300 feet per second. We disassembled and reassembled the weapon several times, each time checking for loose parts that could cause inaccuracy. As shown in Figure B-2, the standard weapon had an average velocity of 1320 feet per second, with a 7/8 inch bullet grouping and a noise level of 155 db.

2. **Standard and Modified Barrel Evaluation**

   The extensive testing that was performed on the Gustaf and Sten weapons, were conclusive enough that repeating these tests for the modified barrels, with increased twist, would not yield any different results on this weapon. However, to prove the results on the new barrel developed for the Gustaf in this program, we fabricated two (2) different barrels for this weapon, as follows:

   Barrel No. 1

   This barrel was modified in the same manner as that used on the Production Model Gustaf. It consisted of four (4) pressure relief holes .125 inches in diameter, drilled at an angle of 10° from the center line of the bore and eliminated the drilling of the 48 holes. This is done to vent the high pressure gasses into the "barrel silencer" and to reduce the velocity of the bullet.

   Barrel No. 2

   This barrel was modified in the same manner as barrel No. 6 in Assignment I of this program. It consisted of six (6) .086 inch diameter and two (2) .090 inch diameter equally spaced holes drilled around the outside circumference of the barrel. These holes are drilled at an angle of 11° from the center line of the bore, and enter the bore of the barrel just forward of the chamber. This is don done to vent the high pressure gasses into an expansion chamber or "barrel silencer." We have found that these eight (8) holes bleed off sufficient gas pressure to reduce the velocity of the projectile to approximately 1,000 feet per second, without the need of drilling the four (4) rows of twelve (12) holes each at right angles, to each other along the length of the barrel. Sufficient tests were performed on the U.S. M-3 with a standard barrel and the modified barrels to substantiate the previous results obtained on the Gustaf and Sten. Each of these barrels were tested with Canadian ammunition (1,300 feet per second). The results of these tests are shown in Figure B-2.

3. **Ammunition**

   The tests with the standard commercial ammunition and the Canadian ammunition were repeated. We captured several rounds fired through the silenced U.S. M-3 using barrel configuration No. 6 to check for bullet stripping. There were no evidence of excessive stripping of the bullet jacket that would cause the inaccuracy. However, there was some stripping of the bullet jacket using barrel No. 1.

4. **Barrel Deflection**

   Because of the barrel deflection tests performed on the Gustaf and Sten, we did not repeat these tests on the U.S. M-3. The U.S. M-3 barrel is attached to the receiver in a similar manner and it is recessed about 1-1/2 inches in the receiver, which provides more bearing support surface than either the Sten or Gustaf.

5. **Ballistic Upset**

   From all the previous tests we have concluded that the prime reason for the inaccuracy of the modified weapons studied on other programs, and on this program, is due to the reduced velocity of the projectile. This is evidenced by the tests performed with underloaded ammunition in the standard weapon, see Figure B-2. It is also true that the stripping of the bullet jacket adds to the inaccuracy, but this has been virtually eliminated with the present method of drilling the pressure relief holes in barrel No. 6, as described above.

6. **Muzzle and Barrel Silencer**

   As shown in Figure B-3, a muzzle and barrel silencer was made for this weapon using the same diameter outside tubing. The barrel silencer consisted of a outer tube, a new barrel nut which was machined to fit the

U. S. M - 3 ACCURACY AND SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
Canadian	Stock	1320	7/8 inch	155
Canadian Underload	Stock	1010	7/8 inch	155
Remington	Stock	1180	3/4 inch	154
Remington Underload	Stock	985	3/4 inch	153
Canadian *	Modified No. 1 Barrel & Silencer	1005	1-1/2 inch	134
Canadian	Modified No. 1 Barrel & Silencer	1000	1-5/8 inch	118
Canadian	Modified No. 2 Barrel & Silencer	972	1-1/2 inch	120

* Silencer had no bleed holes in center bushing

FIGURE B - 2

Experimental M-3

FIGURE B-3

inside diameter of the rear tube, a spacer to create a chamber in the rear of the barrel silencer, a baffel ring, and a screen roll with a center bushing that threaded on the muzzle of the barrel. The muzzle silencer consisted of an outer tube which threaded on the center bushing, screen washers, and an end cap to retain the washers. This silenced weapon was tested with the two (2) different barrels made for a comparison. The results of these tests are shown in Figure B-2. Using barrel No. 1 and the above silencer, the tests resulted in velocities of 1005 feet per second, a group size of 1-1/2 inches, and noise levels of 134 db. Using barrel No. 2 and the same silencer, the tests resulted in velocities of 972 feet per second, a group size of 1-1/2 inches, and noise levels of 120 db. Because the velocities and the noise level were high using barrel No. 1, the weapon was disassembled and the silencer modified. This modification consisted of drilling four (4) .201 diameter holes in the center bushing to provide more expansion area for the gasses. The weapon was reassembled using the prescribed assembly procedure. Using an aligning rod, all the component parts of the silencer were assembled loosely on the gun, the aligning rod with the front bushing, and screen washers for packing the muzzle silencer was then inserted through the muzzle end of the weapon. Starting at the chamber end, each component is tightened one at a time, out to the front bushing. It has been established that weapons which are assembled in this manner will shoot a tighter group. Tests were performed with barrel No. 1 and No. 2 which, as shown in Figure B-2,

Experimental Model

Name: Submachine Gun	Type: Automatic
Make: U. S. Model M - 3	Caliber 9mm Parabellum
Description Unmodified: Standard	Description Modified: Silenced
Operation: Blowback, full automatic	Operation: Blowback, full automatic
Size: L - 29", W - 7-3/8", Thick 2 - 13/16"	Size: L - 35-1/2", W - 7-3/8", Thick - 2 - 13/16"
Weight: 8 lbs. 8 oz.	Weight: 11 lbs. 5 oz.
Other: Stock extended - w/o magazine	Other: Stock Extended - w/o magazine

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 1313 E. V. - 74		Ave - 1041 E. V. - 99	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards	-	-	-	-
b) 10 yards	-	-	-	-
c) 15 yards	1"		1-7/8"	
d) 25 yards	1-3/4"		2-3/4"	
e) 50 yards	3-1/4"		7"	
f) 75 yards	4-1/2"		10"	
g) 100 yards	6-5/8"		16"	
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards				
3; Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	175 yards		80 yards	
b) Range of 6" Vertical Drop	75 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	155 db		118 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE B - 4

gave the following results. Barrel No. 1 with silencer gave velocities of 1000 feet per second, group size 1-5/8 inches and noise level of 118 db. Barrel No. 2 with silencer assembled in the same manner, gave velocities of 972 feet per second, group size of 1-1/2 inches and a noise level of 120 db. The same results as above, without the addition of the four (4) holes in the center bushing. This weapon is the quietest to date with velocities close to 1000 feet per second.

7. **Malfunction**

The only malfunction observed in the U.S. M-3, after modifications were made to it, was again a tendency for the gun to runaway. Due to the bleeding of the high pressure gasses and the strong (original) recoil spring, the bolt could not move rearward far enough to engage the sear, thereby, causing a runaway gun. Again we modified the recoil spring to prevent this problem and no other malfunctions were observed.

B. **Results**

The results of all the above tests, evaluations, and modifications are as follows:

1. **Standard Weapon**

The standard U.S. M-3, 9mm submachine gun is designed for high quantity production, and is a uniquely constructed weapon which has all the requirements for the addition of a silencer. We have found no loosening of parts that would interfere with the accuracy of the weapon which, as shown in Figure B-4, unmodified fired an 4-1/2 inch group at 75 yards and modified fired a 16 inch group at 100 yards, using Canadian ammunition.

2. **Modified Barrel**

Our experiments in location, size, and angle of the gas pressure relief holes resulted in using barrel No. 6, which reduces the velocity of the bullet to approximately 980 feet per second with very minor indications of stripping the bullet jacket. With this approach to reducing the velocity of the bullet, only the gas pressure relief holes at the chamber were needed. After the pressure relief holes were drilled on a standard barrel, only the muzzle has to be threaded to accept the center bushing.

3. **Barrel Silencer**

The results, shown in Figure B-2, required the use of stainless steel screen roll and a stainless steel baffel plate, to accomplsih a noise level of 118 db's as compared with the 127 db recorded with the Production Model Gustaf.

4. **Muzzle Silencer and Center Bushing**

The use of the same size tubing to make the muzzle silencer gives the weapon a more uniform appearance. It should be noted that a center bushing with four (4) bleed holes was necessary to reduce the noise level to 127 db or lower in the case with the U.S. M-3.

5. **Accuracy**

The effect of a silencer on the accuracy of this weapon, as shown in Figure B-4, is a 16 inch group at 100 yards, and a 10 inch group at 75 yards. Based on the accuracy tests run throughout this program, it is evident that the reduced velocities effect the accuracy of the bullet more than any other modification.

6. **Malfunction**

When modifying a weapon of this type, any change in the operating pressure involved will upset the designed characteristics of the weapon. The malfunctioning of the weapon can only be corrected by redesigning those components that are affected. In the case of the U.S. M-3, only the recoil spring had to be modified. This has been the case with all the submachine guns throughout this program.

C. **Conclusions**

Reviewing the results of all the work done to date, we feel that the silent weapon produced for this program incorporates all of the best features resulting from all the past programs.

This weapon, as shown in Figure B-5, is capable of firing over 10,000 rounds of ammunition through its silencer with no increase in its noise level of 120 db, and can be refurbished by a simple cleaning process. The decrease in the accuracy of this weapon, and all the other weapons of this type, is mainly caused by an upset of the ballistics due to the reduced velocities.

It was also found that the use of an asbestos wrapping around the barrel silencer would help protect the operator from burning his hands, but is not essential if only a few rounds are to be fired or if the operator is careful.

The use of attachments to the chamber area of this weapon to help reduce the blowback noise

Experimental M-3

FIGURE B-5

emitting from this area, is a hindrance to the operation of the weapon and to the operator, and on this weapon in particular, due to the hinged ejection port door safety. It can also not be attached to the weapon without obstructing the line of sight and would effect the accuracy which was the main objective of selecting this weapon for evaluation.

The U.S. M-3 submachine gun in its final configuration, resulting from this program, using the Canadian ammunition and being operated as a submachine is a very effective weapon.

D. **Recommendations**

After evaluating the results of this program and the amount of work that has been done on weapons of this type, there are only two (2) areas that may be considered for future investigations, are the packing and the reduction of some of the metallic noise.

1. **Muzzle Silencer Packing**

Some effort should be made to reduce the weight of the material used in the packing of the muzzle silencer, and if possible, to reduce the noise level to below 120 db. In some instances, packing arrangements, using a few washers made of rubber or elastometers, have reduced noise levels below 120 db's, but also have effected the accuracy and deteriorate rapidly. Work in this area would help to reduce the unbalance in the uneven weight distribution of the weapon and may result in lower noise level, which may be possible on this weapon.

2. **Metallic Noise Reduction**

The reduction of the metallic noise generated by the bolt moving in the receiver of this weapon, as was the case with the Madsen, would probably be a very difficult task, due to the construction. Some thought was given to using thin plastic guide rails, however, this would be rather expensive. It is our feeling that there would be no simple solution to the reduction of the metallic noise in this weapon.

Assignment III — Telescoping Bolt Action 9mm Submachine Guns

This assignment was established to develop silencers for submachine guns with telescopic bolts, that is, weapons having hollow bolts which telescope over the rear six or seven inches of the barrel when the bolt is in the forward or firing position.

The two (2) weapons that were chosen for this assignment were the Beretta, Model 12, and the Uzi, Number 2, Mark A.

Beretta Model 12
9mm Submachine Gun

BERETTA SUBMACHINE GUN

A. **Beretta Model 12, 9mm Submachine Gun** (See Figure A-1)

The Model 12, represents six years of intensive development work, it is a high quality submachine gun which incorporates up-to-date production techniques. The weapon is primarily made up of heavy sheet metal stampings which are spot welded or rivited together.

The reason for selecting the Beretta Model 12, for this program was primarily due to the bolt design.

The mass of the bolt is carried forward of the chamber of the barrel and is concentric to the axis of the barrel. That is, the bolt encircles the barrel, the bolt is hollowed out to guide on the barrel. The telescoping bolt arrangement enables the weapons to be made shorter in over-all length by approximately six to eight inches.

This arrangement works well to shorten the over-all length of the weapon but does not do much in the way of increasing the accuracy of the weapon. The barrel is not a fixed barrel and is only held in place by two (2) lugs on the front of the barrel that are held by the retaining nut.

Both the barrel and the bolt are free floating and are only guided in relation to each other but not in relation to the receiver which is a rolled sheet metal tube.

Purpose: The purpose of this assignment was to investigate the problems associated with silencing a telescoping bolt type submachine guns, and to develop a silencer for this weapon.

Procedure: Our approach in solving the problems associated with silencing the Beretta Model 12 submachine gun was to develop data starting with the standard weapon. We also developed layout drawings of the barrel and bolt assembly to devise a method for bleeding off the high pressure gasses.

Using this approach it was possible to use some of the techniques and data developed on the previous assignments.

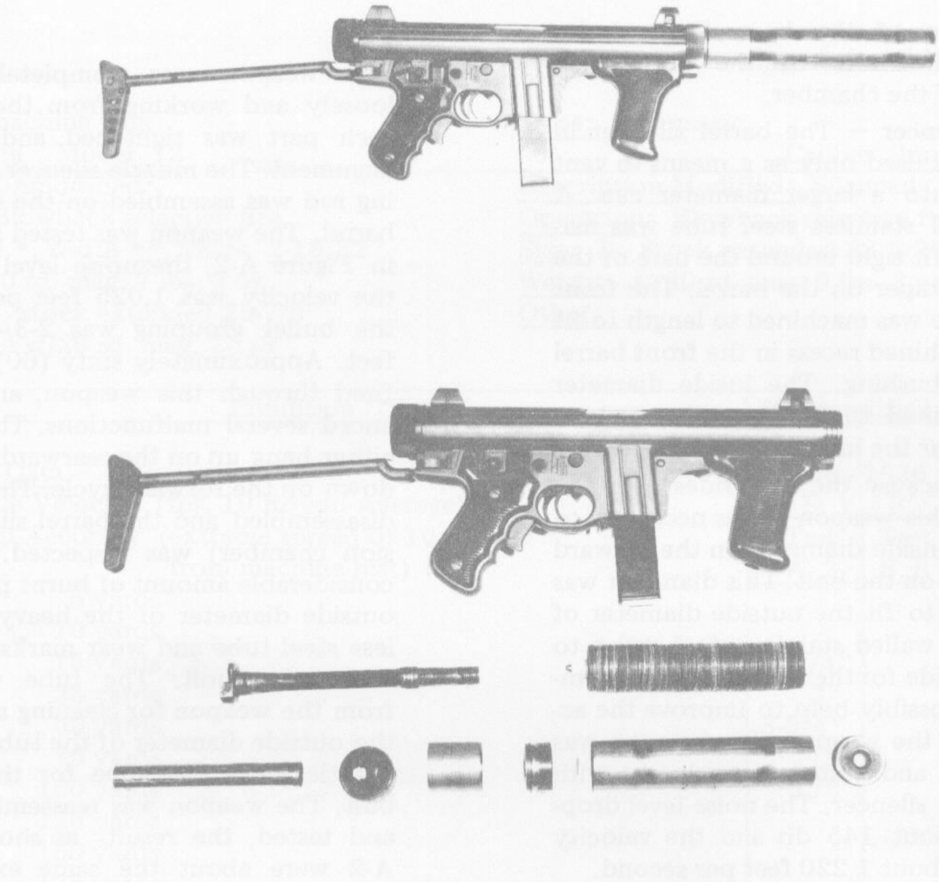
1. **Standard Weapon Test and Evaluation**

The standard weapon was disassembled and the component parts were dimensionally checked for loose fits which may cause misalignment. The construction of this weapon is such that misalignment of the barrel in relation to the bolt and the barrel retaining nut during firing is possible as discussed above. **Any sliding members must have clearance plus the barrel locking has clearance to accept the barrel lugs.** The barrel is retained axially by the barrel retaining nut which is threaded onto a rolled sheet metal receiver. The retaining nut also engages two (2) flat lugs on the barrel that are 180° apart, and holds them in an internal groove. The rear portion of the barrel is retained in the hollowed out portion of the bolt which has two (2) guide bars 180° apart, that act as a rear bearing for the barrel. The two (2) guide bars on the bolt mate with the two (2) ears on the rear of the barrel and act as a guide to maintain alignment of the rear of the barrel with the muzzle of the barrel. This arrangement is unique however, the mating fit of the guide bars and the ear of the barrel above could cause a misalignment with the muzzle of the barrel. The standard weapon was reassembled several times and tested for accuracy on a 40 foot range using Canadian ammunition with an average velocity of

MODEL 12 BERETTA ACCURACY & SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
Canadian	Stock	1225 fps	13/16 inch	154 db
Canadian Underload	Stock	940 fps	2-3/16 inch	154 db
Canadian	Modified	1025 fps	2-3/4 inch	127 db
Canadian	Modified	1025 fps	2-3/16 inch	127 db

FIGURE A - 2



Silenced Beretta Model 12

FIGURE A-3

1300 feet per second. The weapon was disassembled and reassembled several times and tested for accuracy. As shown in Figure A-2, the standard weapon has an average velocity of 1225 feet per second, with 13/16 inch inch bullet grouping and a noise level of 154 db. To establish what would happen to the accuracy of this weapon when the velocity was dropped to about 1,000 feet per second, several rounds were underloaded and the weapon tested. As shown in Figure A-2, the standard weapon with underloaded Canadian ammunition had an average velocity of 940 feet per second, with a 2-3/16 inch bullet grouping and an average noise level of 154 db. This bullet grouping was compared with all the fixed barrel type submachine guns previously tested with underloaded ammunition and is considered very poor. We bevlieve that although the telescoping bolt arrangement is unique and reduces the over-all lengt length, however, it does affect the accuracy of the weapon.

2. Silencer Design

In order to develop a silencer for the Beretta assembly drawings were made of the barrel and the telescoping bolt. These drawings were reviewed to determine the best possible means for venting the high pressure gasses from the chamber into a large diameter can. Based on the data developed on the previous assignments the most economical means to vent the high pressure gasses from the chamber is to drill angle holes into the barrel just forward of the chamber. Our next problem was to contain the gasses and vent them into a large expansion chamber, with a minimum of leakage. Working from the chamber end of the weapon our approach is as follows: (see Figure A-3)

a. Barrel — The outside diameter of the barrel was turned down, with a taper at the chamber end. Four .125 inch diameter holes were drilled at 90° from each other, at an angle of 10° from the center line of the bore. These holes entered the bore of the barrel just forward of the chamber.

b. **Barrel Silencer** — The barrel silencer in this case is used only as a means to vent the gas into a larger diameter can. A heavy wall stainless steel tube was machined to fit tight around the base of the machined taper on the barrel. The front of the tube was machined to length to fit into a machined recess in the front barrel retaining bushing. The inside diameter was machined to fit over a heavy boss section near the muzzle of the barrel.

c. **Bolt** — Because the bolt rides over the barrel in this weapon it was necessary to open the inside diameter on the forward guide ring on the bolt. This diameter was machined to fit the outside diameter of the heavy walled stainless steel stube, to act as a guide for the recoiling bolt assembly and possibly help to improve the accuracy of the weapon. The weapon was assembled and tested for velocity with no muzzle silencer. The noise level dropped to about 145 db and the velocity averaged about 1,220 feet per second.

d. **Increase Volume Capacity of Expansion Chamber** — Our next problem was to vent the gasses in our barrel expansion chamber into a larger diameter can to reduce the muzzle velocity. Notches were cut along the heavy boss on the front of the barrel to allow gas to pass freely to the barrel retaining bushing, where the gas could pass through the bayonet slots. The barrel retainer nut was machined to accept a large diameter tube. The muzzle of the barrel was threaded to accept a muzzle silencer similar to the other 9mm submachine guns.

3. **Malfunction**

The weapon was assembled as shown in Figure A-3, and was test fired. As was suspected, the weapon would not function automatically, this was due to the venting of high pressure gasses reducing the blowback pressure. The pressure was insufficient to compress the recoil spring enough to allow the bolt to travel to the rear far enough to engage the sear. To correct this difficulty, we modified the recoil spring to allow for the reduction of the blowback pressures.

4. **Test**

The weapon was completely assembled loosely and working from the breech end, each part was tightened and checked for alignment. The muzzle silencer with an aligning rod was assembled on the muzzle of the barrel. The weapon was tested and, as shown in Figure A-2, the noise level was 127 db, the velocity was 1,025 feet per second and the bullet grouping was 2-3/4 inch at 40 feet. Approximately sixty (60) rounds were fired through this weapon, and we experienced several malfunctions. The bolt would either hang up on the rearward cycle or slow down on the forward cycle. The weapon was disassembled and the barrel silencer (expansion chamber) was inspected. We found a considerable amount of burnt powder on the outside diameter of the heavy walled stainless steel tube and wear marks made by the telescoping bolt. The tube was removed from the weapon for cleaning and we turned the outside diameter of the tube to allow for a little more clearance for the telescoping bolt. The weapon was reassembled as before and tested, the results as shown in Figure A-2 were about the same except for the 2-13/16 inch bullet grouping. Sixty (60) rounds were fired through the weapon which again resulted in malfunction of the bolt. On examination we found slight buldging of the expansion chamber tube close to the vent holes in the barrel. See Figure A-4 for field test results on the standard and modified weapon.

B. **Results**

The results of the above procedures, test, evaluations, and modifications made on the Beretta Model 12 are as follows.

1. **Standard Weapon**

The standard Beretta Model 12, 9mm submachine gun is am example of fine production workmanship. The weapon is well balanced and compact and if fired as a submachine gun by spotting rounds to get on target it is fine. The accuracy of firing a single round does not compare with that of a fixed barrel type weapon. This is due to the fact that the barrel is floating and is held in place by the two (2) bayonet lugs on the front of the barrel in the retaining nut. The rear of the barrel is only guided on the two

Experimental Model

Name: Submachine Gun — Type: Automatic

Make: Beretta Model 12 — Caliber 9mm Parabellum

Description Unmodified:	Description Modified: Silenced
Operation: Blowback selective fire	Operation: Blowback selective fire
Size: Length *, Width **, Thick 2-13/32"	Size: L - Stock extended 32-1/2", folded 23-1/8"
Weight: w/20 rd. mag. 7 lbs. 3 oz.	Weight: w/20 rd. mag. 9 lbs. 3 oz.
Other: * L - stock extended 25-7/8" ** W - w/20 rd. mag. 7-1/8"	Other:

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 1326 E. V. - 8'		Ave - 966 E. V. - 79	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards	-	-	-	-
b) 10 yards	-	-	-	-
c) 15 yards	1-3/4"		6"	
d) 25 yards	3"		10-1/2"	
e) 50 yards	8-3/4"		27"	
f) 75 yards	11"			
g) 100 yards	17"			
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards				
3; Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	80 yards		30 yards	
b) Range of 6" Vertical Drop	75 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	154 db		127 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot	YES		YES	
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE A - 4

(2) guide rails of the telescoping bolt, which is a relatively loose fit. The bolt itself is guided in a rolled sheet metal tube and held in position by the cocking knob riding in a slot cut out in the receiver. The loose fits of these parts effects the one shot accuracy of the weapon and, as shown in Figure A-2, with underloaded ammunition the bullet grouping was worse then any of the fixed barrel submachine guns previously tested.

2. **Modified Barrel and Barrel Silencer**

Because of the telescoping bolt the venting of the high pressure gasses into a large expansion chamber was impossible. The vent holes drilled into the barrel were capable of reducing the velocity of the bullet, however, the barrel silencer or expansion chamber around the barrel did not present enough volume to reduce the velocity of the bullet and as a result another chamber had to be added to absorb the expanding gasses. Although the velocity of the bullet was reduced the noise level was still high. Using a screen roll on the barrel reduced the volume of the barrel silencer and increased the velocity. It was determined to sacrifice some noise level to assure that the velocity of the bullet would be kept below the sonic range.

3. **Muzzle Silencer**

The muzzle silencer used on this weapon was identical to those used on all the fixed barrel submachine guns in this program. This type unit was used to more or less standardize the muzzle silencer for use on any submachine gun. It should be noted that the bushing that is threaded on the muzzle of the barrel had four 0.201 inch diameter holes, which were necessary to reduce the noise level to 127 db.

4. **Accuracy**

It is difficult to say what is the major contributing factor that causes the inaccuracy of this weapon. The bullet grouping of the weapon with an underloaded round was 2-3/16 inches, with all the modifications added to the weapon the grouping was 2-3/4 inches. We believe that the weapon itself, due to the floating barrel, is inaccurate plus the reduced velocity of the bullet upsets the ballistic characteristics just increases the inaccuracy.

5. **Malfunction**

When silencing a blowback operated weapon any change which reduces the operating pressure will upset the design characteristics of the weapon. The reduction of the gas pressure to reduce the velocity of the bullet also reduced the blowback pressure which in turn reduced the pressure applied to the face of the bolt. This reduction in pressure caused a malfunction in that the bolt did not compress the recoil sufficiently to engage the sear and resulted in a runaway gun. A lighter weapon recoil spring was substituted which corrected this problem. Another malfunction that occurred with this weapon caused misfires, and failure to eject was caused by the accumulation of burnt powder on the outside diameter of the barrel silencer and a buldging of the tube itself near the chamber. Both of these presented obstructions which slowed the movement in the forward and rearward action of the telescoping bolt.

C. Conclusions

Reviewing the results of the work done on the Beretta, we feel that this weapon does not lend itself to an economical straight forward method of silencing.

The wide spread in the bullet grouping indicates that the floating action of the barrel effects the accuracy of the weapon and the reduced velocity just increases the inaccuracy.

It is also evident that to reduce the noise level of the weapon a more sophiscated method of venting the high pressure gasses into a large expansion chamber is required.

The Beretta Model 12 has some distinct advantages, compact size, many safety features, and quality workmanship that warrant further investigations into increasing its accuracy and the silencing of this weapon.

D. Recommendations

From the work accomplished on this assignment, and the data established from this program there are three (3) areas that should be investigated to developed a silent Beretta Model 12 submachine gun, that is comparable to and possible better then any of the fixed barrel type developed to date.

1. **Accuracy**

The floating barrel arrangement on the Beretta as manufactured does not lend itself to a real accurate weapon. If the barrel, the barrel locking ring and the attachment of the barrel and muzzle could be made up of one single concentric assembly rigidely attached to the receiver, the accuracy of the weapon would be greatly improved.

2. **Malfunction**

   The action of the telescoping bolt over the barrel silencer caused malfunctions in this unit because of the collection of burnt powder and the bulging of the tube. This could be corrected by the cold working the tubing used to make the barrel silencer to increase the strength of the tube and prevent it from bulging. By making the barrel as part of an assembly, described above in D1, the barrel silencer should be threaded to the barrel which would prevent any burnt powder from collecting on the outside diameter of the tube. The tube could then be ground to be concentric with the bore of the barrel and a guide bushing pressed into the forward guide ring of the telescoping bolt, which could help the over-all accuracy and prevent any malfunctioning.

3. **Noise Level**

   Experiments would have to be made into the best methods of bleeding the high pressure gasses into a large expansion chamber or barrel silencer. Some thought should be given to using the muzzle silencer to accomplish this by using a tube within a tube, and using the outer annulas for the expansion chamber or barrel silencer. These modifications would improve the performance of this weapon, however, they would not be the most economical.

UZI SUBMACHINE GUN

B. Uzi 9mm Submachine Gun

The Uzi 9mm submachine gun was selected for modification on this program in order to develop data and experience on telescoping bolt type weapons.

This weapon varies slightly from the Beretta Model 12, 9mm submachine gun in that the telescoping bolt does not guide on the barrel and the main mass of the bolt when view from the muzzle is in the upper right hand side of the weapon. The bolt encases the barrel on three (3) sides except for the upper left hand quadrant of the barrel near the ejection port.

The weapon is compact, and the receiver is made from sheet metal stampings as shown in Figure B-1, Standard Uzi.

Purpose: The purpose of this assignment was to investigate the problems associated with the silencing of a telescoping bolt type submachine gun and to develop a silencer for this weapon.

Procedure: Our approach to solving the problem associated with the silencing of the Uzi submachine gun was to develop data, starting with the standard weapon, and to produce layout drawings. The layout drawings were used to evaluate what area near the chamber of the barrel could be utilized to vent the high pressure gasses.

From these drawings and dimensional checking of the weapon we found that none of the conventional methods used on the previous programs could be used in the modification of this weapon.

1. **Standard Weapon Test and Evaluation**

   The standard weapon was disassembled and the component parts were dimensionally checked for loose fits and areas of misalignment. The barrel is inserted in the front of the receiver and a collar fits in the receiver recess. The barrel is locked in place by a retaining nut and held in position by two (2) machined diameters that mate with machined surfaces in the receiver. The bolt rides in the sheet metal frame of the two (2) bottom edges, any misalignment between the barrel and bolt would have little effect on the accuracy of the weapon. The weapon was assembled and tested for accuracy both with standard Canadian ammunition with a velocity of 1,300 feet per second and with underloaded Canadian ammunition with a velocity of 950 feet per second. The results of this test, as shown in Figure B-2, is a bullet group size of 11/16 inch with the standard ammunition and a 3/4 inch group with the underloaded ammunition.

2. **Silencer Design**

   In the development of a silencer for the Uzi, assembly drawings of the barrel and the telescoping bolt were made to determine what area should be used to vent the high pressure gasses from the chamber. It was not possible to drill holes around the diameter of the barrel as is our normal method for venting the high pressures from the chamber. The only accessible area was just forward of the ejection port. This was an open area on the bolt and only a small portion forward of the ejection port had to be cut away. Two (2) rows of two 0.125 inch diameter holes were drilled in the barrel just forward of the

Standard UZI

Modified UZI

Note the manifold and tubing needed to carry the gas forward to the front can.

FIGURE B-1

chamber. To vent these gasses into an expansion chamber it was necessary to weld a manifold block on to the barrel. This, in turn, required the cutting away of a 1/4 inch bridge at the front of the bolt which would allow the bolt to recoil past the manifold block. The collar on the barrel that mated with the recess on the receiver had to be machined off to allow removal of the barrel rearward through the receiver because of the manifold block. A threaded collar was made to replace the one on the barrel to hold the barrel in place. We assembled the weapon to check the velocity of the bullet and the result was 1,000 feet per second. A high pressure stainless steel tube fitting was threaded into the manifold block and a stainless steel tube was made to carry the high pressure gasses to an expansion chamber threaded over the muzzle of the barrel (see Figure B-3). This expansion chamber had to be made eccentric to allow room for another stainless steel fitting for connecting the manifold tube.

3. **Muzzle Silencer**

A standard muzzle silencer was made up the same as that used on all weapons selected for this program to try standardize on one type.

4. **Test**

The weapon was assembled and the muzzle silencer attached with the use of an aligning rod. The weapon was tested, and as shown in Figure B-2, the noise level was 126 db, the velocity was 1,000 feet per second, and the bullet grouping was 3-5/8 inches. The results

9mm UZI ACCURACY & SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
Canadian	Stock	1310 fps	11/16 inch	155 db
Canadian Underload	Stock	950 fps	3/4 inch	155 db
Canadian	Modified	1000 fps	3-5/8 inch	126 db

FIGURE B - 2

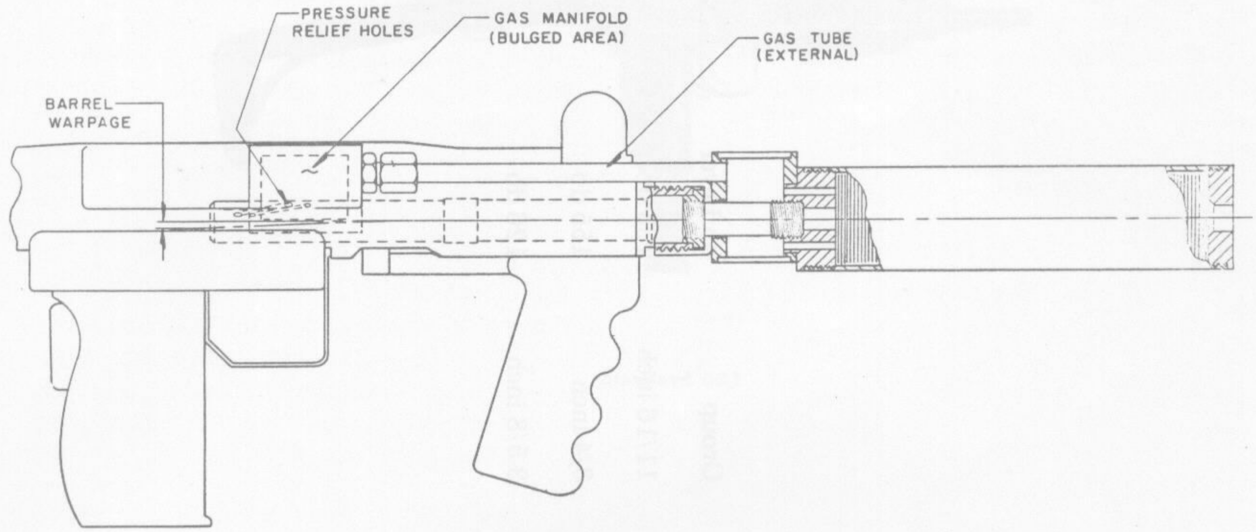


FIGURE B-3

of this test, especially the accuracy, caused us to disassemble the weapon and dimensionally check all the component parts from the barrel to the muzzle silencer. This inspection showed the following.

a. **Barrel Warped** — The area at the chamber where the heavy manifold was welded to the barrel was warped. This resulted from the heat required in welding heavy steel block to a thin walled barrel. The warpage occurred throughout the length of the barrel and was due to the fact that all the heat was applied to only the chamber end of the barrel.

b. **Manifold Block Bulge** — On inspection it was found that the heavy steel manifold block was bulged from the high pressure gasses generated at the chamber.

c. **Bullet Stripping** — From the test, several rounds fired through the Uzi were captured and inspected for bullet jacket stripping. On inspection it was found that the barrel jackets were stripped on one side only. This was caused by the pressure relief holes near the chamber being drilled into the barrel on one side only. Normally, the small vent holes in the barrel are equally spaced around the diameter and any slight stripping which may occur is symmetrical and does not effect the accuracy. As a result of all the extensive problems which accompanied the silencing of the Uzi and the excessive cost of modifications, we completed work on this weapon with the field testing of the standard and modified units.

B. **Results**

The results of the above modifications, tests, and evaluation performed on the Uzi 9mm submachine gun are as follows:

1. **Standard Weapon**
   The standard Uzi submachine gun is a compact, well made and accurate, because of the fixed barrel, weapon. It has all the desired safety features, but is very uncomfortable to fire. The magazine fits in the pistol grip and there is no forward grip to hold with the left hand and it is difficult to fire without extending the shoulder stock.

2. **Modified Weapon**
   The modifications made to this weapon were extensive and was directly responsible for the inaccuracy which resulted. The

welding of a heavy manifold block to a thin walled barrel caused warpage of the barrel throughout the length. The drilling of the vent holes in one small location near the chamber caused excessive stripping of the bullet jacket which also contributed to the inaccuracy of the modified weapon. The manifold tube added to the outside of the weapon, to bring the high pressure gasses to the front of the weapon, required extensive machining of the expansion chamber to make the necessary high pressure connection. All these factors plus reworking the barrel to make it possible to remove it from the rear of the receiver instead of from the front required extensive modification to the basic weapon.

C. **Conculsions**

Reviewing all the work that went into the modification of the Uzi 9mm submachine gun for silencing and the results of this program, it is obvious that this weapon does not lend itself to silencing.

This does by no means say that the weapon cannot be silenced, however, the number of component parts that would have to be reworked would not make it economically justifiable.

The bolt would have to be machined to allow clearance for a barrel silencer. The barrel support in the front of the receiver would have to be removed and replaced with a newly designed front end to support the barrel and barrel silencer and provide for the attachment of the muzzle silencer.

Even with the extensive reworking of these parts no guarantee could be given as to the results or what effect it would have on the rest of the weapons mechanisms.

D. **Recommendations**

From the above program the cost of silencing this weapon is not justifiable.

It is also recommended that if this weapon was needed in a silenced condition, that a standard muzzle silencer could be threaded on the muzzle of the barrel, and used with underloaded ammunition. Even with this arrangement it probably would be necessary to modify the recoil spring and lighten the bolt to provide automatic operation.

Assignment IV — **High Powered Rifles**

This assignment is essentially a carry over of a previous study program which resulted in the silencing of a .303 Enfield MK 5 rifle. Due to the fact that the Enfield is basically an outdated weapon, the 30.06 Springfield rifle was selected for further investigations. Because both the Enfield and the Springfield rifles were fired from a locked bolt arrangement, it was decided to include in this assignment a semiautomatic rifle of similar caliber for investigation, therefore, the F.N. - F.A.L., 7.62mm NATO automatic rifle was chosen.

SPRINGFIELD RIFLE

A. **1903 - 30.06 Springfield Bolt Action Rifle**

The reason for selecting the Springfield 30.06 rifle for this assignment was to carry on some of the work that was done on another study program.

In the previous program a silencer was developed for the .303 Enfield rifle. The results that were accomplished on this program reduced the velocity of the bullet to 1,020 feet per second and an overall noise level of 130 db, using standard military ammunition having an average speed of approximately 2,700 feet per second. With the use of pressure relief holes near the chamber of the barrel, a large diameter barrel silencer, and a large muzzle silencer, we were able to produce the above results.

The weapon itself was heavy and unbalanced with the use of a stainless steel screen roll and washers in heavy walled silencer containers, added about two (2) pounds to the basic weapon.

The over-all results proved that a high powered rifle could be silenced, however, the accuracy of the weapon was greatly affected because of the reduced velocity of the projectile, and to some degree by the screen washers.

This assignment was established to develop a muzzle silencer to be used in conjunction with underloaded ammunition having an average velocity of 1,000 feet per second.

Purpose: The purpose of this program was to evaluate the work done on high powered rifles and to determine the best approach for silencing weapons of this type.

Procedure: Review of all the work done on high powered rifles and underloaded ammunition.

1. **Review, Evaluation, and test**

   As mentioned above in the development of a silencer for the Enfield .303 caliber rifle we were able to obtain relatively good results using standard military ammunition using a large silencer. The reduction in velocity caused the bullet to keyhole and resulted in very poor accuracy. From this point we used a standard Enfield rifle with underloaded ammunition (1,000 feet per second) with the same results, keyholing and poor accuracy. In an effort to maintain our velocity as close to 1,000 feet per second a program was initiated to fill the remaining volume of the cartridge case with flour, and other substances. This worked well to stabilize the velocity but did nothing to improve the accuracy. The addition of a muzzle silencer and the underloaded ammunition gave good results on the noise level, but deteriorated rapidly when the screens became clogged with filler material used. From all the above work and the results of all our silencing work to this point, it was concluded that the decrease in velocity accomplished either by silencing the weapon or underloading the ammunition to about 1,000 feet per second causes inaccuracy both at short ranges and at 120 ft. The object was to develop ammunition that would maintain its accuracy up to 200-300 yards, with a velocity of about 1,000 feet per second.

2. **Ammunition Development**

As was stated above, several attempts were made to develop underloaded ammunition for use on this program with limited results. Concurrently with this study program another contract was let by your organization to the H. P. White Laboratories to develop a 30.06 round having a velocity of approximately 1,000 feet per second, with a projectile that would remain stable in flight and accurate between 200-300 yards. The ammunition resulting from this program had the following components.

1. 8.5 Grains, Bull's-eye powder
2. Winchester 120 Primer
3. Remington Case
4. 220 Sierra round nose, Soft-point bullet (resized to a diameter of .3047 inches)

Tests were made with this ammunition, using a stand rifle and with a muzzle silencer. The results of that test are shown in Figure A-1.

3. **Muzzle Silencer**

The muzzle silencer used for the above test was Maxim type, using expansion chambers and metal discs. The noise level was 128 db, which was better than any weapon developed to date. Another muzzle silencer was developed for the Springfield rifle using stainless steel screen washers and tests were performed on our 40 foot range. The results of that test are shown in Figure A-2, using a standard weapon, and standard weapon with the newly developed ammunition and muzzle silencer. The muzzle silencer packed with stainless steel washers reduced the noise level but effects the accuracy. This could be corrected by increasing the inside diameter of the holes in the screen washers but the noise level would increase.

B. **Results**

The results of the above program, tests, and evaluations are as follows.

1. **Standard Weapon**

The use of a standard weapon with special designed ammunition and a simple muzzle silencer is the best approach for silencing a bolt action high powered rifle. It is by far the most economical approach to the problem that delivers the accuracy and reduces the noise level desired. This method of silencing presents a problem in the supplying of the special purpose ammunition to the operator. With this system of silencing there is no modifications required to the standard weapon, therefore, no problems such as malfunctions should arise due to reworking of the unit.

2. **Muzzle Silencer**

The muzzle silencer for this weapon can be attached in either of two (2) ways; by threading the muzzle end of the barrel, or by a hinged attachment with a wing nut to clamp around the muzzle of the barrel. The latter arrangement is the best approach in that it does not require any machining of the weapon, therefore, all the operator needs is the special ammunition, a muzzle silencer, and any Springfield rifle or similar unit.

3. **Accuracy**

The accuracy of this weapon is greatly improved over that of any other silenced weapon plus the increase in range. The operator should have at least a chance to get the feel of the weapon and adjust to the derease in the over-all capability of the modified weapon.

C. **Recommendations**

From the data developed from the above programs and the need for increased range and accur-

Name: U. S. Rifle, Caliber .30	Type: Bolt Action Rifle
Make: Springfield Model 1903	Caliber 30 - 06
Description Unmodified: Stock	Description Modified: Muzzle Can
Operation: 5 Shot, Bolt Action	Operation: 5 Shot, Bolt Action
Size: L - 43-3/8", W - 5-3/4", Thick 3-1/8"	Size: L - 50-1/4", W - 5-7/8", Thick 3-1/8"
Weight: 9 lbs.	Weight: 10-1/2 lbs.
Other:	Other:

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	1015 fps		1025 fps	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards	9/16"		5/16"	
c) 15 yards				
d) 25 yards				
e) 50 yards	5/8"		3/4"	
f) 75 yards				
g) 100 yards	1-7/8"		1-3/4"	
h) 125 yards				
i) 150 yards	3-1/8"		3-1/4"	
j) 175 yards				
k) 200 yards (300 meters/30X scope 10 shot group 9-1/2")	5-1/2"		4-3/4"	
3. Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group			300 M	
b) Range of 6" Vertical Drop			70 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)			500 M	
4. Noise Level (db, at muzzle 24' in front, 3' right)	144 db		128 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot	YES		YES	
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS: Ammunition

1) 8.5 Grains Bulls Eye, 200 Grain Cal. .30 (.308" resize to .3047") Serra Match King Ball.

FIGURE A - 1

30 - 06 SPRINGFIELD ACCURACY & SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
30 - 06 MIL	Standard	2740 fps	1/4 inch	153
H. P. White Underload	Standard	950 fps	1/4 inch	138
H. P. White Underload	Standard with muzzle silencer	950 fps	1/2 inch	125

FIGURE A - 2

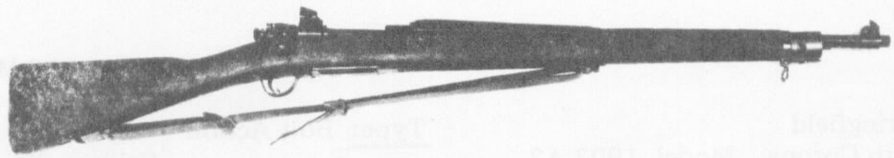
Experimental Model

Name: Rifle - Springfield	Type: Bolt Action
Make: U. S. Smith Corona Model 1903 A3	Caliber 30 - 06
Description Unmodified:	Description Modified: Silencer
Operation: Turning Bolt, magazine fed	Operation: Turning Bolt, magazine fed
Size: L - 43-3/8", W - 6-9/16", Thick 3-1/8"	Size: L - 49-3/4", W - 6-9/16", Thick 3-1/8"
Weight: 8 lbs. 10 oz.	Weight: 10 lbs. 2 oz.
Other: Weights taken w/sling on.	Other: Weights taken w/sling on.

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 976 E. V. - 81		Ave - 976 E. V. - 36	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards				
c) 15 yards			7/8"	
d) 25 yards	1/2"		1-1/4"	
e) 50 yards	1-1/4"		2-3/8"	
f) 75 yards	2-3/8"		3-3/4"	
g) 100 yards	3"		5-1/2"	
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards	8"		13"	
3. Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	250 yards		200 yards	
b) Range of 6" Vertical Drop	70 yards		70 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	153 db		125 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS: Using the 1000 ft/sec Underloaded Ammunition

FIGURE A - 3



30-06 Springfield
Military Ammunition 2, 740 fps
db Level 153

30-06 Springfield
Underload 950 fps
db Level 125

FIGURE A-4

acy for a silenced weapon, the above approach to solving these problems is the logical way to go.

1. **Accuracy**

   The ballistic characteristics of the projectile must be based on velocities of about 1,000 feet per second, the weight of the bullet could be increased depending on the impact velocities, and the range required. This can only be accomplished in the design of the ammunition and not by modifying the weapon. In silencing, no matter what type of weapon we modified, the range is limited to a 12 inch bullet grouping at 100 yards. This is accomplished on some weapons with a very high bullet trajectory and the maximum adjustment on the sights. The accuracy is not condusive to a first shot kill potential due to the reduction in bullet velocity and the upset in the ballistic characteristics which causes the bullet to tumble and vear off the target. With the new system in designing underloaded ammunition, the operator should have more confidence in the weapon achieving his desired goal.

2. **Malfunctions**

   Modification of the working mechanisms or component parts on any weapon will eventually lead to malfunctioning of the unit. Most weapons are designed and tested over long periods of time before they are accepted as a reliable weapon system for use by the combat troops. The reworking of components or the addition of parts necessary to silencing a weapon also affect the design characterisitics of the unit and results in malfunctions. With the use of underloaded ammunition with a standard bolt action rifle and a muzzle silencer reduces the danger of any malfunctioning.

3. **Noise Level**

   The use of underloaded ammunition reduces the velocity of the bullet to below the speed of sound which reduces the sonic crack (see Figure A-2). The major portion of the work involved in silencing a weapon is to bleed the high pressure gasses off fast enough to reduce the bullet velocity to about 1,000 feet per second. The muzzle silencer does not have to absorb and cool such large volumes of gas to muffle the blast and can therefore, be made smaller, when using underloaded ammunition. With the use of underloaded ammunition the muzzle silencer can achieve noise levels in the order of 128 to 125 db.

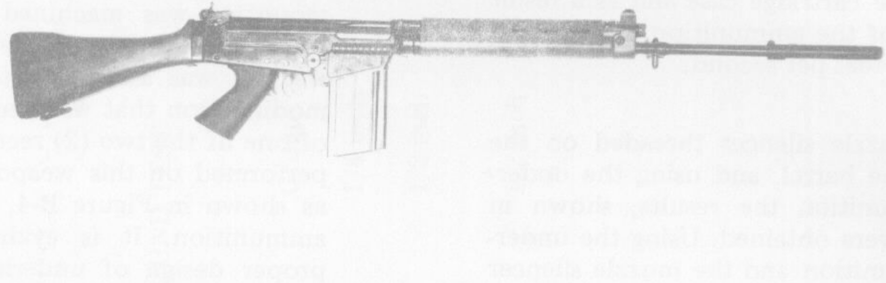
D. **Conclusions**

The design of underloaded ammunition for the use in standard bolt action rifles with a muzzle silencer is probably the most reliable and economical approach to silencing high powered rifles.

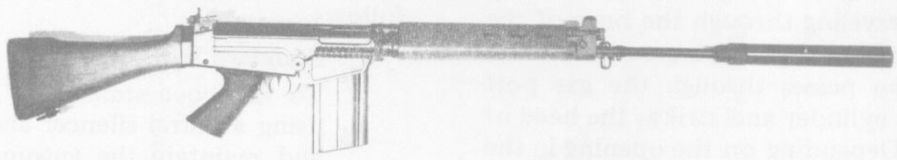
Some thought may be given to improving the muzzle silencer, both from the standpoint of attaching the unit to the rifle, and for noise level reduction.

Methods of quick attachment and positive alignment ought to be investigated to prevent any interference with the bullet.

Experiments should be made in silencer design and packing arrangements to reduce the noise levels at least another 10 db's.



7. 62 FAL
Military Ammunition 2, 690 fps
db Level 153



7. 62 FAL/Muzzle Silencer
Underload 89 fps
db Level 123

F.N. - F.A.L. AUTOMATIC RIFLE

B. **F.N. - F.A.L. 7.62mm NATO Automatic Rifle**

This weapon is gas operated with an adjustable regulator to insure a smoothness of operation without excessive recoil. The bolt is mechanically locked in position before firing can take place and is not unlocked unitl the bullet has left the barrel.

These features were the prime factors in selecting this weapon for study in this assignment, see Figure B-1.

Purpose: The purpose of this program was to silence the F.N. - F.A.L. rifle using underloaded ammunition and try to retain its automatic features.

Procedure: The approach to solving the problems on this program was to silence the weapon first and then to review and evaluate what modifications would be necessary to maintain the functional characterisitics of the weapon.

1. **Muzzle Silencer**

The flash hider on the F.A.L. is threaded on the muzzle of the barrel. Our first step was to make up a muzzle silencer similar to that used on the Springfield rifle with a thread to mate with that already on the barrel, see Figure B-1. The muzzle silencer was packed with stainless steel washers as before which resulted in a 125 db noise level. A comparison between the standard rifle, underloaded ammunition and standard rifle, and underloaded with a muzzle silencer is shown in Figure B-2.

2. **Underloaded Ammunition**

The ammunition used on this program was .308 caliber military ammunition, with sufficient powder removed to reduce the velocity to about 1,000 feet per second. No filler material was used to take up the excess volume in the cartridge case and as a result the velocity of the ammunition ranged from 850 to 1,100 feet per second.

3. **Test**

With the muzzle silencer threaded on the muzzle of the barrel, and using the underloaded ammunition the results, shown in Figure B-3, were obtained. Using the underloaded ammunition and the muzzle silencer produced good over-all noise level results, however, this is partially due to the locked bolt mechanism which prevented any gas from escaping from this area.

4. **Automatic Functioning**

The functioning of the gun is operated by the bullet traveling through the bore of the barrel. A portion of the gas generated from the explosion passes through the gas port into the gas cylinder and strikes the head of the piston. Depending on the opening in the gas regulator, the surplus gas which is not needed to operate the bolt mechanism escapes to the outside atmosphere through a vent. This minimum setting on the gas regulator using standard ammunition must allow the bolt assembly to travel far enough to the rear to engage the sear. It should also be noted that it is the gas pressure that is developed behind the bullet as it travels through the barrel that operates the gas piston rod. After the noise level tests were completed the weapon was reviewed for possible malfunctions that could be made to maintain the automatic features of the weapon. Our first approach to achieve automatic operation of this weapon with underloaded ammunition was to increase the diameter of the gas port hole leading from the bore of the barrel into the gas chamber from .094 inches to .113 inches. The weapon was assembled and tested with underloaded ammunition. There was no movement of the bolt assembly or unlocking of the breech mechanism. Using the same arrangement as above we replaced the two (2) recoil springs with a single lighter spring. The weapon was tested with an underloaded round with the same results as above, the breech did not unlock to allow the bolt to move rearward. In our next approach we plugged the gas port hole that bleeds the gas from the barrel into the gas cylinder. The gas cylinder assembly was removed from the weapon and shortened by 4.560 inches in length. A new vent hole and mounting was machined on the barrel to match the length of the gas cylinder. The weapon was assembled and the only other modification that was made was the removal of one of the two (2) recoil springs. The test performed on this weapon gave the results, as shown in Figure B-4, using underloaded ammunition. It is evident that with the proper design of underloaded ammunition as developed for the Springfield rifle that the automatic function of the rifle can be retained.

A. Results

The results of the above experiments are as follows.

1. **Standard Weapon**

To silence a standard F.A.L. 7.62mm rifle using a barrel silencer and a muzzle silencer and maintain the automatic functioning of the rifle would be virtually impossible due to the location of the gas cylinder assembly. The weapon can be silenced as a single shot weapon using the barrel silencer and muzzle silencer, but the modification would be expensive. To silence this weapon, using underloaded ammunition, and maintain its automatic functioning would also require extensive modification to the unit. From the work done on the F.A.L. the use of a muzzle silencer with underloaded ammunition would be the best approach. The only bad feature would be that the weapon would have to be operated as a single shot weapon. The single shot feature helps in the over-all noise reduction in that it prevents any gas from escaping from the breech of the weapon. With this method of silencing the F.A.L. there is no modifications required to the weapon and the weapon can be used with standard ammunition at any time.

2. **Muzzle Silencer**

The muzzle silencer for this weapon can be attached by removing the flash hider on the

F. N. - F. A. L. 7.62mm NATO ACCURACY & SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
7.62 NATO	Standard	2690 fps	1/4 inch	153
7.62 NATO Underload	Standard	880 fps	1/2 inch	137
7.62 NATO	Standard with muzzle silencer	890 fps	1/2 inch	123

FIGURE B - 2

VELOCITY & NOISE LEVEL TEST

Ammunition	Weapon	Velocity (ft/sec)	Noise Level (db)
.308 Underloaded	Standard muzzle silencer	855	122
.308 Underloaded	Standard muzzle silencer	894	123
.308 Underloaded	Standard muzzle silencer	1109	132
.308 Underloaded	Standard	1100	138
.308 Standard	Standard	2690	153

FIGURE B - 3

AUTOMATIC FUNCTIONING TEST
(Gas cylinder assembly reduced in length)

Bullet Weight	Powder Charge	Velocity	Automatic Operation
144 grains	9.5 grains	900 ft/sec	No
144 grains	15 grains	1350 ft/sec	Yes
220 grains	15 grains	1100 ft/sec	Yes

The powder used was taken from English 7.62 mm NATO ammunition

FIGURE B - 4

Experimental Model

Name: Rifle
Make: Belgium F. N. Model F. A. L.
Description Unmodified: Standard
Operation: Gas, full or semiautomatic
Size: L - 44-5/8", W - 8-1/4", Thick 3-1/4"
Weight: 9 lbs. 13 oz.
Other: w/magazine

Type: Semiautomatic
Caliber 7.62mm NATO
Description Modified: Muzzle Silencer
Operation: Gas, Semiautomatic only
Size: L - 49-3/8", W - 8-1/4", Thick 3-1/4"
Weight: 11 lbs.
Other: Weapon modified to fire semiautomatic only w/magazine

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 900 E. V. - 337		Ave - 966 E. V. - 277	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards				
c) 15 yards				
d) 25 yards	1"		3/4"	
e) 50 yards	1-1/2"		1-1/4"	
f) 75 yards	4"		3-1/2"	
g) 100 yards				
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards				
3. Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	200 yards		200 yards	
b) Range of 6" Vertical Drop	60 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	153 db		112 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE B - 5

muzzle of the barrel and threading the silencer on in its place. This feature does not require any rework of the standard weapon.

3. **Accuracy**

The accuracy of this weapon would be dependent on the design of the underloaded ammunition that would be supplied.

B. **Recommendations**

Our recommendations on the F.A.L. 7.62 automatic rifle are somewhat interrelated and are discussed below.

The first step in developing this weapon for silencing would again begin with the design of the ammunition to be used. Second, the addition of a threaded on muzzle silencer, the weapon would be silenced having a noise level of approximately 120 db and a projectile velocity of 1,000 feet per second. The accuracy, depending on the projectile, would be in the order of an 8 inch group at 200 to 300 yards. The weapon, however, would be a single shot weapon and would have to be reloaded by use of the cocking knob. With this arrangement the use of standard military ammunition would present no problem and the weapon could be used as a standard rifle and a silenced single shot rifle.

A modification of the weapon to retain its automatic function would require underloaded ammunition and a muzzle silencer which would produce about the same results. The use of standard military ammunition in a modified weapon of this type may be marginal and would be entirely dependent on the bleeding off of the high pressure gasses from the gas cylinder assembly. The effect of the high pressure gasses on the recoiling parts may be rather dangerous to the operator and also may cause excessive damage to the weapon.

If the decision is made to go in either of the above directions in the future development of this weapon, we recommend that the following areas be covered.

1. **Ammunition Development**

Development of an underloaded 7.62mm round to produce 1,000 ft/sec velocity. This program should cover the following steps:

a) Select bullet to be used. The bullet should have the heaviest boat tailed projectile possible. The increased weight of the bullet reduces the muzzle velocity, increases gas pressure inside the barrel, and would reduce downrange deflections. Based on the ammunition designed for the Springfield rifle, the boat tailed design resulted in the best accuracy at subsonic speeds. It is desirable to use standard components whereever possible.

b) Perform final adjustment of pressure and velocity by varying the type of primer, powder type and weight to achieve the best over-all range and accuracy.

2. **Weapon Development**

The modified weapon should be completely tested for safety, functioning, and reliability with the underloaded ammunition. The following areas should be investigated.

a) Determine proper recoil spring characteristics and gas port size for use with underloaded ammunition.

b) Replace the frame of the test weapon with an F.A.L. frame having a full automatic position on the selector and test for full automatic functioning. (Weapons received do not have full automatic selector capabilities.)

c) Test the weapon with approximately 5,000 rounds inspecting parts every 500 rounds.

d) Test the weapon for functioning and safety with standard .308 ammunition as mistakes and emergencies do happen. Note that the gas regulator mentioned above may be used to reduce the gas pressure available to the operating rod in this case. The gas valve may also be closed, making the weapon manually operated and safe with high velocity ammunition. Instructions must be explicit on this point to prevent damage to the weapon and possible injury to the operator.

C. **Conclusions**

This weapon merits further investigations, use in the modified condition, using underloaded ammunition and muzzle silencer. The work is necessary to extend the range and accuracy of the silenced weapons.

To date all the 9mm submachine guns using standard Canadian ammunition have a limited range and a below average accuracy. An automatic weapon like the F.A.L., or similar type weapon, would increase the range and accuracy in an automatic weapon with a 20 round magazine capacity.

Assignment V — **Side Arms**

A review of the various side arms were made and the Luger Model P-08, 9mm Automatic and the Beretta Model 1934, .380 Automatic Pistols were chosen for this assignment.

The Luger was chosen because the barrel projects from the receiver and the chamber is accessible for the drilling of the vent holes near the chamber of the barrel.

The Beretta was chosen because of the bullet weight and its subsonic velocity.

Both these weapons have fixed barrels which is essential to maintain a fair amount of accuracy.

Luger P-08, 9mm
db level 155 average

LUGER AUTOMATIC PISTOL

A. **Luger P-08, 9mm Automatic Pistol**

The Luger was selected for modification on this program because of the ease with which it could be modified in comparison to most other automatic pistols. The advantage in the Luger is that the barrel is mounted in such a way as to give good accessibility to the chamber end of the barrel.

Due to the sonic velocity of the 9mm round (1300 fps) a means for reducing the bullet speed is needed. This is best accomplished by the drilling of pressure relief holes in the barrel close to the chamber.

Most of the other 9mm automatic pistols are of a design that do not provide easy access to the chamber area and would require a very complicated gas porting arrangement.

Purpose: The purpose of this program was to provide an effective silenced 9mm side arm.

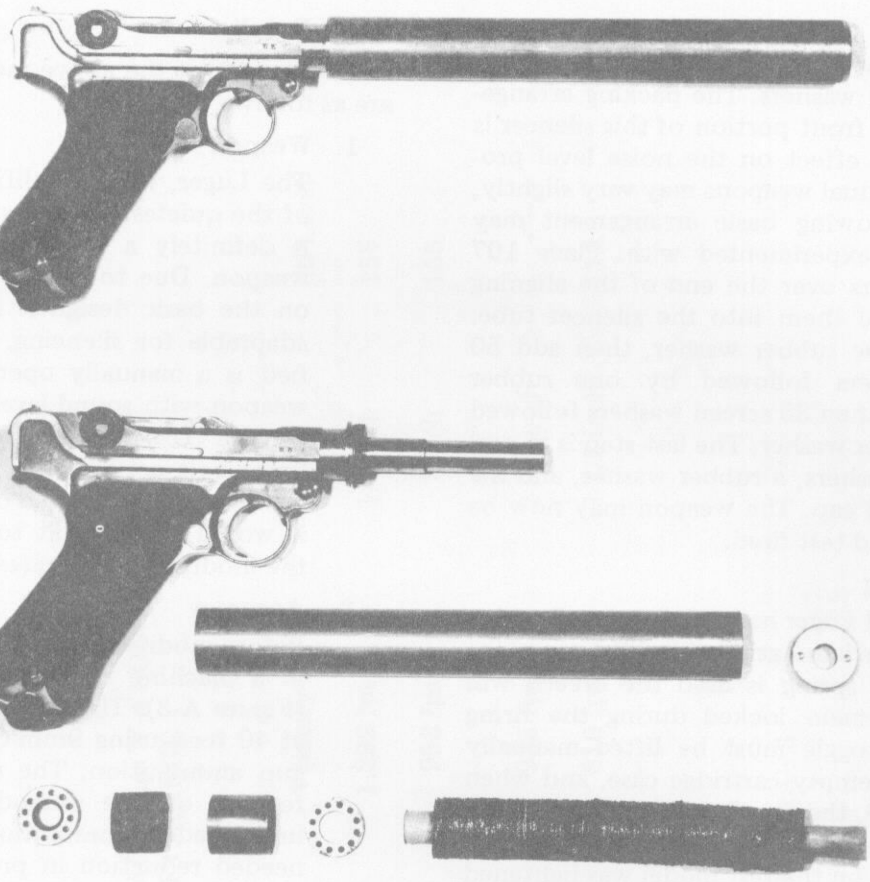
Procedure: As it is our objective on this program to standardize the silencer designs wherever possible, the Luger modifications and silencer were basically the same as found on the silenced 9mm Gustaf SMG, which was very successful.

1. **Design**

   The experience gained on the Gustaf dictated the physical layout of the pressure relief holes, the materials to be used, and the general construction.

2. **Weapon Modifications Performed**

   The barrel was modified in the following manner. The over-all length was cut to 4.50 inches, the material being removed from the muzzle end (if a standard Luger barrel of less than 6 inches length is used, the ring of material at the muzzle where the front sight dove-tail is cut, must be turned off). A shoulder about .060 wide was left where the



Silenced P-08, 9mm
db level 112 average

FIGURE A-2

barrel seats against the receiver. Ahead of this shoulder the barrel was turned cylindrical, and a collar .625 inches long was pressed over the barrel and silver-soldered in place. This collar was then turned to an outside diamter of 1.125 inches and threaded to attach to the rear end of the silencer. Four (4) pressure relief holes of .093 diameter were drilled in the barrel at a distance of 1.50 inches forward of the breech and angled toward the chamber at 12^{o} from the axis of the bore. The pressure holes were located every 90^{o} around the barrel (see Figure A-2).

3. **Silencer Design**

The silencer is made from 1-1/8 inch diameter steel tubing with a 16 gauge wall (.995 inch I.D.). It is threaded at one end to attach to the barrel collar and at the other end to receive the end cap. A ventilated baffle 1/8 inch thick was fabricated to break up the flow of gas leaving the pressure relief holes and a ventilated bushing .312 inches thick with a .406 inch diameter through hole and a counterbore .156 inches deep was also fabricated to support the front end of the barrel (Figure A-2).

4. **Silencer Assembly**

Assembly of the unit is as follows: the barrel is tightened into the receiver and the baffle is slipped over the barrel. A roll of 30 mesh, .013 inch wire diameter, stainless steel screen is placed around the barrel in front of the baffle. The ventilated bushing is located with its counterbore over the end of the barrel. The silencer tube is then slipped over this assembly and threaded to the barrel. A 9mm aligning rod is then passed through the barrel from the chamber and the front portion of the silencer tube is packed with stainless steel washers. The packing arrangement for the front portion of this silencer is critical in its effect on the noise level produced. Individual weapons may vary slightly, and the following basic arrangement may have to be experimented with. Place 107 screen washers over the end of the aligning rod and slide them into the silencer tube. Then add one rubber washer, then add 50 screen washers followed by one rubber washer, and then 35 screen washers followed by one rubber washer. The last step is to add 30 screen washers, a rubber washer, and the threaded end cap. The weapon may now be assembled and test fired.

5. **Recoil Spring**

The standard Luger has a strong recoil spring located in the hand grip behind the magazine well. If this spring is used the breech will positively remain locked during the firing cycle. The toggle must be lifted manually to eject the empty cartridge case, and when it is released, the recoil spring will chamber the next round and lock the breech. The recoil spring on the test model was lightened somewhat. This did not allow the weapon to function automatically, but allowed the barrel and receiver to recoil enough that the toggle unlocked and partially extracted the case with no increase in noise level. The finger knobs on the toggle are left in a position where it is easy to complete extraction and ejection manually. The lighter recoil spring is not powerful enough to chamber a round and close the breech, so the toggle must be slapped down by hand to load and lock the weapon. The weapon can be fired faster if the lighter spring is used than if the standard Luger spring is used. The characteristics of this recoil spring are as follows:

Spring Type	Compression
Free Length	3.45 inches
Outside Diameter	0.384 inches
Material	Music Wire
Wire Size	.045 inch diameter
Spring Rate	6.87 lb/inch
Active Coils	23
Ends	Squared & ground

B. **Results**

The results of the above modification and tests are as follows.

1. **Weapon**

The Luger, when modified, ended up as one of the quietest weapons we have silenced. It is definitely a close range, special purpose weapon. Due to the good features inherent on the basic design it is safe, reliable, and adaptable for silencing. The Luger as modified is a manually operated, locked breech weapon with sound level, and accuracy comparable to the widely known "Welrod" 9mm bolt action pistol. Because the Luger has been sold and used on a world-wide basis it would be difficult to trace the origin of the modified weapon (see Figure A-2).

2. **Accuracy**

Before modifying the weapon it was mounted in a machine rest and tested for accuracy (Figure A-3). The group fired was a 1/2 inch at 40 feet, using 9mm Canadian submachine gun ammunition. The second test was performed on the unmodified weapon, using underloaded ammunition to determine if the needed reduction in projectile velocity (for subsonic speeds) would upset the ballistic characteristics of the projectile. The test was performed to help determine the cause of inaccuracies found in some silenced weapons. As noted in Figure A-3, there is some loss of accuracy caused by the underloading. Two more tests were performed to help determine the cause of inaccuracies, the first of which was the use of standard Canadian ammunition shot through the modified barrel without the silencer in place. The results, as found in Figure A-3, indicates that the pressure relief holes drilled in the barrel which reduced the velocity of the projectile to approximately the same as the underloaded ammunition caused additional instability above that of the underloaded ammunition. This is probably caused by the tearing off of bullet jacking material as the bullet passes over the pressure relief holes. The final test was performed using standard Canadian ammunition with the silencer in place. The accuracy deteriorated even further with the silencer. The lower velocity coupled with the projectile contacting the rubber washers is the most probable cause of this further deterioration.

LUGER P-08, 9mm ACCURACY & SOUNT TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
9mm Canadian	Standard	1,292 fps	1/2 inch	155
9mm Canadian Underload	Standard	953 fps	1 inch	155
9mm Canadian	Modified w/o Silencer	935 fps	2-3/4 inch	—
9mm Canadian	Modified w/o Silencer	810 fps	3-1/2 inch	112

FIGURE A - 3

Experimental Model

Name: Luger Pistol	Type: Automatic
Make: Coded Model 08	Caliber 9mm Parabellum
Description Unmodified:	Description Modified: Silenced
Operation: Recoil, Semiautomatic	Operation: Manual
Size: L - 8-1/2", W - 5-1/2", Thick 1-3/8"	Size: L - 16-1/8", W - 5-13/32", Thick 1-3/8"
Weight: 2 lbs.	Weight: 2 lbs. 4 oz.
Other:	Other: Barrel altered

Condition	Unmodified		Modified	
A. Ballistics Data:				
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 1179 E. V. - 58		Ave - 810 E. V. - 94	
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2	Test B. 8	Test A. 2	Test B. 8
a) 5 yards				
b) 10 yards				
c) 15 yards	2-3/4"		3-1/2"	
d) 25 yards	4-1/2"		8"	
e) 50 yards	7-1/2"		13-1/2"	
f) 75 yards	11"			
g) 100 yards	20"			
h) 125 yards				
i) 150 yards				
j) 175 yards				
k) 200 yards				
3. Effective Range (a, b, or c below, 10 rounds from machine rest)				
a) Range of 12" Group	80 yards		40 yards	
b) Range of 6" Vertical Drop	70 yards		60 yards	
c) Penetration (Range of Penetration of 1" thick pine boards)				
4. Noise Level (db, at muzzle 24' in front, 3' right)	155 db		112 db	
5. Cyclic Rate (Rounds/Minute)				
6. Capable of Single Shot				
B. Environmental & Life Test:				
1. Storage Temperature (- 65°F for 3 days, + 160°F for 2 days)				
2. Operational (- 20°F to + 125°F)				
3. Vibration (per MIL - STD - 810)				
4. Mud Test				
5. Drop Test (3 drops in 3 planes, 3 ft. high)				
6. Humidity (per MIL - STD - 810)				
7. Life Test (1000 Rounds or 6 db noise increase)				
8. Accuracy (same as A. 2 above)				
9. Cyclic Rate (Rounds/Minute)				
10. Muzzle Velocity (fps, 10 Round Average)				

REMARKS:

FIGURE A - 4

3. **Silencer**

The final design and method of packing are discussed in detail early in this report. The modified weapon is approximately 6-1/2 inches longer than the standard and weighs 3 lbs. empty (see Figure A-4).

C. **Conclusions**

The Luger, when modified, ended up as one of the quietest weapons we have silenced. It is definitely a close-range, special purpose weapon, but due to the good features inherent in the basic design, it is safe and reliable and adaptable to production in quantity.

D. **Recommendations**

The weapon is much easier to operate if the modified recoil spring is used.

1934 Beretta . 380

FIGURE B-1

BERETTA AUTOMATIC PISTOL

B. **Beretta Model 1934, .380 Automatic Pistol**

The Beretta was selected for this program mainly for its powerful but subsonic 9mm sonic cartridge. A second feature of the weapon is that even though it is one of the blowback operated design the barrel is locked to the frame and should have fair accuracy even with a silencer attached. No modifications other than a barrel extension to accommodate a muzzle silencer will be needed (see Figure B-1).

Purpose: The purpose of this program was to provide an affective silenced side arm that could be used either with or without the silencer.

Procedure: The first step was to determine the accuracy of the weapon both with and without a muzzle silencer.

Having determined the weapon accuracy, the next step will be to try different muzzle can sizes and packing configurations.

1. **Weapon Accuracy**

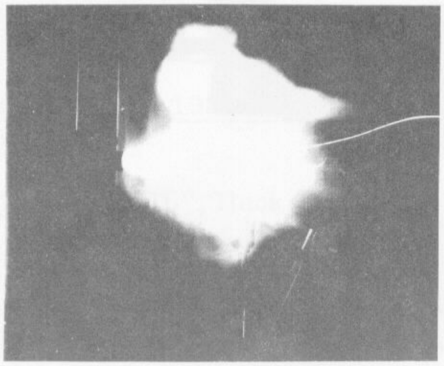
The standard weapon was mounted in the machine rest and test fired for accuracy. Group size was 1-1/4 inch at 40 feet, (see Figure B-2). An extension was then silver-soldered to the muzzle and a standard type muzzle silencer was fabricated. Ordinary 9mm screen washers and rubber discs were used to pack the muzzle silencer. The accur-

BERETTA .380 ACCURACY & SOUND TEST
40 FT. RANGE

Ammunition	Barrel	Velocity	Group	db Level
.380 Western	Standard	920 fps	1-1/4 inch	145
.380 Western	Standard w/Silencer	920 fps	1-1/2 inch	127
.380 Western *	Standard w/Silencer	920 fps	1-1/2 inch	125

* Heavy recoil spring and weight added to the slide to delay blowback.

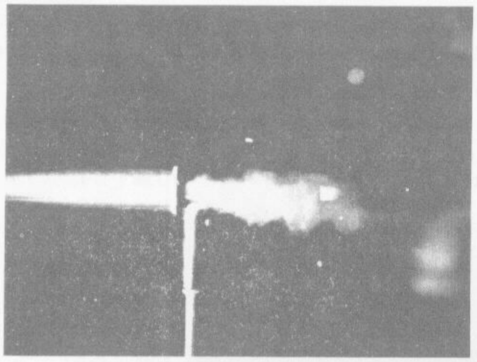
FIGURE B - 2



Beretta .380 without silencer.

Bullet in gas cloud

NOTE: Burning power particles to right of photograph, this is the most probable cause of silencer deterioration.



Beretta .380 with silencer.

NOTE: No sparks of flash and reduced disturbance of gas cloud. Some gas excapes before bullet, therefore, perfect silencer unlikely with standard ammunition.

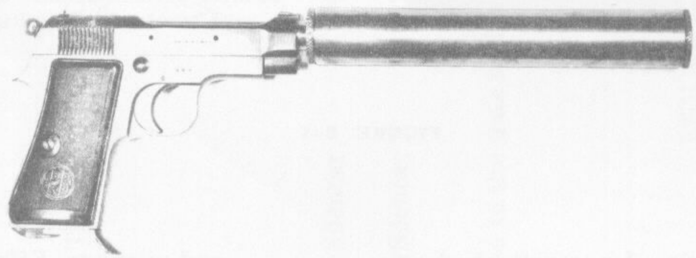
FIGURE B-3

acy with the muzzle silencer attached was 1-1/2 inches at 40 feet. The weapon was mounted in the deflection test setup, Figure B-3, and the measurements were taken at the extreme end of the barrel. The deflection measured record on the stock weapon were .007 to .010 of an inch, and with the silencer attached the deflection was .017 to .020 of an inch.

2. **Muzzle Silencer**

The muzzle silencer was made from 1 inch I.D. steel tubing with a length of 7 inches. Both ends of the muzzle silencer were threaded one end to accommodate the bushing silver-soldered to the barrel and the other for the end cap. The silencer was packed with approximately 300 stainless steel screen washers 1 inch O.D. x .410 I.D., .030 mesh and four (4) 1 inch O.D. x 1/4 inch I.D. x 1/4 thick rubber washers. The initial test results gave muzzle velocities of 900 fps and noise levels of 128-129 db. The noise level is typical of weapons of this type of weapon and silencer. Efforts were then made to reduce this noise level as much as possible. Changing the arrangement of the screens and rubber washers helped somewhat. It was possible to reduce the noise level to 127-138 db by this means. It was apparent that a considerable amount of the total noise was due to the amount of gas escaping from the breech when the slide opened, some attempts were made to delay the opening of the slide. A stronger recoil spring was made and a steel weight was fastened to one side of the slide to retard the blowback. These modifications reduces the noise level to 125-127 db. It should be noted that these modifications to retard blowback are limited on this weapon. The recoil spring on the 1939 Beretta works on a guide rod, and inside a hole drilled through the front of the slide, and only a slight increase in the size of this spring is possible. Also, increasing the strength of the recoil spring increases the force required to load the first round in the

Note; Threaded portion of barrel, this is the only modification needed on the weapen.



Silenced Beretta .380

Silencer contains stainless steel screen washer only.

FIGURE B-4

chamber, which is excessive to begin with. The addition of the weight on the slide presents additional edges which can catch in the holster or pocket. The weapon should probably be used without the side weight added to the slide, but with a slightly heavier recoil spring.

A. Evaluation

The 1934 Beretta, as modified, is a compact, powerful, and lightweight weapon. The silencer may be removed easily by hand and carried separately. The weapon may be used without the silencer if noise is not objectionable.

This phase of the program indicates that it is possible to achieve the same noise level with the .380 automatic as with some .32 ACP pistols, without making difficult modifications. The important characteristics of both cartridges are as follows, using the advertised data:

	.32 ACP (7.65mm)	.380 Auto (9mm short)
Bullet Weight	71 grains	95 grains
Muzzle Velocity	960 ft/sec	955 ft/sec
Muzzle Energy	145 ft/lb	192 ft/lb
Penetration, inches of soft pine	4-3/8 in.	4-13/16 in.

Experimental Model

Name: Pistol
Make: Beretta Model 1934
Description Unmodified:
Operation:
Size: L - 6-1/2", W - 4-9/16", Thick 1-11/16"
Weight: 1 lb. 7 oz.
Other:

Type: Automatic
Caliber 9mm Short (.380)
Description Modified: Silencer
Operation: Blowback, Semiautomatic
Size: L - 12-29/32", W - 4-9/16", Thick 1-1/16"
Weight: 2 lbs. 4 oz.
Other: Barrel Lengthened

Condition	Unmodified	Modified
A. Ballistics Data:		
1. Muzzle Velocity (fps, 10 Round Average)	Ave - 920 E. V. - 33	Ave - 920 E. V. - 46
2. Group Accuracy (extreme spread of 10 rounds from machine rest) at,	Test A. 2 / Test B. 8	Test A. 2 / Test B. 8
a) 5 yards		
b) 10 yards		
c) 15 yards	3-1/2"	5"
d) 25 yards	8"	9-1/4"
e) 50 yards	13"	15-1/2"
f) 75 yards		
g) 100 yards		
h) 125 yards		
i) 150 yards		
j) 175 yards		
k) 200 yards		
3. Effective Range (a, b, or c below, 10 rounds from machine rest)		
a) Range of 12" Group	50 yards	40 yards
b) Range of 6" Vertical Drop	45 Yards	45 yards
c) Penetration (Range of Penetration of 1" thick pine boards)		
4. Noise Level (db, at muzzle 24' in front, 3' right)	145 db	125 db
5. Cyclic Rate (Rounds/Minute)		
6. Capable of Single Shot		
B. Environmental & Life Test:		
1. Storage Temerature (-65^{O}F for 3 days, +160^{O}F for 2 days)		
2. Operational (-20^{O}F to +125^{O}F)		
3. Vibration (per MIL - STD - 810)		
4. Mud Test		
5. Drop Test (3 drops in 3 planes, 3 ft. high)		
6. Humidity (per MIL - STD - 810)		
7. Life Test (1000 Rounds or 6 db noise increase)		
8. Accuracy (same as A. 2 above)		
9. Cyclic Rate (Rounds/Minute)		
10. Muzzle Velocity (fps, 10 Round Average)		

REMARKS:

FIGURE B - 5

As the .380 projectile is bigger and has a greater impact force than the .32 projectile with the same noise level it would seem to be a more desirable cartridge. We would recommend that more work be done with weapons in this caliber to achieve the maximum possible noise reduction. Also, the bullet is the same diameter as the 9mm Parabellum and could be fired through 9mm pistol or submachine gun barrels if the chamber were properly altered. It would not be necessary to provide pressure relief holes for velocity reduction in such a weapon so there should be no problems with accuracy or jacket stripping. The .380 cartridge is shorter than the 9mm cartridge and should function in 9mm magazines. It would be interesting to consider a modified or special submachine gun using this cartridge and having only a muzzle can for noise reduction.

B. **Conclusion**

From the work done in this assignment, which was the modification of a 9mm Luger pistol and the .380 Beretta pistol, that the costs differences involved in the silencing of these weapons would be great.

The extent of the work involved in modifying the Luger becomes rather expensive and requires the use of a good machine shop facilities. The modification to the Beretta is simple in that only a threaded bushing be added to the muzzle of the barrel.

In the selection of a side arms weapon for silencing, consideration should be given to the amount of work that is involved in machining the weapon for the addition of a barrel silencer to reduce the velocity of the projectile to below sonic speeds.

The muzzle silencer developed for the .380 Beretta is simple, inexpensive, and can be adapted to any weapon that has a projectile size similar to the .380 caliber, with speeds below 1,000 feet per second.

Assignment VI — **Data Need For Future Designs**

This assignment was included in this program to summarize the work that has been done and to establish area's of investigation for future designs.

A. **Packing of Muzzle Silencers**

To date, there are basically two (2) types of muzzle silencers that are widely used; they are the MAXIM type and the Stainless Steel Washer type.

1. **MAXIM Type**

The MAXIM type silencer uses disc's and spacers of various lengths to capture and cool the expanding gasses from the muzzle of the barrel. This arrangement provides chambers and deflectors in the muzzle silencer which muffles the noise generated by the muzzle blast. The MAXIM silencer has a long life, does not effect the accuracy of the bullet, but does not reduce the noise level as well as the Stainless Steel Screen type silencer without going to an excessively long or large diameter tube.

2. **Stainless Steel Screen Washer Type**

This type of silencer uses stainless steel screen washers packed in the muzzle silencer tube to cool the expanding gasses and it's size is dependent on the caliber of the weapon it is used on. The inside diameter of the hole in the screen washers are only a few thousandth's larger then the bullet diameter to retain the expanding gasses behind the projectile as it moves through the silencer. This type of silencer has a long life and can be cleaned and reused within a few minutes time. It's size is smaller in comparison to the MAXIM type and it's over-all noise reduction is better.

3. **Packing**

Most of the work done to date with muzzle silencers has been accomplished with these two (2) type silencers. Some work has been done by combining the concepts of both types, such as using rubber washers to form chambers between the stacks of screen washers, or using various lengths of tubing to leave expansion chambers. These combinations have reduced noise levels by as much as 10 to 15 db's, but have also caused inaccuracies and reduced the life of the silencer. It is felt that investigations into entirely new methods for fabricating and packing muzzle silencers should be made to achieve greater accuracy, longer life, and lower noise levels. Work in this area would be useful for all types of silenced weapons, using underloaded ammunition or using barrel silencer with the vent holes drilled near the chamber.

B. **Materials for Packing**

In the Stainless Steel Washer type silencers many experiments have been made to reduce the noise level by varying the muzzle silencer.

Some of the material used are as follows:

1. **Substitutes for Stainless Steel Screen Washers**

a) Sintered metal

(i) Copper

(ii) Stainless Steel

b) Copper screen

c) Copper screen tin plated

d) Steel wool

e) Metalized cloth

2. **Baffels**

Experiments with new rubber baffels, creating small expansion chambers.

a) Neoprene rubber washers of various thicknesses from 1/32 inches thick to 1/4 inch thick and different durometers.

b) Buna rubber washers of various thicknesses and durometers.

c) Silicon rubber washers of various thicknesses and durometers.

All of these materials were tried, but all had adverse effects on the life of the silencer of the accuracy of the bullet.

Since the conclusion of this program there have been some experiments using combinations of discs, screens, and cups which are used to retain or confine rubber washers that have shown some promising results.

C. Methods to Reduce Mechanical Noise

In many silenced weapons the mechanical noises are louder than those of the muzzle. Noise sources not only come from the metal-to-metal contact in the blowback type automatic weapon, but also in the actual early opening of the bolt causing some of the high pressure gasses to escape from the chamber area. There is further noise caused by the ejection of the spent case in automatic weapons and bolt action weapons. Another source of noise in the bolt action type weapon is the actual firing pin fall which does make a distinct sound. Many efforts have been made in attempting to eliminate these noises and although it appears to be a difficult task to do, it does warrant a study into different methods for reducing and muffling these noises.

Possible methods for reducing these mechanical noises would be the use of teflon coatings, reinforced fiberglas and insulator materials. Also, the use of external baffle bags to enclose the rear portion of a weapon might be investigated.

D. Field Test Data

All the weapons modified in this program were field tested for accuracy and maximum ranges. This data is recorded on the enclosed data sheets for each weapon.

Also included in the field testing of these weapons was a noise or db level reading on each weapon. Measurements were taken at a distance of 50 and 100 yards, and at angles of 0^{o} to 120^{o} using a General Radio type 1551-B sound level meter.

The tests were recorded in a country type surrounding with the shooter and the target in a valley with low rolling hills on either side of the line of fire. The ambient noise level was approximately 40 db, with variations between 32 to 55 db's. Temperature varied between 35^{o}F to 45^{o}F, with gusty winds approximately 2-15 knots blowing towards the shooter.

All the recording points at the 100 yard ranges were higher in elevation then that of the shooter with the exception of the 0^{o} angle which was in line with the line of fire and at the same height as the shooter. At the 50 yard range the elevation varied from 5 feet below to 5 feet above that of the shooter.

The similarity in the curves achieved by each of the weapons will be noted in the enclosed sound charts for each individual weapon tested.

E. Conclusion

1. The loudest noise occurred at an angle of 30^{o} from either side of the line of fire or 0^{o} line. This noise is assumed to be a combination of the bullet noise plus the muzzle blast noise.

2. The next loudest noise occurred at an angle of 90^{o} from the line of fire. This noise was predominantly mechanical noise.

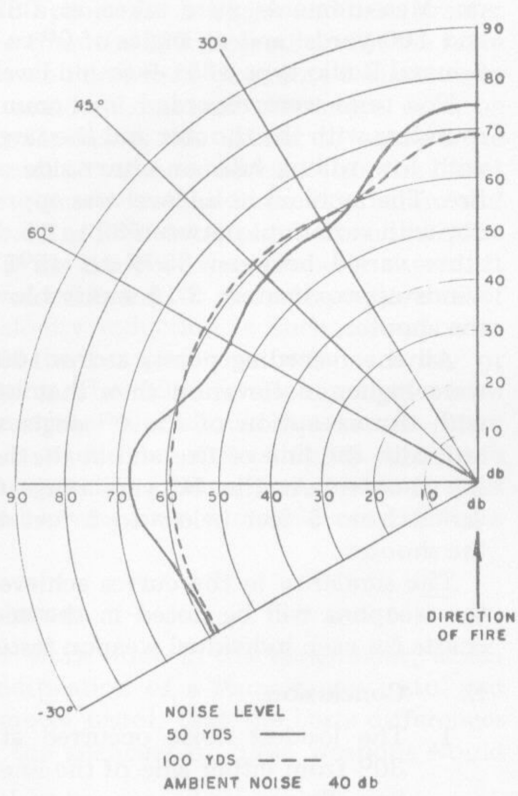
3. As noted on some of the curves at 50 yards, and at an angle of 45^{o} from the line of fire, the weapon tends to get louder. This could have been caused by an increase in the elevation at this point, or the result of additive noise from the breech of the weapon.

The results of these tests are not conclusive, but they do tend to bear out some of the recommendations given for each weapon and that additional work should be done to reduce the mechanical noise and possible improvements by repacking the muzzle silencer. This is indicated by the noise level readings taken at the 60^{o} angle from the line of sight.

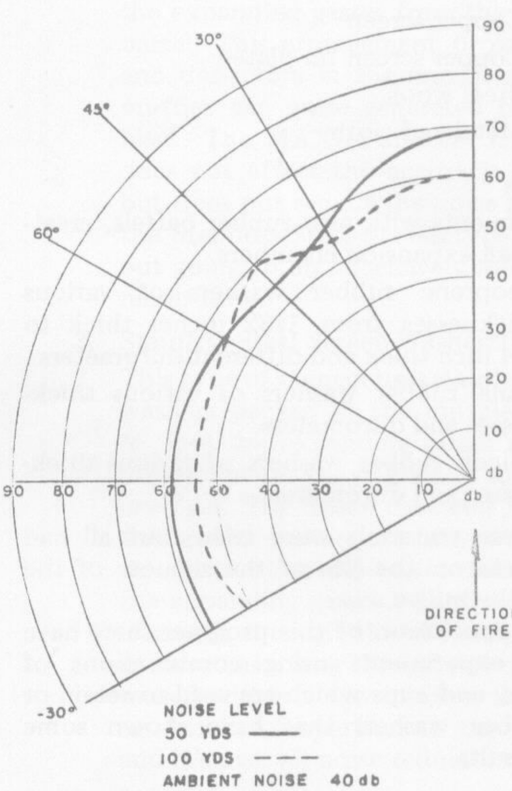
F. Safety Accessories

With the modification of any weapon consideration should be given to the safety of the operator of a silenced weapon.

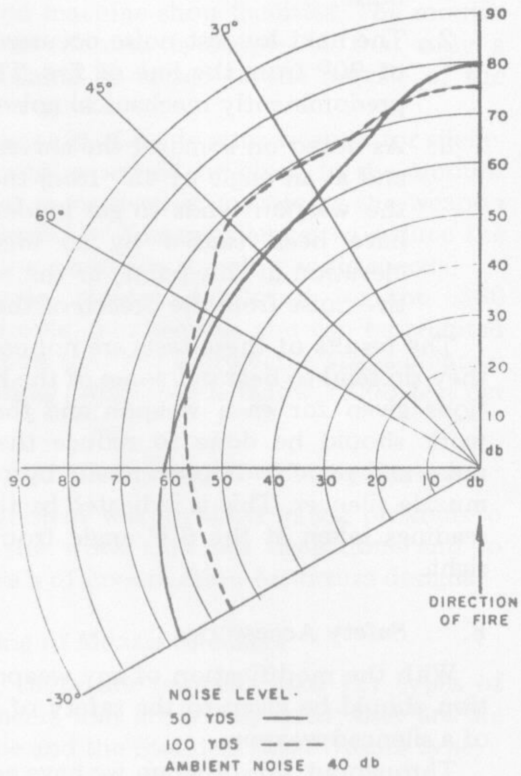
Throughout this program we have endeavored to make these weapons as safe as possible. We have modified recoil springs to prevent runaway guns,



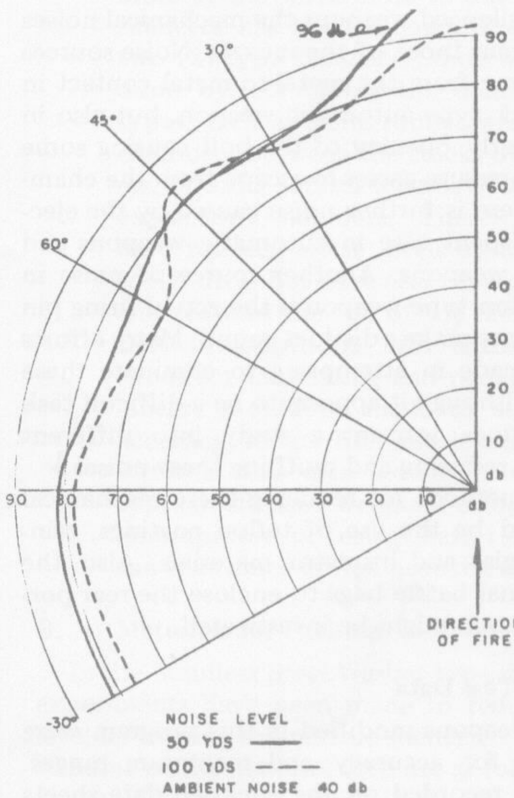
.380 MOD



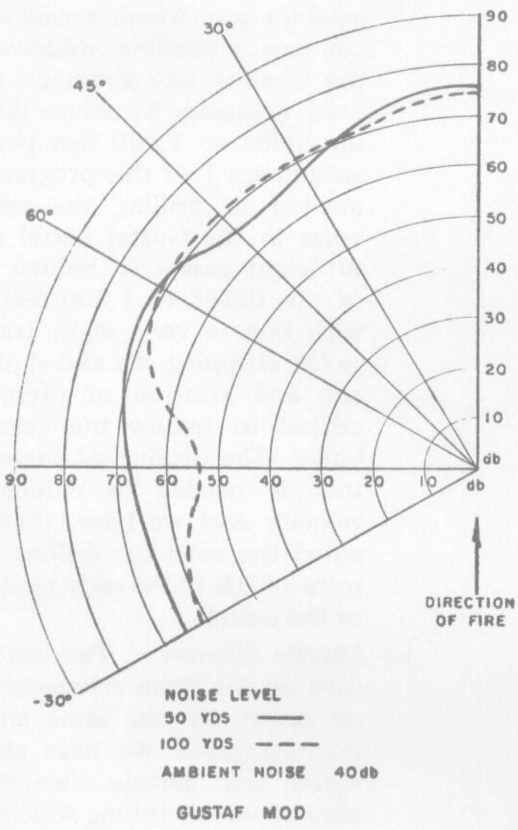
LUGER MOD

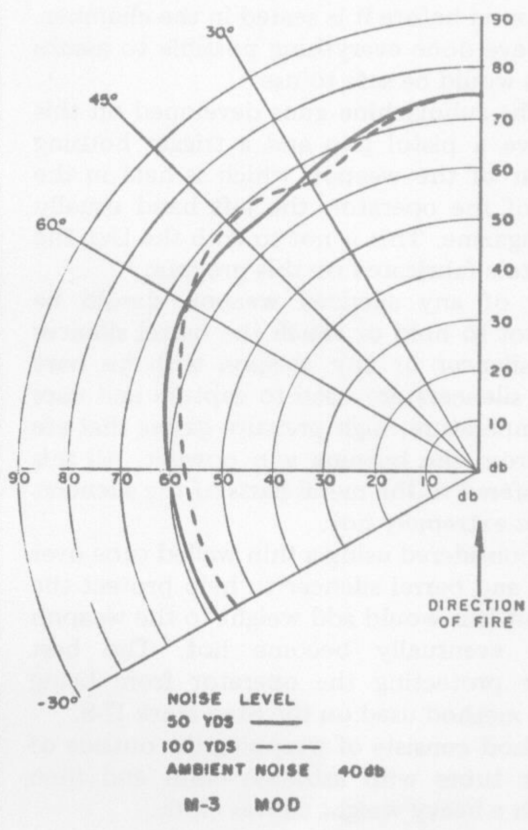


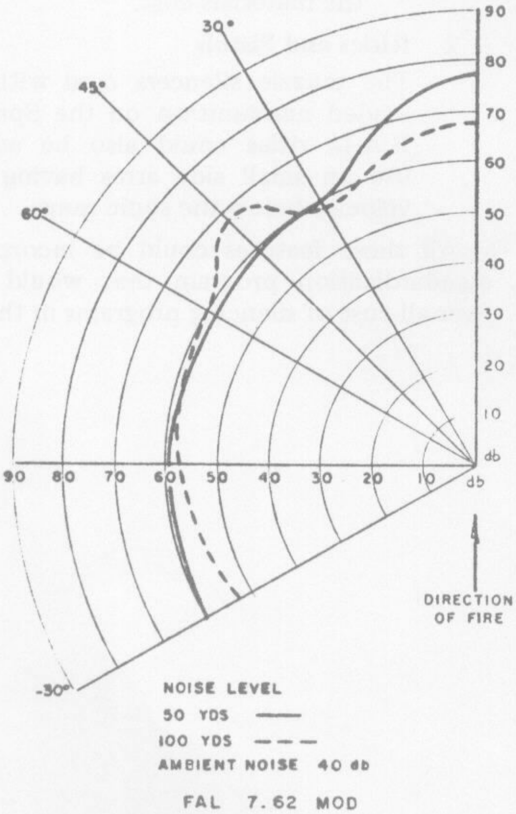
SMG BERETTA MOD

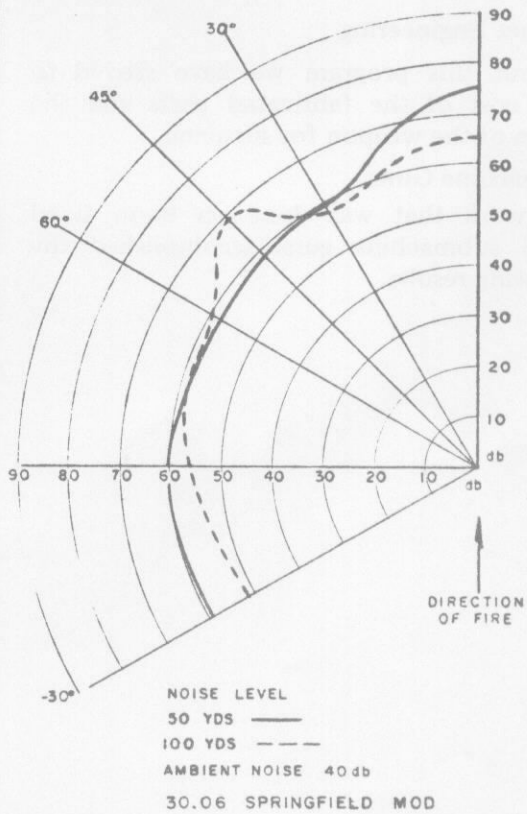


SMG BERETTA STANDARD


30°
45°
60°
-30°
90 80 70 60 50 40 30 20 10 db
DIRECTION OF FIRE
NOISE LEVEL
50 YDS
100 YDS
AMBIENT NOISE 40 db
GUSTAF MOD


30°
45°
60°
-30°
90 80 70 60 50 40 30 20 10 db
DIRECTION OF FIRE
NOISE LEVEL
50 YDS
100 YDS
AMBIENT NOISE 40 db
M-3 MOD


30°
45°
60°
-30°
90 80 70 60 50 40 30 20 10 db
DIRECTION OF FIRE
NOISE LEVEL
50 YDS
100 YDS
AMBIENT NOISE 40 db
FAL 7.62 MOD


30°
45°
60°
-30°
90 80 70 60 50 40 30 20 10 db
DIRECTION OF FIRE
NOISE LEVEL
50 YDS
100 YDS
AMBIENT NOISE 40 db
30.06 SPRINGFIELD MOD

eliminated bullet stripping to prevent premature firing of a round before it is seated in the chamber. In all, we have done everything possible to assure the weapons would be safe to use.

Most of the submachine guns developed on this program have a pistol grip and a trigger housing near the rear of the weapon which is held in the right hand of the operator, the left hand usually grips the magazine. This is not so with the Uzi, the rifles, or pistols fabricated on this program.

The user of any silenced weapon should be cautioned not to hold or touch the barrel silencer or muzzle silencer or any weapon with his bare hands. The silencers are used to capture and cool the high temperature, high pressure gasses that are developed from the burning gun powder. All this heat is transfered to the metal parts of the silencers and becomes extremely hot.

We have considered using a thin walled tube over the muzzle and barrel silencer to help protect the operator, but this would add weight to the weapon and would eventually become hot. The best method for protecting the operator from being burnt is the method used on the Sten Mark II-S.

This method consists of wrapping the outside of the silencer tubes with asbestos cloth and then covered with a heavy weight canvas cloth.

G. **Product Engineering**

Throughout this program we have strived to reduce the cost of the fabricated parts and the modification of the weapon for silencing.

1. **Submachine Guns**

   The work that was done on 9mm fixed barrel submachine guns accomplished the following results.

   a) **Bleed Holes** — In a fixed barrel submachine gun where access to the chamber area is possible, we have established the location size and angle of the bleed holes necessary to reduce the velocity of the bullet to 1,000 feet per second. In assignment I of this program we experimented in drilling the pressure relief holes in the Gustaf barrel to bleed off sufficient gasses to reduce the velocity of the bullet to 1,000 feet per second with only a very slight trace of bullet jacket stripping. We also showed that the size and location of these holes were critical to reduce the velocity of the bullet. The drilling of these holes is all that is needed to reduce the bullet velocity and we have, therefore, eliminated the need for drilling the four (4) rows of 12 holes each along the length of the barrel.

   b) **Muzzle Silencer** — The muzzle silencers used on the 9mm submachine guns were all essentially the same and would be interchangable. We have also made the barrel and muzzle silencers from the same diameter tubing which also reduces the materials cost.

2. **Rifles and Pistols**

   The muzzle silencers used with the underloaded ammunition on the Springfield and F.A.L. rifles could also be adaptable for use on small side arms having a projectile velocity below the sonic range.

All these features could be incorporated in a standardization program that would reduce the over-all cost of silencing programs in the future.