PROPOSAL FOR THE

DEVELOPMENT OF A

MACHINE GUN CONCEPT CAPABLE OF

FIRING 7.62mm MOLDED CASELESS PROPELLANT CARTRIDGES

Prepared For:

United States Army
Rock Island Arsenal
Rock Island, Illinois

IN RESPONSE TO:

RFQ DAAF-01-67-Q-1662

27 March 1967

TRW JET & ORDNANCE DIVISION
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005	B. Z. Jones
006	E. M. Stoner
007	K. J. Tobola
008	R. J. Manion
009	W. H. Brown
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1.0 INTRODUCTION (Cont.)

These investigations have considered three (3) approaches to the caseless solution:

1. Combustible case
2. Semi-caseless
3. Caseless molded propellant.

The combustible case was rejected as a candidate solution in small arms applications due to the thick wall required for support and the requirement for the case material to contribute to the gas generation to match the ballistic capabilities of existing small arms ammunition.

Semi-caseless rounds, which are not truly caseless since it requires a non-combustible stub base such as steel or brass, have been manufactured and fired extensively. This approach is possibly an interim solution pending the results of firing evaluation.

The most recent approach to caseless ammunition, as currently designed by Frankford Arsenal, involves solid propellant molded about a support tube and the bullet, using a completely combustible primer. Test firings of this concept have been conducted using modified versions of M-14 and M-73 weapons.

1.0 INTRODUCTION (Cont.)

The investigations thus far have been mostly centered about the development of caseless ammunition which has been test fired from present conventional small arms. The results of the tests have generally proven the feasibility of molded caseless propellant cartridges in relation to their interior ballistics characteristics, however, the underlying problems yet to be resolved, such as; obturation, heat transfer, erosion, and extraction and ejection of an unfired cartridge are related to the weapon/ammunition interface.

It thus appears obvious, that to reach a complete solution to the problems associated with the caseless ammunition approach, a new weapon system must be developed

This weapon system, be it small arms or larger caliber guns, must be designed and developed specifically for firing caseless ammunition. The multitude of design factors directly related to the caseless weapon/ammunition system must be considered. However, during the development of a weapon/ammunition concept, primary considerations of simplicity of design and reliability of function must not be sacrificed at the expense of the complexity of the final system.

1.0 INTRODUCTION (Cont.)

Development of a system which will lead to a useful weapon and ammunition involves great effort, coordination, and cooperation of many people in various industries and Government agencies.

It is the desire of TRW Inc. to work with the Government and other companies involved to aid in solving the problems to be encountered during the development of a concept for a machine gun capable of firing molded caseless propellant cartridges.

2.0 SUMMARY (Cont.)

TRW will also have the services of Mr. E. M. Stoner, TRW Weapon Designer and full-time consultant, who will be available for specific weapon, ammunition and systems integration consultation. This team of key personnel with the available facilities will coordinate with the United States Army throughout the duration of the program to insure an acceptable and logical approach to the solutions of the problems associated with the caseless weapon/ammunition concepts.

TRW has considered the advantages inherent in developing weapon systems capable of firing caseless ammunition and have recognized the potential problem areas identified by the Army in this RFQ. Preliminary investigations have already been conducted by TRW in related aspects of the caseless ammunition/weapon problems.

These investigations have included such aspects as determination and analysis of the heat transfer pnehomena, materials research into plastic seals for obturation, and investigation of high strength, corrosion resistant steel alloys. These investigations have considered weapon systems and ammunition configurations ranging in caliber from 7.62mm to 40mm.

2.0 SUMMARY (Cont.)

TRW's qualifications for the satisfactory performance of the caseless ammunition machine gun design study are based upon the knowledge, experience and facilities available to perform weapon, ammunition and weapon system development programs. In his capacity as a full-time consultant, Mr. Stoner's knowledge, experience and success in the design and development of small arms weapons will be extensively utilized.

TRW's Ordnance Development Center was created for weapon system development and is totally devoted to the designing, developing and testing of weapons, ammunition and overall weapon systems. TRW has acquired the property and facilities of the Army's Erie Proving Ground upon its closing by DOD, and are presently expanding the capabilities of this facility. For example, to complement the existing test facilities, TRW recently completed the installation of an environmental firing chamber (-65°F to +165°F) designed to test weapon systems.

TRW has the required engineering manpower and spectrum of technical skills, disciplines, and backgrounds immediately available to successfully perform this program for the Army. TRW's Ordnance Development Center's contractual performance history is excellent in technical performance, costs and schedules.

3.0 TECHNICAL APPROACH

The TRW concept of a machine gun capable of firing caseless ammunition revolves around one basic gun mechanism. This basic gun mechanism can be modified to fire a variety of caseless ammunition configurations.

Three (3) approaches to the concepts of caseless ammunition have been considered. Each of these three concepts can be readily adapted to the basic machine gun mechanism.

Prior to the discussion of the basic gun mechanism, it is necessary to describe the three ammunition concepts considered. Their relationship to the design of the weapon will then be discussed during the description of the technical approach to the machine gun concept.

3.1 CASELESS AMMUNITION CONCEPTS

3.1.1 Modified Frankford Arsenal Concept

This concept, and the one which appears most promising as related to the weapon/ammunition interface, is a modified version of the Frankford Arsenal concept as currently designed. (Figure 3-1)

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.1 Modified Frankford Arsenal Concept (Cont.)

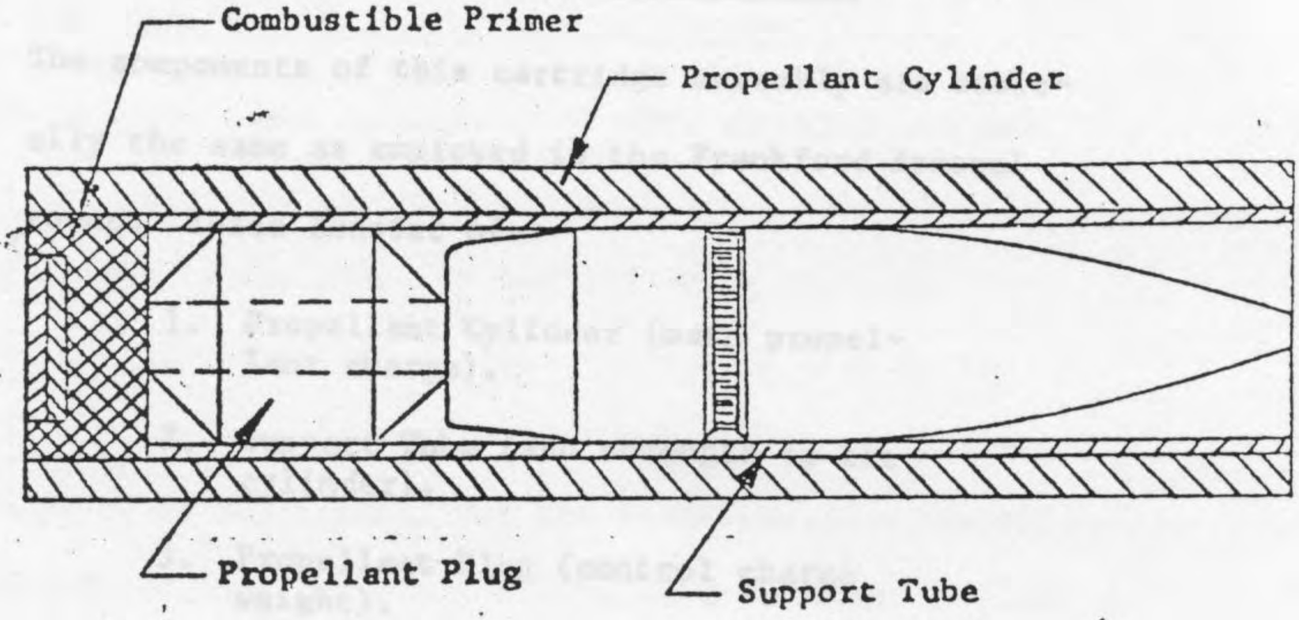


Figure 3-1

It employs a "telescoping" or "folded round" design which would result in a completely cylindrical cartridge configuration. The feasibility of a folded round technique has already been established by test firings and evaluation conducted by Government and non-Government agencies.

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.1 Modified Frankford Arsenal Concept (Cont.)

The components of this cartridge assembly are basically the same as employed in the Frankford Arsenal round. These consist of:

1. Propellant Cylinder (main propellant charge).
2. Support Tube (add strength to the cylinder).
3. Propellant Plug (control charge weight).
4. Combustible Primer (provide ignition and in addition, provide the initial impulse to the folded bullet.

In addition to these components, integral cartridge case seals can be adapted to this round to assist in the obturation of the propellant gases (Figure 3-2).

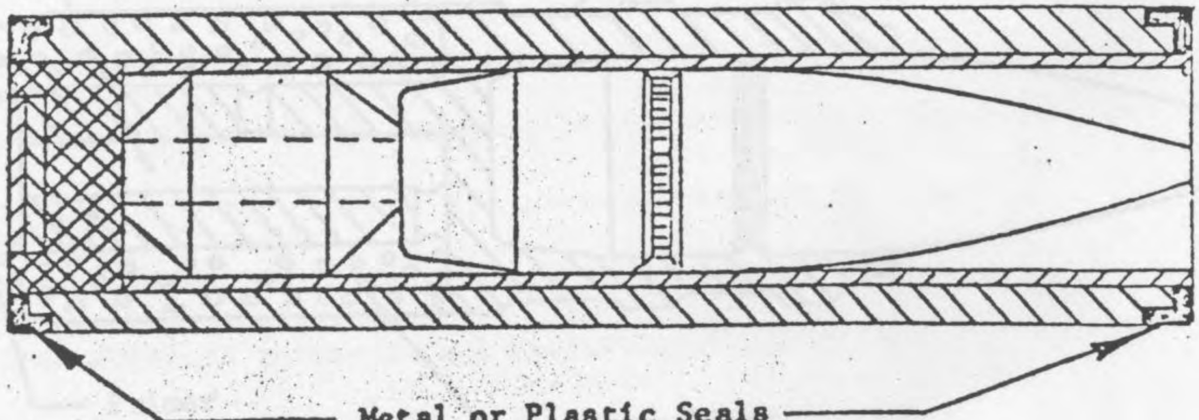


Figure 3-2

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.1 Modified Frankford Arsenal Concept (Cont.)

These seals could be made of plastic or metal and are ejected from the weapon after each shot. The ejection technique is explained in the following sections. The primary advantage of this concept is that it is the most readily adaptable to the basic gun mechanism; there is no requirement for the insertion of a protruding bullet into the leade of the barrel. Thus, the gun mechanism is greatly simplified. The cartridge can be designed to provide NATO ballistics.

3.1.2 TRW Saboted-Bullet Concept

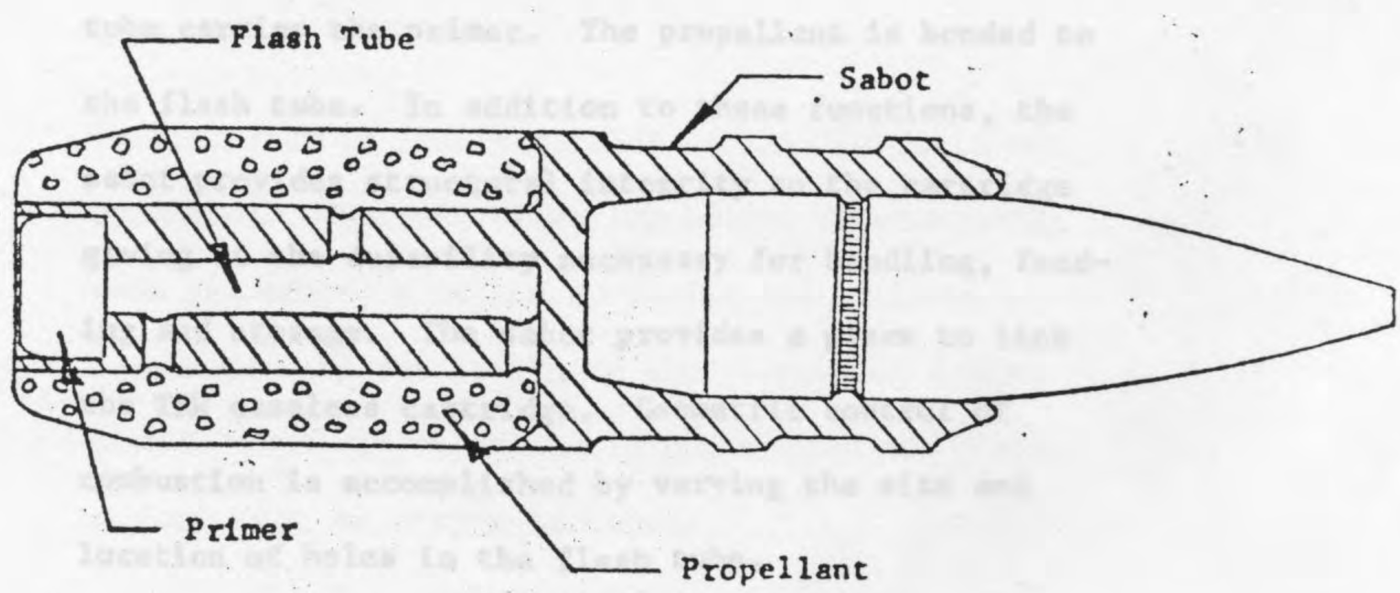


Figure 3-3

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.2 TRW Saboted-Bullet Concept (Cont.)

The TRW 7.62 caseless round (Figure 3-3) is designed to provide NATO ballistics with the lowest possible pressures. The cartridge is built around a sabot which has an integral flash tube. All components of the cartridge are carried down the gun tube. These components are:

1. Sabot
2. Projectile
3. Primer
4. Propellant

The sabot carries the projectile. The integral flash tube carries the primer. The propellant is bonded to the flash tube. In addition to these functions, the sabot provides structural integrity to the cartridge giving it the durability necessary for handling, feeding and storage. The sabot provides a place to link the TRW caseless cartridge. Geometric control of combustion is accomplished by varying the size and location of holes in the flash tube.

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.2 TRW Saboted-Bullet Concept (Cont.)

The cartridge lends itself to a variety of projectiles including shot and flechettes. Because the projectile or projectiles need not touch the bore of the gun or any component of the cartridge other than the sabot; the kind, shape, number and material of the projectiles is practically unlimited. Single component bullets may be used in place of the unconventional two-piece (lead core and guilding metal jacket). Undeformed projectiles are delivered as they do not touch the gun's bore.

Either combustible or non-combustible primers may be used. Non-combustible primers are carried down the gun bore with the sabot.

This concept is also adaptable to the TRW basic gun mechanism. However, since the bullet is protruding from the sabot, a method of moving the stationary breech forward the length of the protruding bullet must be provided in the basic gun mechanism. (These methods will be discussed later).

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.3 Currently Designed Frankford Arsenal Concept

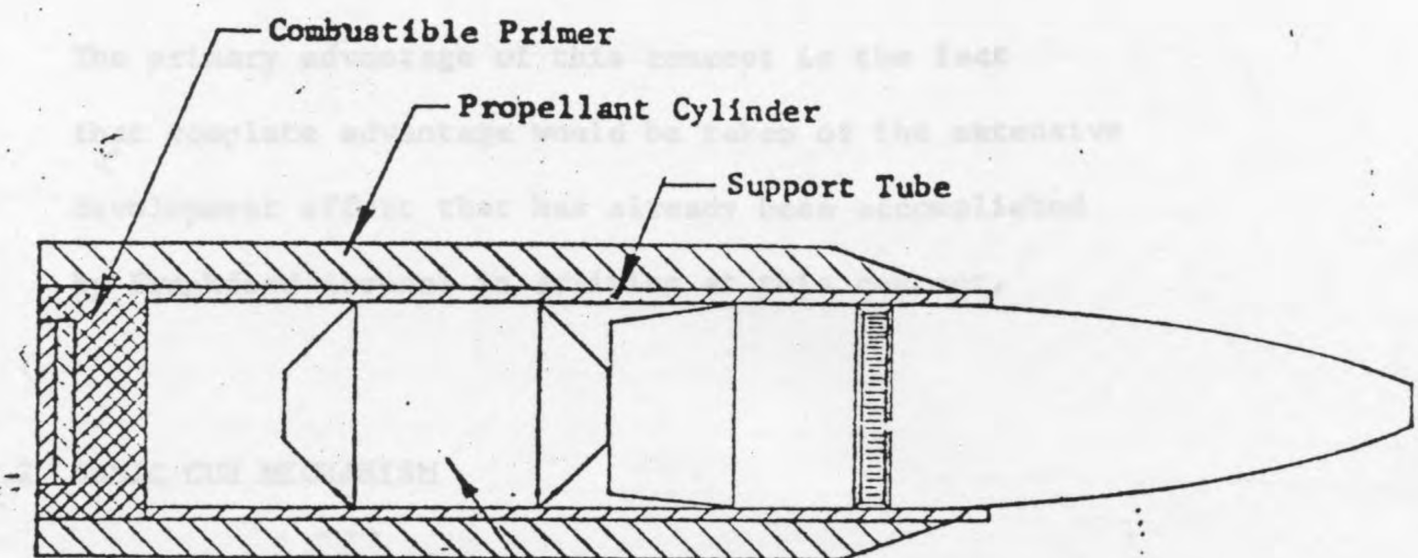


Figure 3-4

The third concept which can be adapted to the basic gun mechanism, utilizes the currently designed Frankford Arsenal Caseless Cartridge (Figure 3-4). In relation to the gun mechanism, this would also require the stationary breech be moved forward the length of the protruding bullet, as in the TRW Saboted-Bullet Concept. This however, can be accomplished readily and will be explained in detail later.

3.0 TECHNICAL APPROACH (Cont.)

3.1 CASELESS AMMUNITION CONCEPTS (Cont.)

3.1.3 Currently Designed F/A Concept (Cont.)

The primary advantage of this concept is the fact that complete advantage would be taken of the extensive development effort that has already been accomplished by Frankford Arsenal in arriving at this concept.

3.2 BASIC GUN MECHANISM

3.2.1 Principle of Operation

The mechanism essentially consists of a reciprocating sleeve of which the internal cylindrical volume provides the firing chamber of the gun. This sleeve slides over and is supported at the aft end by a mating stationary breech. The forward portion of the sleeve is supported by the gun barrel. This mechanism is shown in its most basic form in Figure 3-5.

To load the weapon, the sliding chamber is moved to the rear to expose the space between the breech and the barrel. A round is then placed in this space and the sliding chamber is slid forward over the round and over the rear end of the barrel.

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.1 Principle of Operation (Cont.)

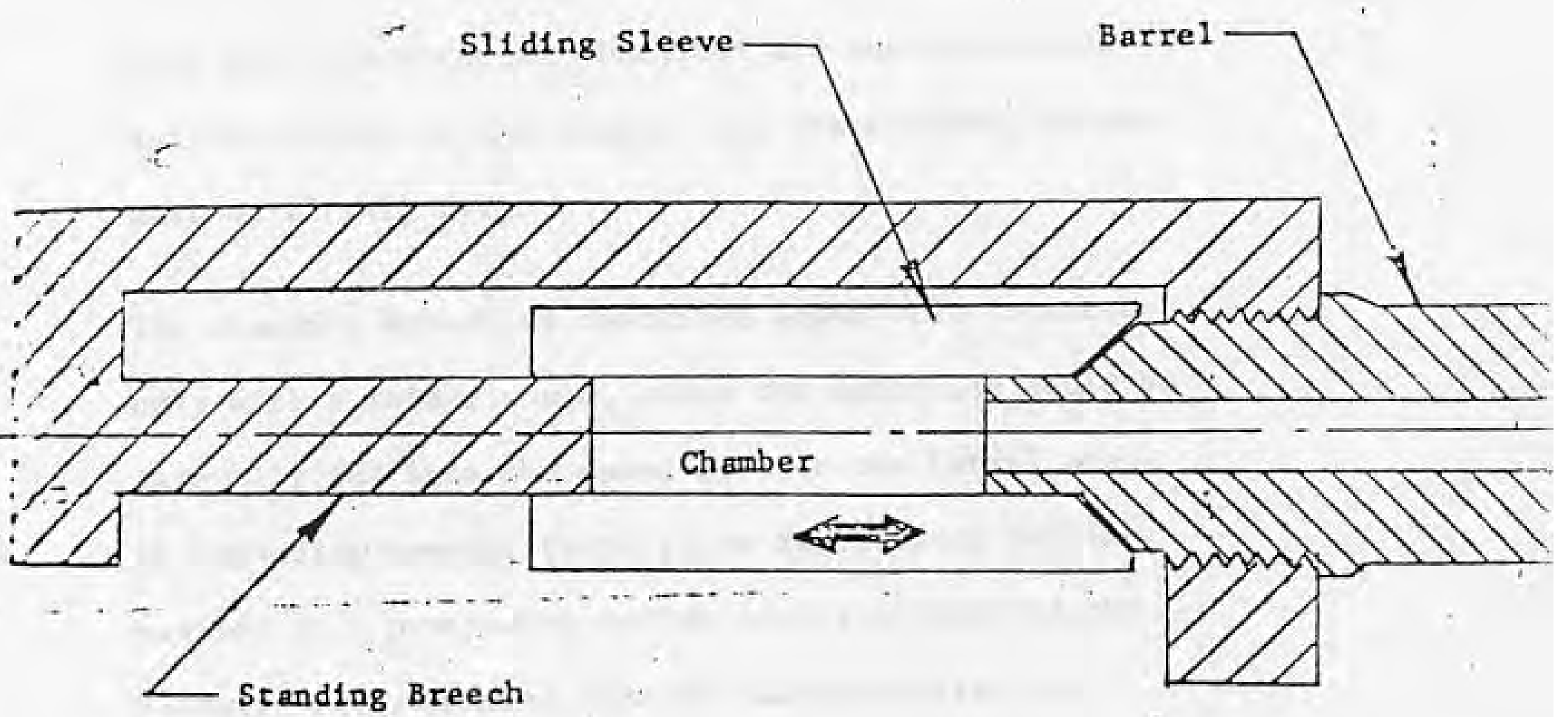


Figure 3-5

As soon as the sleeve ends its forward most travel, the propellant charge is ignited, propelling the bullet down the barrel. In this design, the gas pressure exerts only a radial force against the internal walls of the sleeve. No axial force is applied to the sleeve that would tend to force it rearward. There is a requirement however,

3.0 TECHNICAL APPROACH (Cont.)

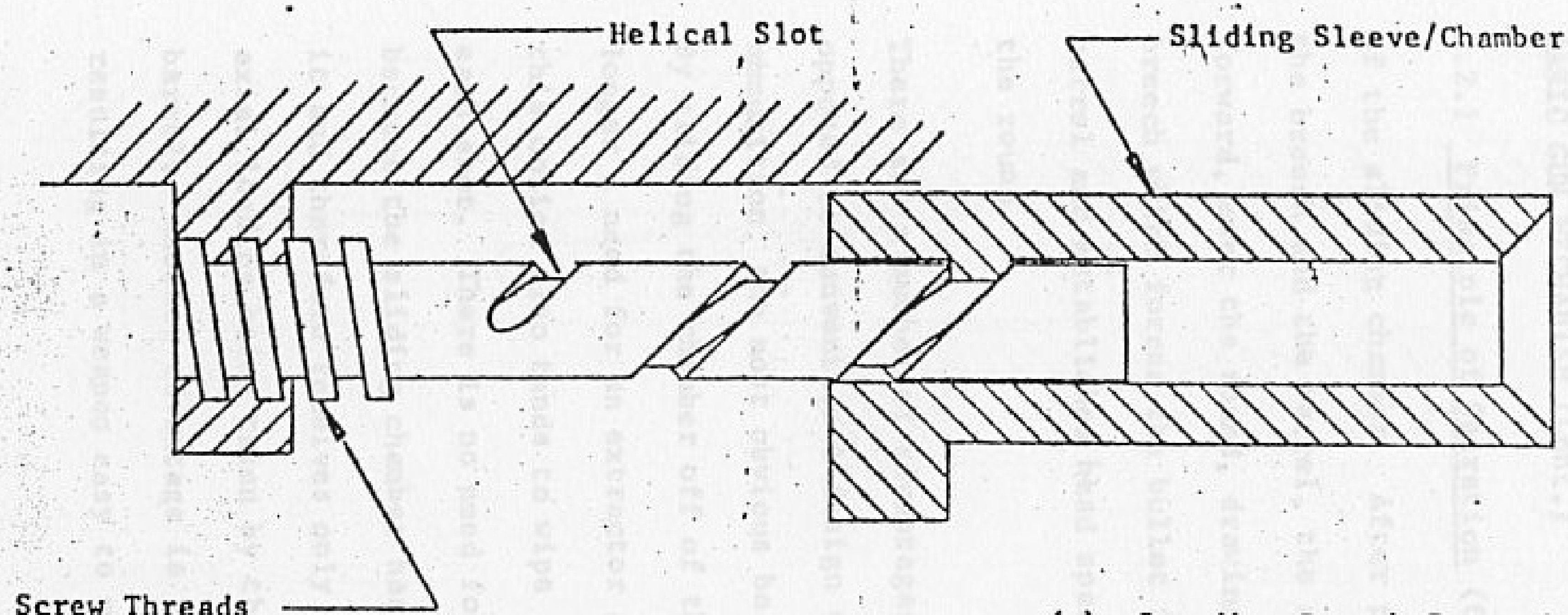
3.2 BASIC GUN MECHANISM (Cont.)

3.2.1 Principle of Operation (Cont.)

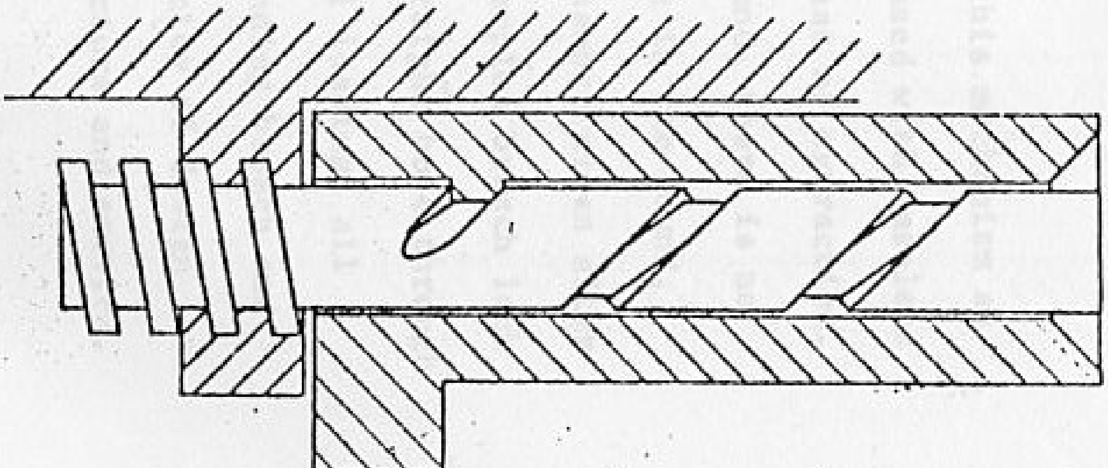
that the tolerances on dimension and the micro-inch surface finish of the chamber and the standing breech must be closely held.

The standing breech as described above will function only with a folded round, since the cartridge would be laterally fed into the space between the barrel and the standing breech, there is no requirement for insertion of a protruding bullet into the leade of the barrel. For rounds of the TRW Saboted-Bullet or Frankford Arsenal types (Figures 3-3 and 3-4), some method of moving the standing breech must be provided to establish proper head space.

Two methods of moving the breech are illustrated. Figure 3-6 shows a screw breech controlled by a helical slot and Figure 3-7 shows a turning bolt breech again controlled by a helical slot. With each of the above methods, the standing breech would move to the rear a short distance, (about 1/2 inch depending upon the round used) during full rearward travel of the



(a) Standing Breech Forward


(b) Standing Breech Moved Re

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.1 Principle of Operation (Cont.)

of the sliding chamber. After placing a round between the breech and the barrel, the sliding chamber moves forward, over the round, drawing with it the standing breech which forces the bullet into the leade of the barrel and establishes head space on the shoulder of the round.

There are a number of advantages to this mechanism as opposed to conventional design when used with caseless ammunition, the most obvious being that of extraction. By sliding the chamber off of the round, there is no longer a need for an extractor groove in the round, this motion also tends to wipe the chamber clean after each shot. There is no need for a complex breech lock because the sliding chamber has a straight hole through it and therefore receives only radial loading, all axial loading being taken by the standing breech and barrel. Another advantage is simplicity of design resulting in a weapon easy to manufacture and service.

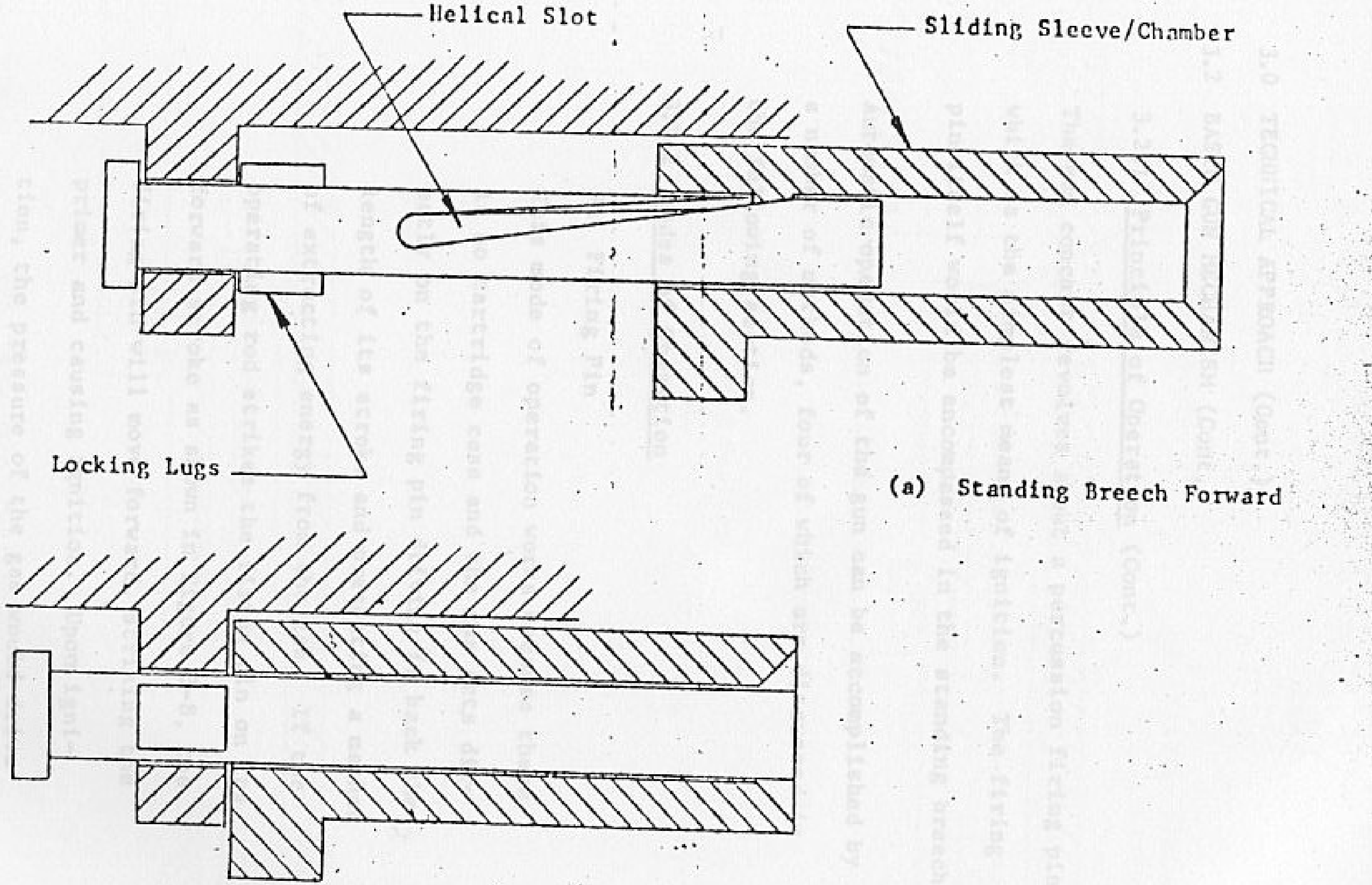


Figure 3-7. Rotating Breech Locking Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.1 Principle of Operation (Cont.)

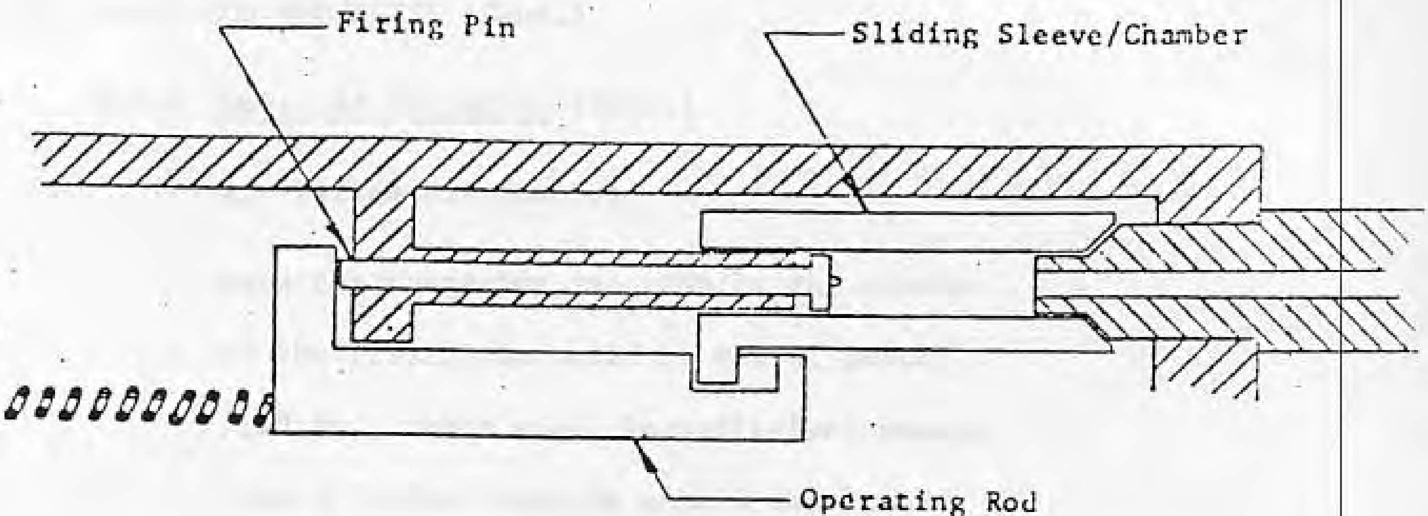
The gun concept revolves about a percussion firing pin, which is the simplest means of ignition. The firing pin itself would be encompassed in the standing breech.

Automatic operation of the gun can be accomplished by a number of methods, four of which are discussed in the following section.

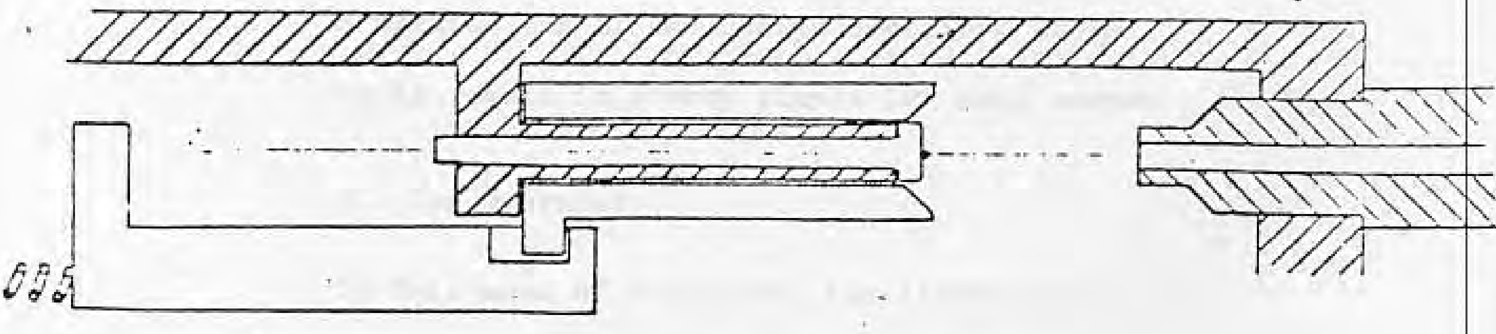
3.2.2 Modes of Operation

A. Firing Pin

This mode of operation works because there is no cartridge case and the gas acts directly on the firing pin driving it back the length of its stroke and presenting a method of extracting energy from the gas. If the operating rod strikes the firing pin on its forward stroke as shown in Figure 3-8, the firing pin will move forward, striking the primer and causing ignition. Upon ignition, the pressure of the gas would drive the firing pin rearward which in turn would



(a) Fire Position



(b) "Open Bolt" Position

Figure 3-8. Firing Pin Operated Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.2 Modes of Operation (Cont.)

A. Firing Pin (Cont.)

move the operating rod. While the stroke of the firing pin would be short, about .100 in., there would be sufficient energy from a 7.62mm round to give a two-pound operating rod a maximum velocity of 34 FPS. Enough dwell would be built into the operating rod so that it would move by itself for a short distance before moving the sliding chamber, this would allow the pressure in the chamber to drop to a safe level before opening.

A machine gun of the design described above would result in a very simple low cost weapon.

B. Gas Operated

In this mode of operation, the firing pin is struck by a hammer in a conventional manner, and as the bullet moves down the barrel, it

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.2 Modes of Operation (Cont.)

B. (Cont.)

passes over a gas port and a portion of the gas is diverted and allowed to act on a piston which is attached to the operating rod (Figure 3-9). The operating rod moves to the rear a short distance by itself to allow pressure in the barrel to drop to a safe level at which time the sliding chamber is contacted and drawn to the rear with it. This motion also compresses the operating rod spring and cocks the hammer. The feeder would then deposit a round in position and the sliding chamber with the operating rod would move fotward to encompass the round and release the hammer causing the cycle to repeat again.

C. Recoil Operation

This mode of operation would be of the conventional short recoil type in which the barrel and breech assembly recoil together a short

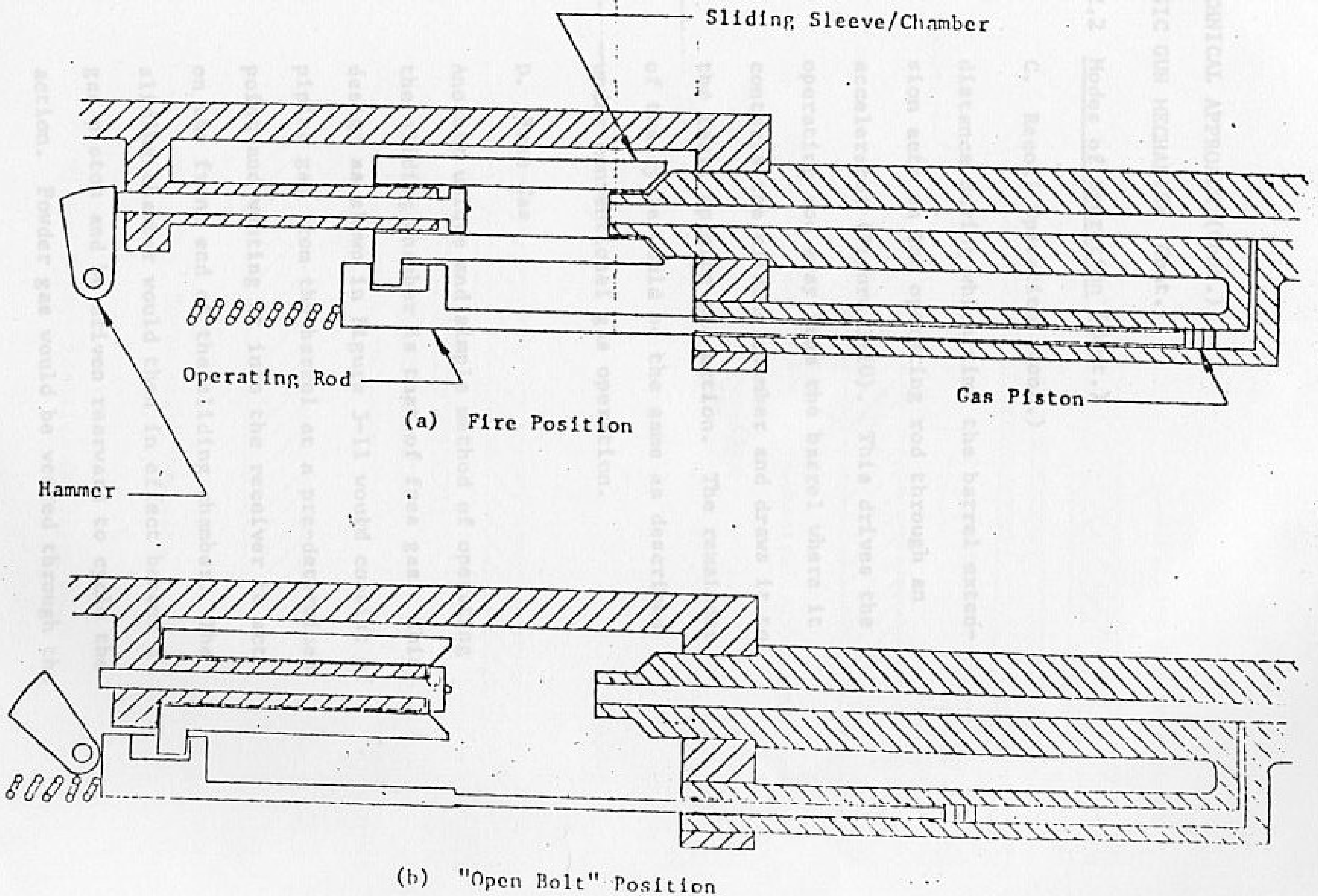


Figure 3-9. Gas Operated Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

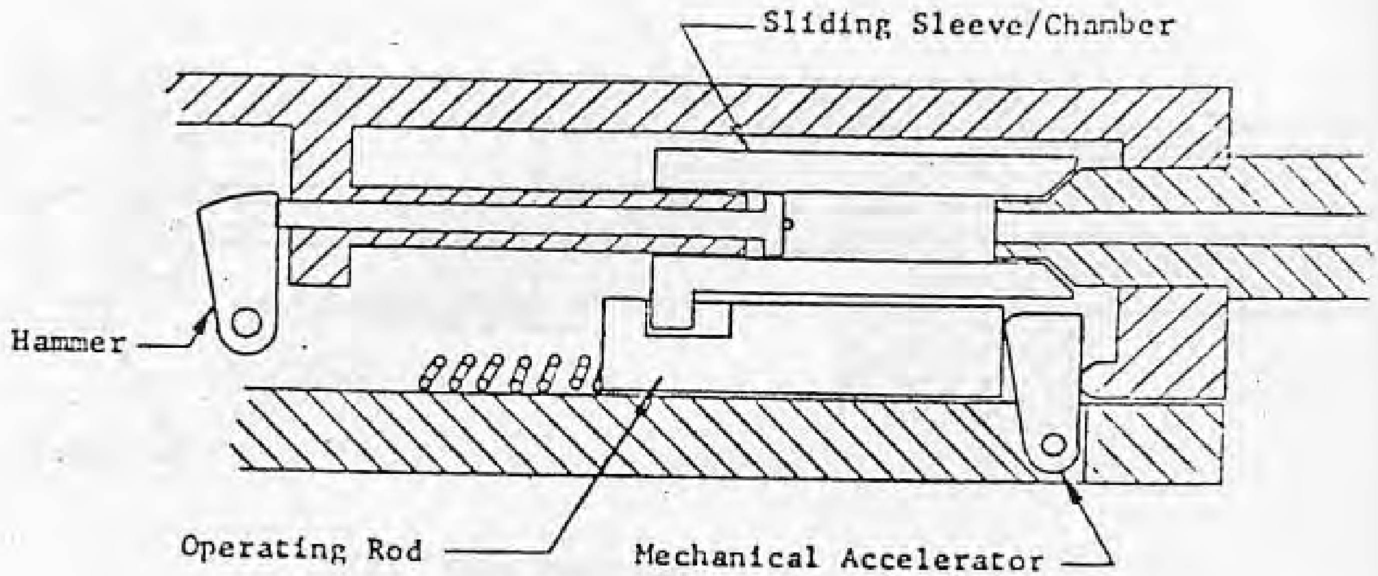
3.2.2 Modes of Operation (Cont.)

C. Recoil Operation (Cont.)

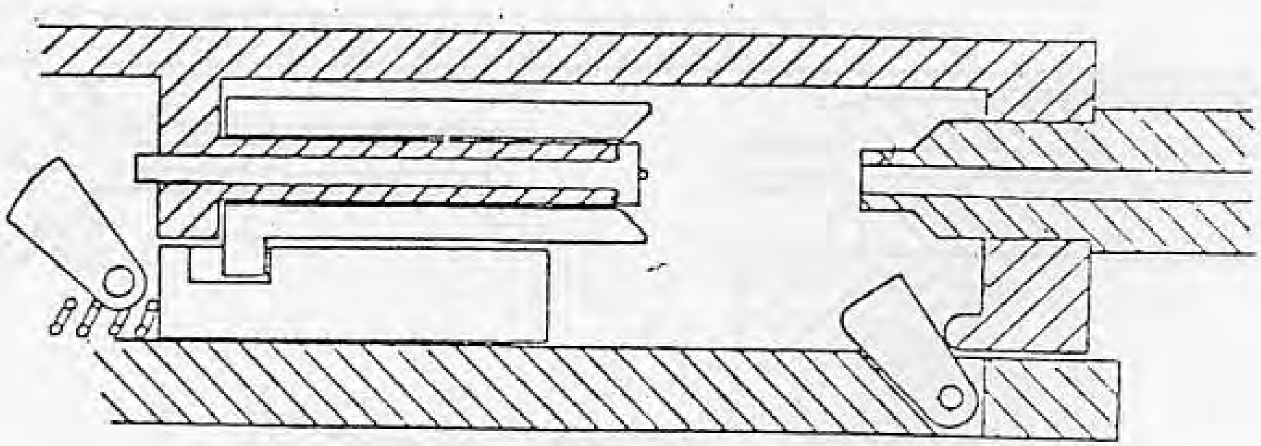
distance during which time the barrel extension acts on the operating rod through an accelerator (Figure 3-10). This drives the operating rod away from the barrel where it contacts the sliding chamber and draws it to the rear, opening the action. The remainder of the cycle would be the same as described under conventional gas operation.

D. Free Gas

Another unique and simple method of operating the sliding chamber is that of free gas. This design as shown in Figure 3-11 would consist of piping gas from the barrel at a pre-determined point and venting it into the receiver to act on the front end of the sliding chamber. The sliding chamber would then in effect become a gas piston and be driven rearward to cycle the action. Powder gas would be vented through the

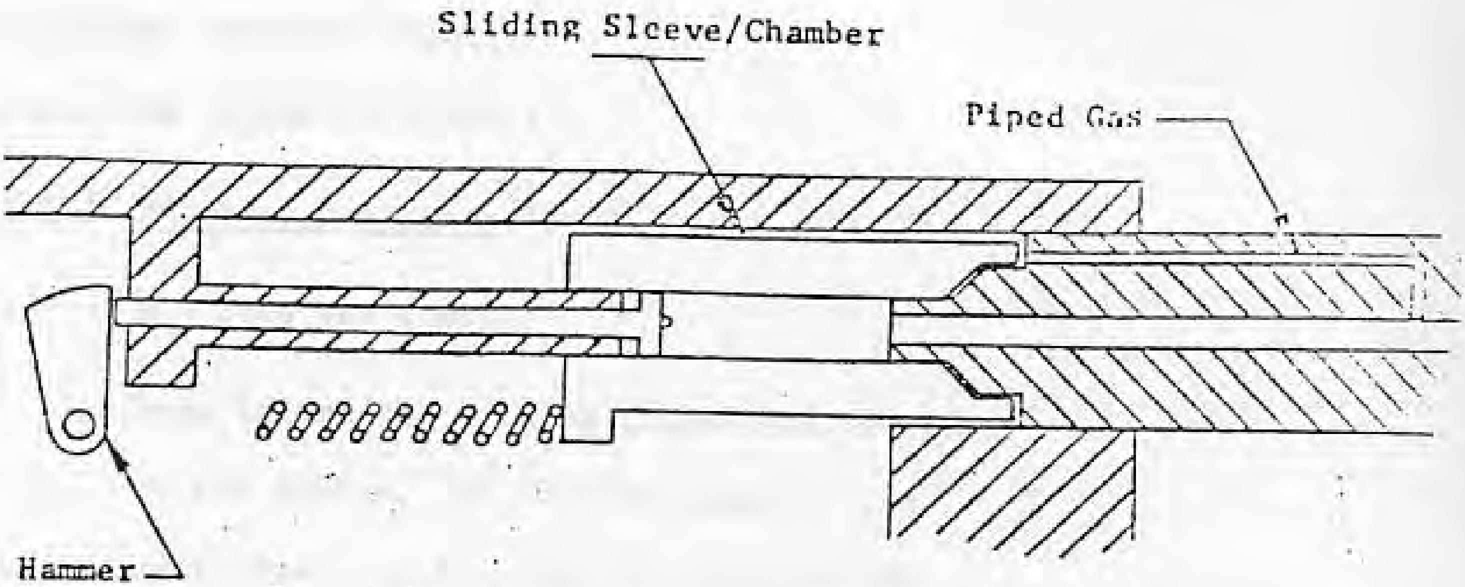


(a) Fire Position

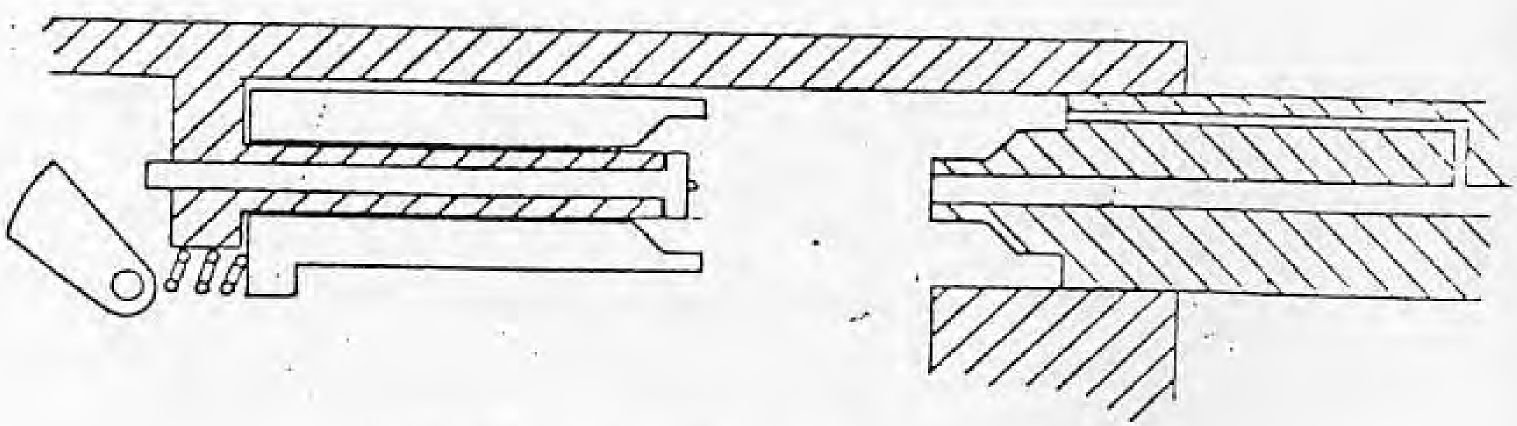


(b) "Open Bolt" Position

Figure 3-10. Recoiled Operated Concept



(a) Fire Position



(b) "Open Bolt" Position

Figure 3-11. Free Gas Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.2 Modes of Operation (Cont.)

D. Free Gas (Cont.)

bore before the sliding chamber is opened to the action, and the remainder of the cycle would be the same as that for the conventional gas operation.

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.3 Obturation

The major problem area for this weapon, or any caseless weapon, is that of sealing the chamber. The TRW concept of a sliding sleeve/chamber, as well as the simplicity of design affords an approach to the solution of the obturation problem.

Forward obturation is provided by a dynamic sealing technique wherein the sliding sleeve and the thin walled rear section of the barrel are forced together under propellant gas pressure to provide a completely sealed metal-to-metal surface. This is schematically illustrated in Figure 3-12.

This dynamic sealing technique, although not used specifically in weapon systems, has been employed in other high pressure applications. For example, adaptors have been designed to mount pressure transducers which are sealed by the radial expansion of a thin walled section of the adaptor against the face of the transducer. This sealing technique has proved successful under pressures up to 100,000 PSI.

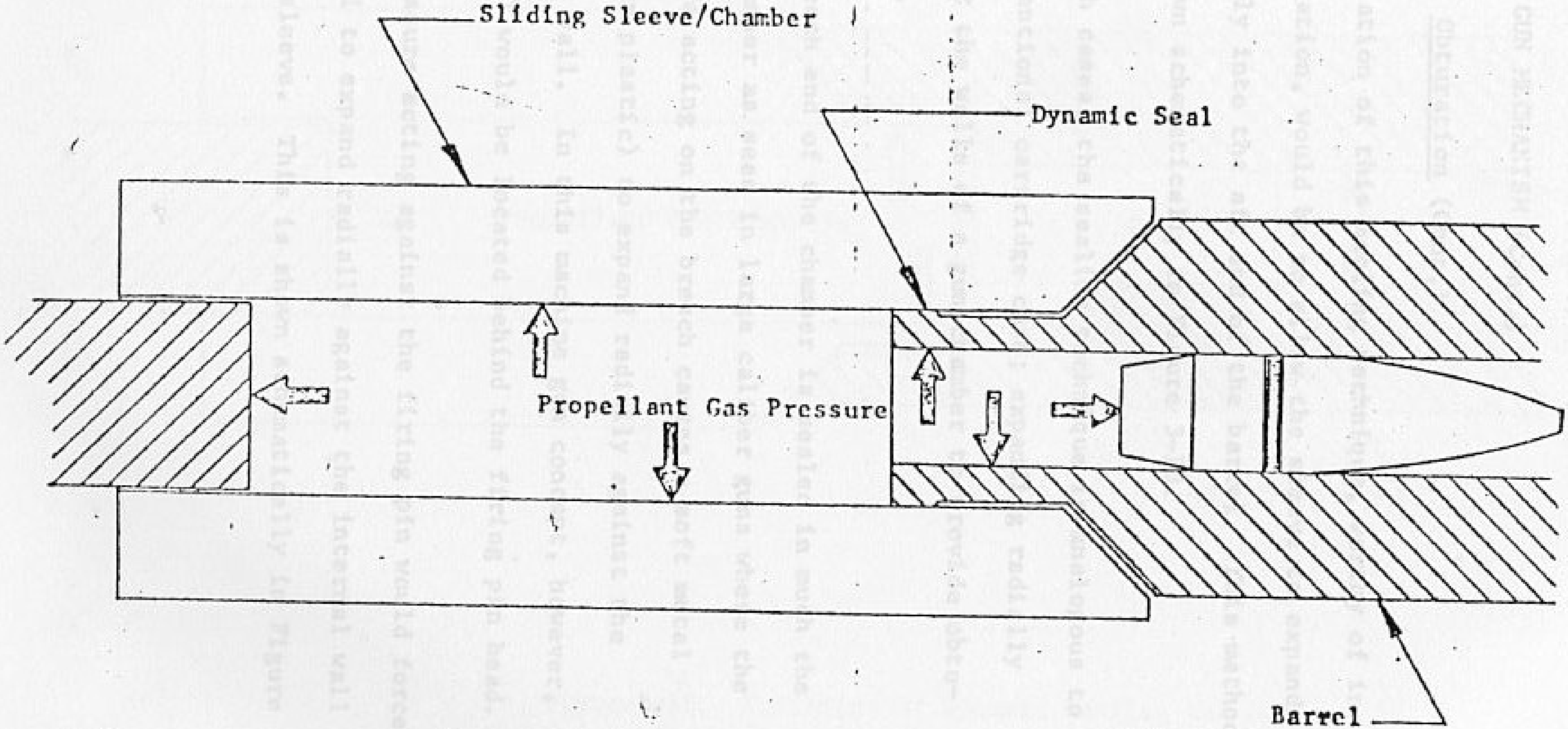


Figure 3-12. Forward Obturation by Dynamic Sealing Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.3 Obturation (Cont.)

A variation of this sealing technique, worthy of investigation, would be to allow the sleeve to expand radially into the aft end of the barrel. This method is shown schematically in Figure 3-13.

In both cases, the sealing technique is analogous to a conventional cartridge case; expanding radially against the walls of a gun chamber to provide obturation.

The breech end of the chamber is sealed in much the same manner as seen in large caliber guns where the pressure acting on the breech causes a soft metal ring (or plastic) to expand radially against the chamber wall. In this machine gun concept, however, the seal would be located behind the firing pin head.

Gas pressure acting against the firing pin would force the seal to expand radially against the internal wall of the sleeve. This is shown schematically in Figure 3-14.

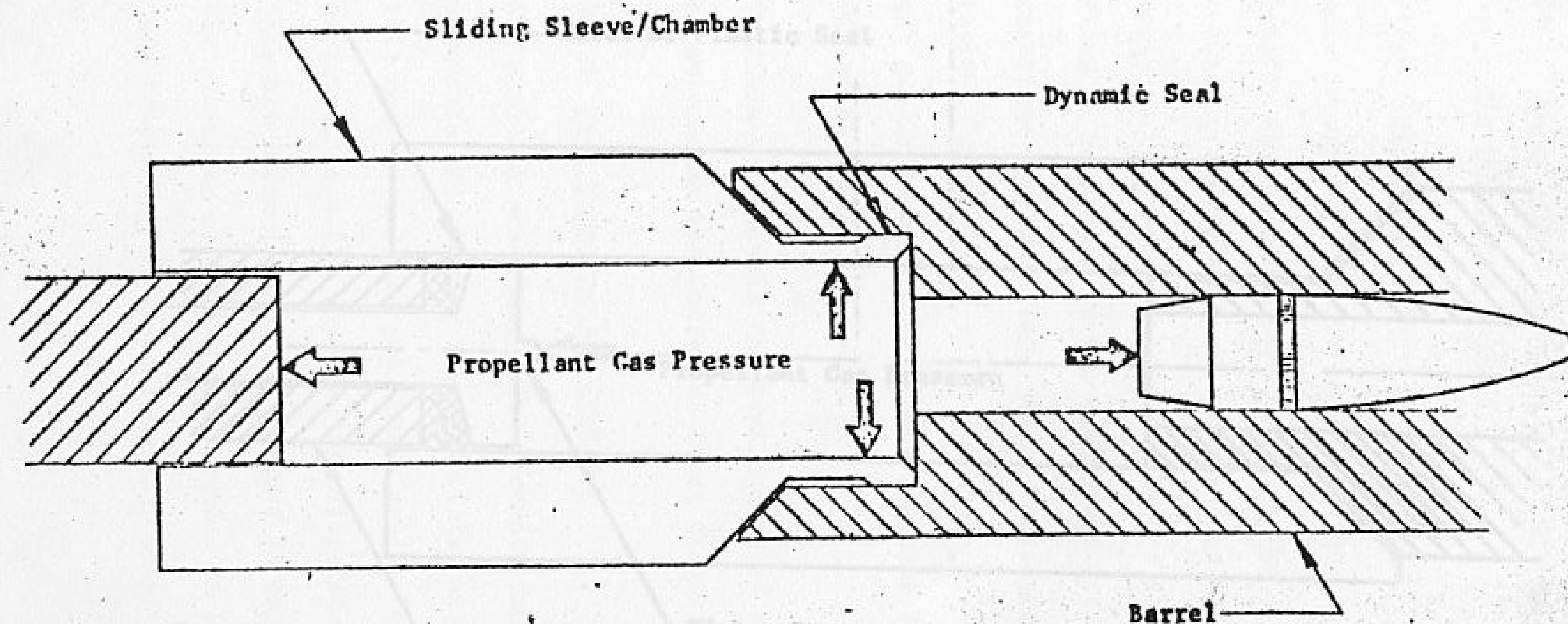


Figure 3-13. Variation Of Dynamic Sealing Concept

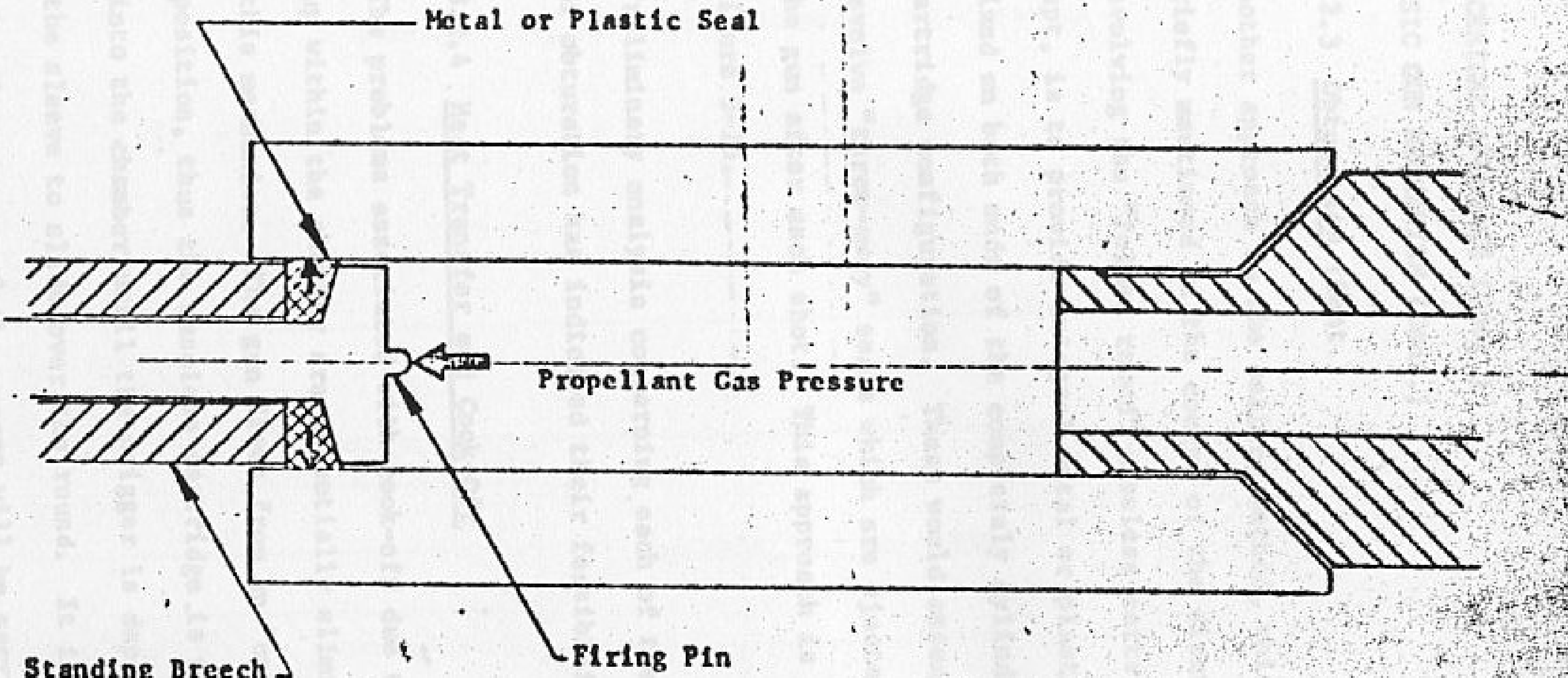


Figure 3-14. Breech End Sealing Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.3 Obturation (Cont.)

Another approach to the sealing method, which was briefly mentioned in the course of the discussion involving the "folded round" caseless cartridge concept, is to provide integral metal or plastic seals fixed on both ends of the completely cylindrical cartridge configuration. These would essentially involve "throw-away" seals which are ejected from the gun after each shot. This approach is shown in Figure 3-15.

Preliminary analysis concerning each of these methods of obturation has indicated their feasibility.

3.2.4 Heat Transfer and Cook-Off

The problems associated with cook-off due to heat build-up within the chamber are essentially eliminated with this mechanism. The gun fires from an "open-bolt" position, thus the caseless cartridge is never inserted into the chamber until the trigger is depressed, releasing the sleeve to slide over the round. It is not expected that inaccuracy of the weapon will be sacrificed because

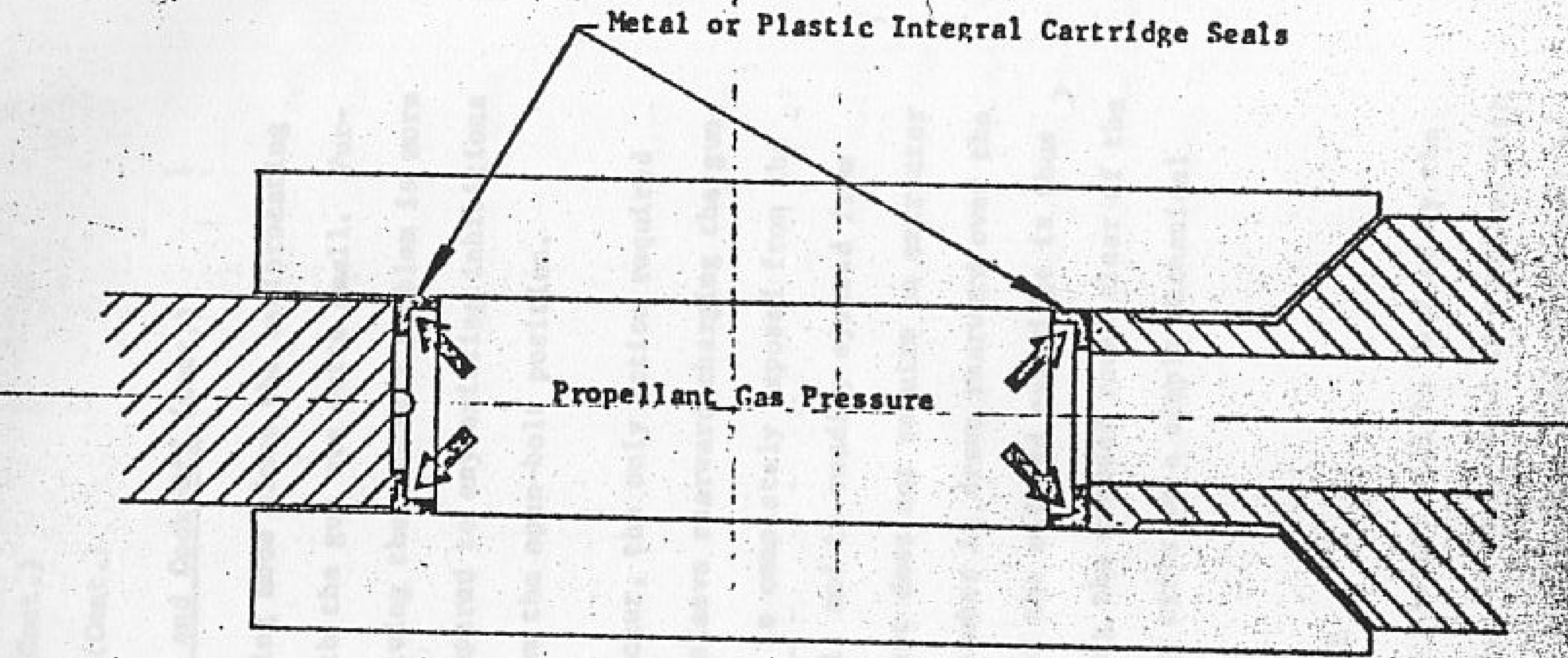


Figure 3-15. Integral Cartridge Seals Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2. BASIC GUN MECHANISM (Cont.)

3.2.4 Heat Transfer and Cook-Off (Cont.)

of the open-bolt firing mode since the reciprocating masses associated with the gun are quite small. Further, the gain in solving the cook-off problem is more than satisfactory compared to any existing inhibitions concerning firing from the open-bolt position.

If a misfire should occur, the only action required would be to draw the sleeve rearward charging the gun, thus the round itself is completely exposed from the chamber and the barrel; and is readily ejected from the weapon. The concept does not require an extractor mechanism since the chamber is drawn rearward over the cartridge. Ejection of the unfired cartridge is thus accomplished by sweeping the exposed round clear of the gun during the charging cycle by a simple mechanical lever.

3.2.5 Ejector Operation

The final motion of the ejector will be decided by the type of ammunition used. If each round is supplied with its own non-combustible seals, then some effort must be

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.5 Ejector Operation (Cont.)

made to sweep these seals out of the weapon after each shot is fired, but if all seals are integral with the weapon, then the ejector need operate only when the charging handle is drawn to the rear as would be done to load or clear the chamber.

The ejector itself would be a curved plate that lays along side of the space between the space between the standing breech and the barrel, but out of the way of the sliding chamber. In length, it would be only slightly shorter than a round and its motion would be that of sweeping across the gap to force any round or part of a round out through the ejection port. This sweeping motion would be caused by the operating rod forcing a follower along the ejector pivot rod which is twisted on the end as seen in Figure 3-16.

3.2.6 Feed Mechanism

The feeder would be designed to handle-linked belt ammunition and with only minor changes could feed from right or left side.

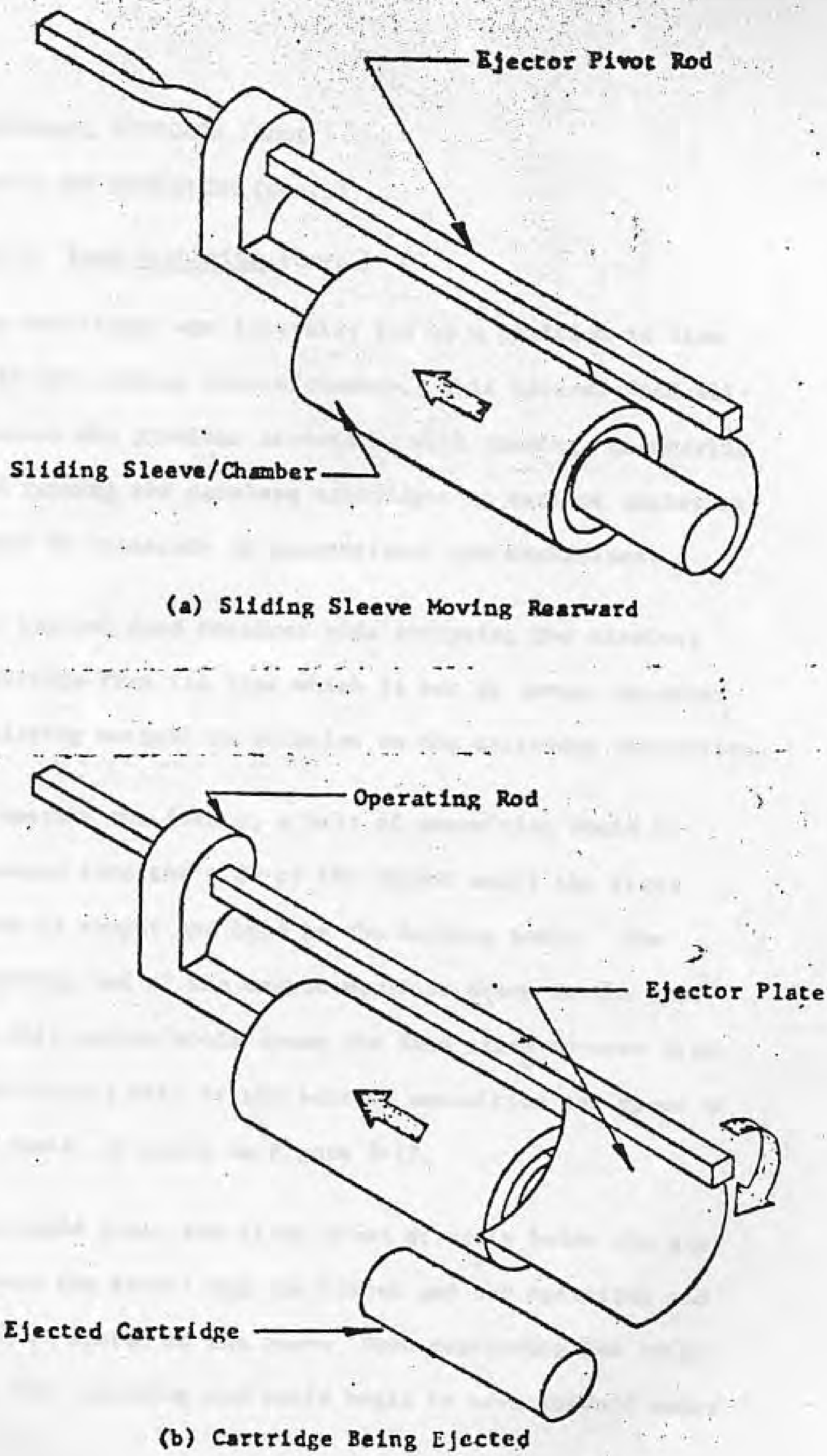


Figure 3-16. Ejector Operation Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.6 Feed Mechanism (Cont.)

The cartridges are laterally fed to a position in line with the sliding sleeve/chamber. This lateral feed eliminates the problems associated with ramming, chambering and ramping the caseless cartridges at extreme angles as would be necessary in conventional gun mechanisms.

The lateral feed requires side stripping the caseless cartridge from its link which is not as severe as other stripping methods in relation to the cartridge durability.

To operate the feeder, a belt of ammunition would be inserted into the side of the feeder until the first round is caught and held by the holding pawls. The operating rod of the weapon would be drawn to the rear and this motion would cause the feed slide to move sideways drawing with it the belt of ammunition the space of one round, as shown in Figure 3-17.

This would place the first round directly below the gap between the barrel and the breech and the operating rod would be seared to the rear. Upon depressing the trigger, the operating rod would begin to move forward under

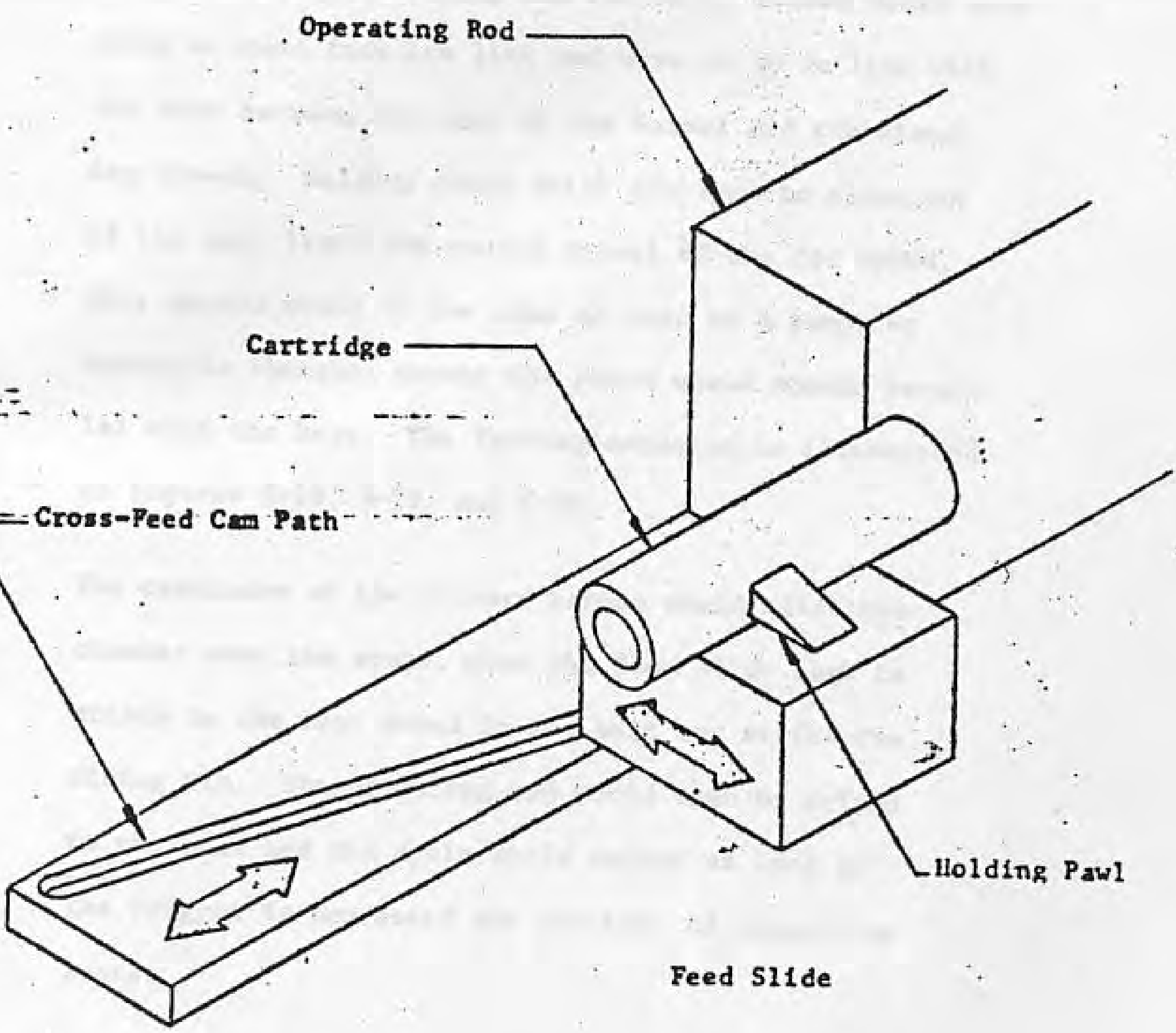


Figure 3-17. Cross-Feding Concept

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.6 Feed Mechanism (Cont.)

the impulse of its spring and its first motion would side strip a round from its link and move it up in line with the bore between the rear of the barrel and the standing breech. Holding pawls which are free to pivot out of the way, limit the upward travel of the fed round. This motion would be the same as seen on a pump, or automatic shotgun, except the round would remain parallel with the bore. The feeding sequence is illustrated in Figures 3-18, 3-19, and 3-20.

The remainder of the forward stroke would slide the chamber over the round, move the feed slide back to attach to the next round in the belt and strike the firing pin. The operating rod would then be driven to the rear and the cycle would repeat as long as the trigger is depressed and the belt of ammunition lasts.

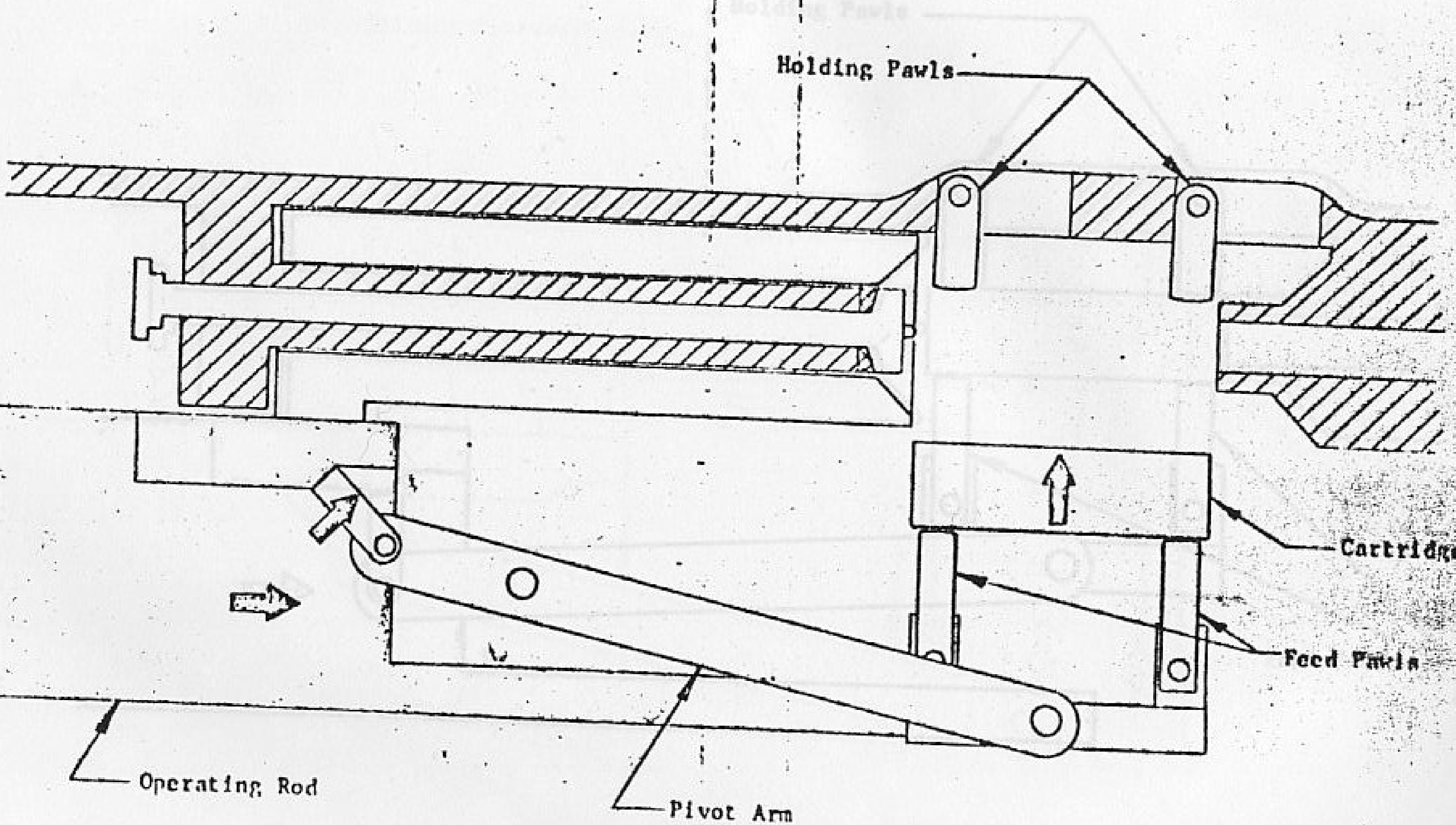


Figure 3-18. Feed Concept, Side Stripping Started

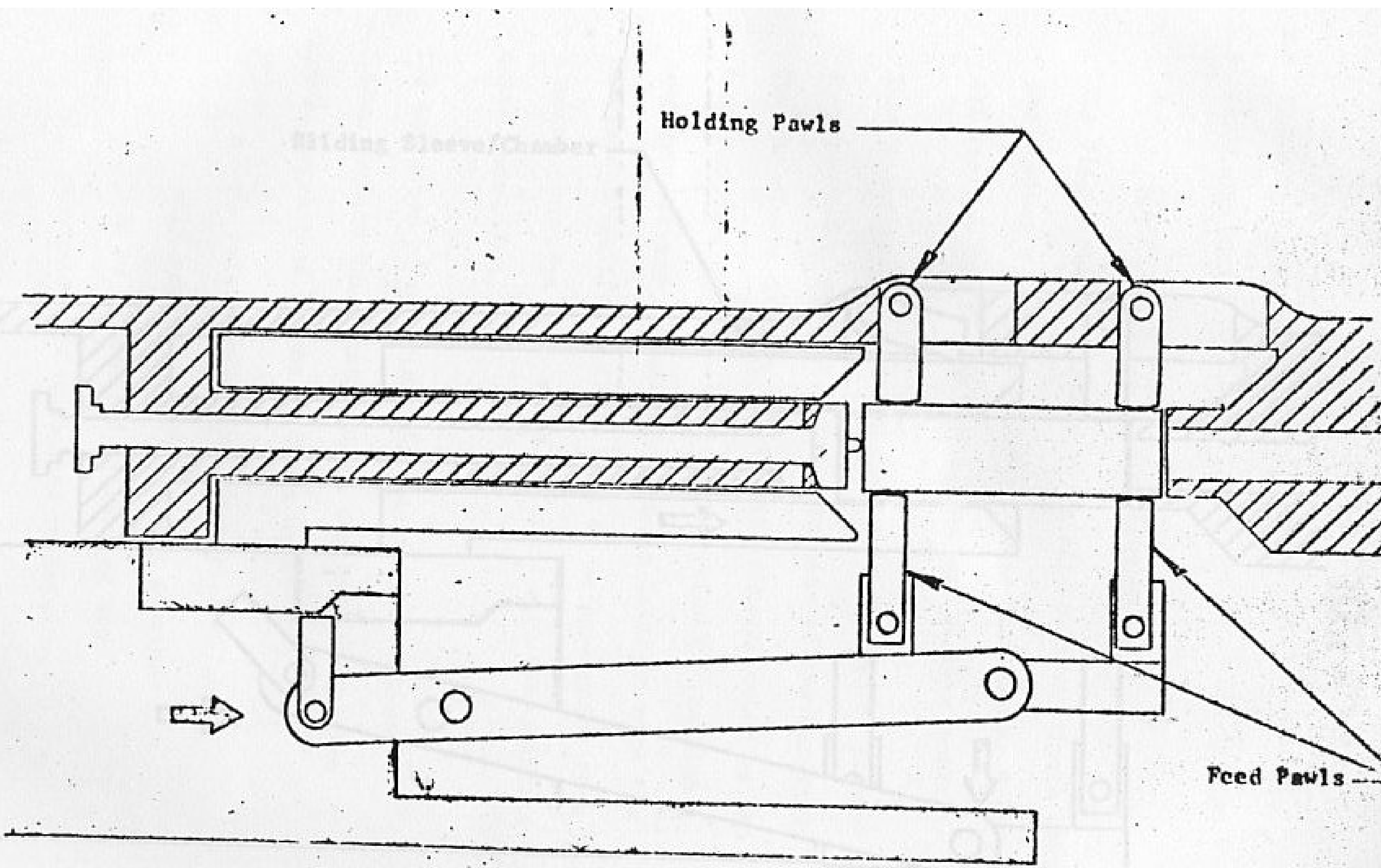


Figure 3-19. Feed Concept, Stripping Complete

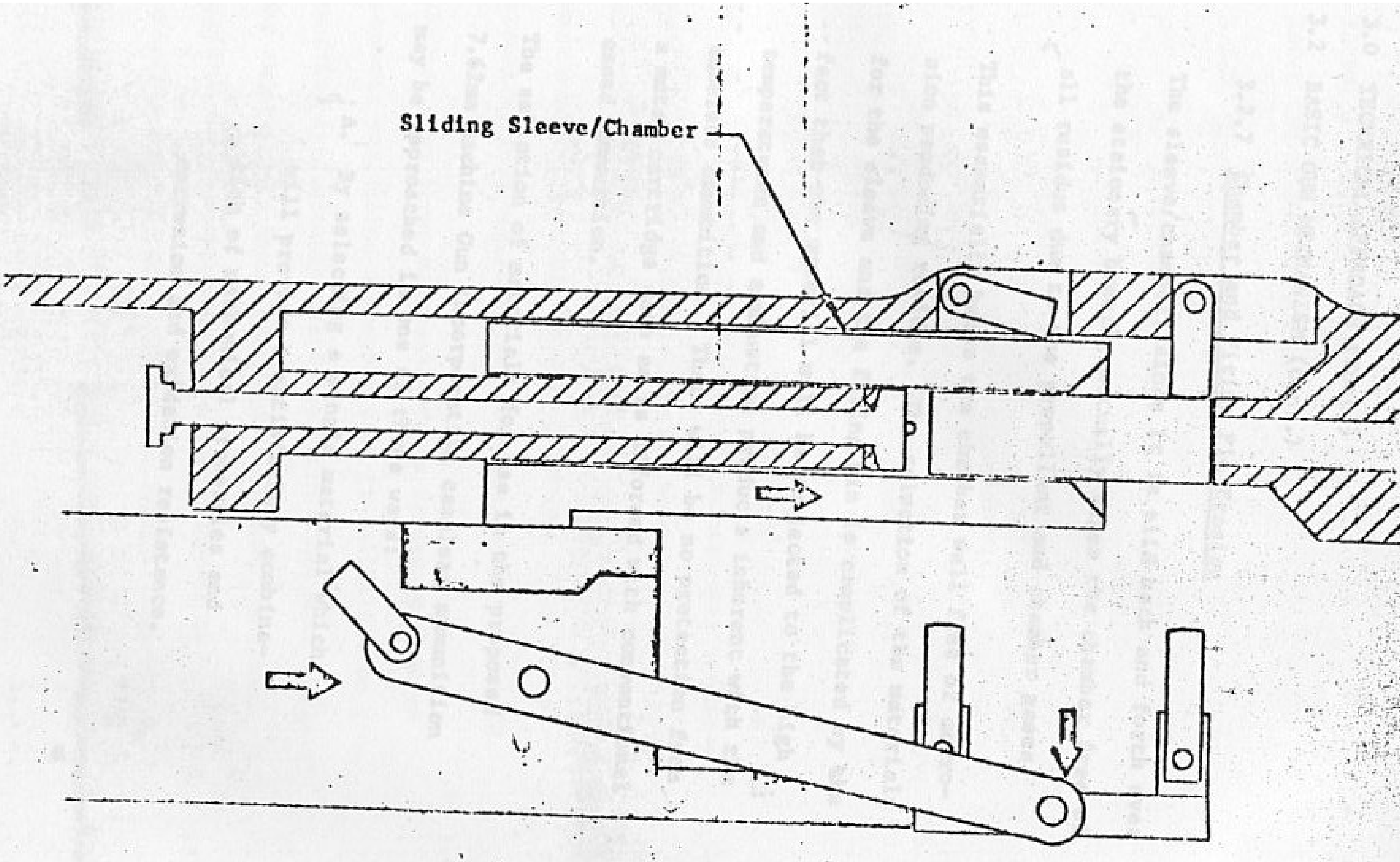


Figure 3-20. Feed Concept, End of Feed Cycle

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.7 Chamber and Firing Pin Erosion

The sleeve/chamber, since it is slid back and forth over the staionary breech, actually wipes the chamber free of all residue due to the propellant and chamber gases.

This essentially keeps the chamber wall free of corrosion producing residue. The selection of the materials for the sleeve and the firing pin is complicated by the fact that ~~the~~ material will be subjected to the high temperatures and combustion products inherent with the caseless ammunition. There will be no protection from a metal cartridge case as is afforded with conventional cased ammunition.

The selection of materials for use in the proposed 7.62mm Machine Gun incorporating caseless ammunition may be approached in one of three ways:

A. By selecting a single material which will provide a satisfactory combination of mechanical properties and corrosion and oxidation resistance.

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.7 Chamber and Firing Pin Erosion (Cont.)

B. Incorporating a liner material which possesses adequate corrosion and wear resistance with one which has the required mechanical properties,

C. Selecting a material capable of being surface treated to provide the desired properties.

Though an adequate description of the property requirements is not yet available, it can be assumed that the material considered should possess good corrosion and wear resistance at elevated temperatures, high yield strength, good toughness and adequate fatigue strength.

Whereas, the first approach appears favorable from an economic and design standpoint, it is unlikely that a material is currently available which would meet all the requirements demanded by such a system. The precipitation-hardenable stainless steels appear to satisfy a majority of requirements, though a sacrifice in yield strength, toughness and wear resistance is

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.7 Chamber and Firing Pin Erosion (Cont.)

made for the increased oxidation and corrosion resistance. The three (3) classes of precipitation hardening stainless steels include the martensitic types (17-4HP), the semi-austenitic types (17-7PH, AM350), and the austenitic types (A-286, 17-10P).

The martensitic types have somewhat higher tensile properties than the austenitic types, but lack formability in the annealed condition when compared to the other types, and they maintain these properties up to around 900°F. No information is available on the wear resistance of these alloys; however, it is doubtful whether they can stand up to the service conditions encountered in this type of system without some form of surface treatment.

The semi-austenitic types have higher tensile properties, but sacrifice toughness. They have good corrosion resistance to 800°F and their higher hardness would indicate they would have better wear resistance than the other precipitation hardening stainless steels. Their use would be limited due to their low toughness and the fact

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.7 <u>Chamber and Firing Pin Erosion</u> (Cont.)

that they are not recommended for service at temperatures greater than 700°F due to embrittlement at these temperatures.

The austenitic precipitation hardenable stainless steels have lower room temperature tensile properties than the other two (2) types, but retain their tensile, rupture and creep properties better at elevated temperatures up to the aging temperature.

Various other grades of austenitic and ferritic stainless steels have been used successfully at elevated temperatures, but their tensile properties and toughness are often too low to justify their use in an application of this type. Various Ni-Cr-V-Mo steels have recently been developed which appear to satisfy the majority of requirements for this application, however, insufficient data is available on forming and corrosion and wear resistance for further consideration.

The second approach appears more realistic from a materials standpoint at this time. A permanent or replaceable corro-

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

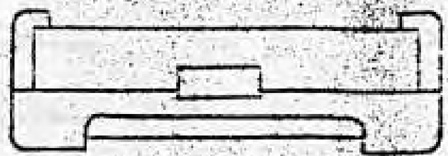
3.2.7 Chamber and Firing Pin Erosion (Cont.)

sion resistant liner in conjunction with a tough back-up material would provide the necessary combination of properties required.

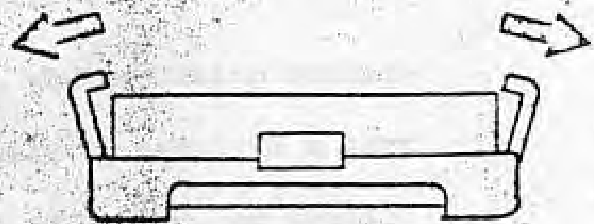
Various insert materials have been used successfully. They include Stellites, and columbium or molybdenum base alloys. The Stellites have been used extensively in several automatic weapon applications. The major problem which arises from this approach is the selection of materials with corresponding thermal properties.

The final approach would be to properly surface treat a material to obtain the property requirements desired. Chrome plating of the type used on numerous conventional weapon components would improve both the corrosion and wear resistance of the majority of alloy steels. However, the chrome plate begins to lose its effectiveness at temperatures greater than 600°F. Nitriding also increases the corrosion and wear resistance of alloy steels and is effective to approximately 1000°F. However, when used in

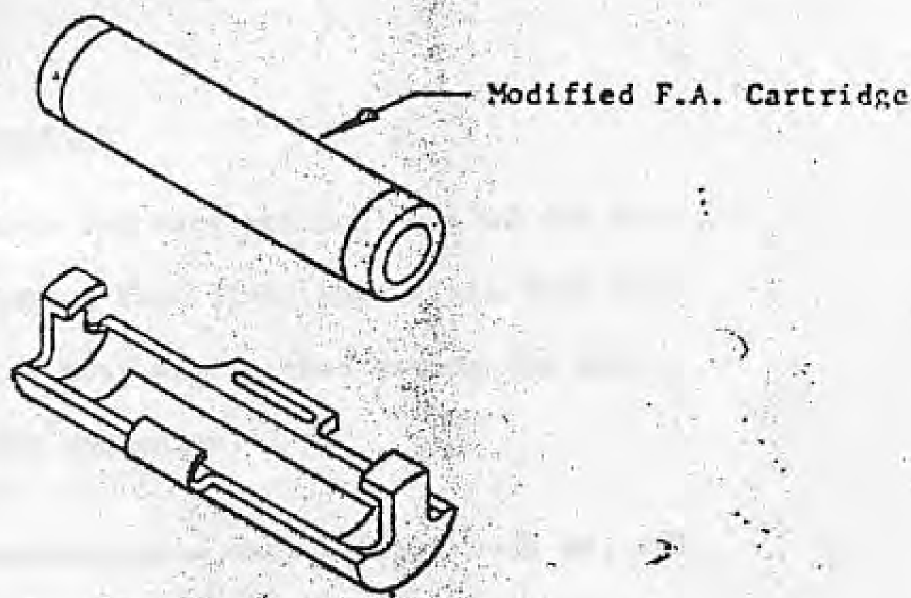
(a) Side Views



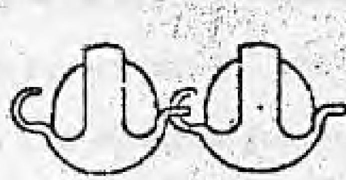
(b) Side View Showing Link Cammed Open for Side-Stripping



(c) Exploded View



(d) End View of Linked Belt



3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

3.2.7 Chamber and Firing Pin Erosion (Cont.)

conjunction with stainless steels, the corrosion resistance is decreased. Hard facing (welding metal to a part to increase resistance to erosion, corrosion, or heat) also warrants consideration for such components as the firing pin.

3.2.8 Link and Magazine

Because of the simple but very critical job of the belt, suitable side stripping belt links,compatible with the ammunition concepts, must be designed during the development of the feed mechanism.

Link design is dependent upon many things; such as, the shape of the round used, the amount of belt flexibility needed, and compatibility with the gun mechanism. The link could also be designed to act as a round protector for the somewhat fragile caseless round. A link with this concept is shown in Figure 3-21. This link would function well with the modified Frankford Arsenal Round as illustrated, and in operation, would be cammed open as it is drawn into the machine gun, thus freeing the round for side stripping.

3.0 TECHNICAL APPROACH (Cont.)

3.2 BASIC GUN MECHANISM (Cont.)

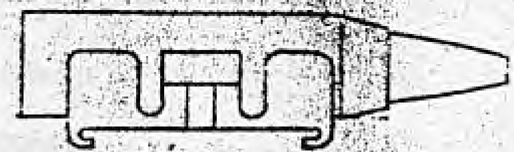
3.2.8 Link and Magazine (Cont.)

Figure 3-22 shows a more conventional link which would function with almost any round design. With this link, some means of indexing the round to the link must be provided, such as a groove in the round and a detent in the link. This link would not provide the protection of the first link described, but would be more adaptable to different shaped rounds.

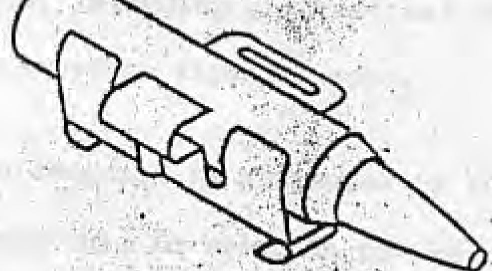
During the course of the development, a suitable magazine, preferably a plastic-disposable type, would be designed. The design would be compatible with the gun concept and provide the desired versatility to the weapon.

3.3 TECHNICAL SUMMARY

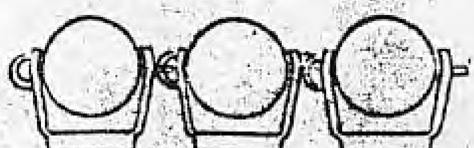
The TRW concept of a machine gun capable of firing 7.62mm molded caseless propellant cartridges is a feasible approach to the requirements of an automatic weapon of this nature. The design approach of a sliding sleeve/chamber with lateral feed results in



(a) Side View



(b) Isometric View



(c) End View of Linked Belt

Figure 3-22 Link Concept for Frankford Arsenal Round

3.0 TECHNICAL APPROACH (Cont.)

3.3 TECHNICAL SUMMARY (Cont.)

a very simple gun mechanism that will require a minimum of parts, thus enhancing the gun reliability and ease of maintenance.

It is anticipated that the final gun design will result in a weapon weight much less than the 30 lb. maximum requirement for this caliber. The design concept can be easily scaled to 5.56mm size. The machine gun concept can be readily adaptable to a variety of mounting conditions, including aircraft and vehicles, as well as ground mounts and shoulder fired weapons.

The three caseless ammunition concepts as presented in this proposal appear feasible and compatible in relation to the proposed gun concept.

4.0 RELATED EXPERIENCE

The TRW Ordnance Development Center was created for the sole purpose of developing weapon systems for military roles in order to fulfill a wide spectrum of user requirements.

The Engineering Staff has gained wide experience in the design of gun mechanisms tailored for specific applications. Among the myriad of development programs conducted by the Ordnance Development Center, the following are submitted as examples of work related to the solution of problems to be encountered in fulfilling the work scope of this proposal:

A. TRW 6425-25mm Vehicle Rapid Fire Weapon System

Began as a paper concept in September of 1964, this weapon system is currently under evaluation by the United States Army and other NATO countries. Prior to the prototype hardware phase, TRW engineers, with the design consultation of E. M. Stoner, conducted weapon system design studies, including extensive heat transfer work to determine barrel material and thickness, chamber configuration and probable parts life.

4.0 RELATED EXPERIENCE (Cont.)

A. (Cont.)

An outgrowth of these studies is the continuous product improvement program on this weapon system, which has led to extensive environmental testing. TRW engineers have fired this weapon at temperature ranges of -70°F to +165°F in order to evaluate the impact of extreme temperature changes on the basic cannon design parameters.

B. TRW 65/7.62 - 7.62mm Machine Gun

TRW Development Engineers conducted an in-house design and development program intended to fulfill a potential requirement for a vehicular mounted machine gun. The design is basically a "scaled" version of the TRW 6425 which incorporates the simplified design features and expected reliability of performance inherent in the 25mm Weapon.

C. SPIW Magazine Feed

TRW, under Government contract, let by Springfield Armory, has participated in the design and development of a plastic-disposable magazine feed system for the SPIW Weapon. The design effort resulted in the

4.0 RELATED EXPERIENCE (Cont.)

C. SPIW Magazine Feed (Cont.)

fabrication of prototype units which demonstrated the feasibility of the design and the compatibility with the weapon requirements.

D. 7.62mm Caseless Investigation

In early 1965, TRW Development Engineers conducted an in-house study to determine the adaptability of an open chamber weapon system to a caseless concept.

The data collected from the above are highly pertinent to the areas under consideration for this study and will be used as required.

E. TRW 6425-25mm Ammunition Propellant Development

TRW Ammunition Engineers have recently conducted a thorough propellant evaluation for the TRW 6425-25mm Weapon System. During this course of work, a complete interior ballistics program was established to aid in determining the necessary propellant parameters. This included trade-off studies comparing energy content, burning rates, and peak pressures produced in order

4.0 RELATED EXPERIENCE (Cont.)

E. Ammunition Development (Cont.)

to maximize propellant efficiency, while simultaneously allowing for the design parameters of weapon functioning requirements.

The accuracy of these studies has been repeatedly proven in actual firing tests.

TRW Ordnance Development Center has called upon its corporate resources to assist and participate in various programs related to the ordnance field. Such studies related to weapons and weapon systems were:

A. Ordnance Applications of Plastics and High Strength Steels

An investigation conducted by the Materials and Processes Department, TRW Equipment Laboratories related to the ordnance applications of plastics. This study concerned itself with the use of plastics in weapon systems for obturation, projectile sabot and disposable magazine applications.

The Materials and Processes Department has also assisted TRW-ODC in the investigation of high strength materials, such as maraging steels, to be used for critically stressed components in weapon systems.

4.0 RELATED EXPERIENCE (Cont.)

B. Heat Transfer Studies Related to Caseless Ammunition

TRW's experience in heat transfer analysis has both breadth and depth.

In many programs, it has been our skills, capabilities, and experience in heat transfer that resulted in significant advances in the state-of-the-art. These programs range from studies of specific heat transfer phenomenon to system development requiring the solution to new heat transfer problems.

TRW has recently completed an investigation into the heat transfer problems associated with caseless ammunition. As a result of these preliminary investigations, TRW is quite capable of proposing technical approaches to the solution of these problems and can, by analytical and experimental means, perform all analyses required as related to the TRW Machine Gun Concept.

5.0 STATEMENT OF WORK

TRW will conduct a best efforts program leading to the design and development of a machine gun capable of firing 7.62mm molded caseless propellant cartridges at a maximum rate of fire of 650 RPM. The required weapon characteristics as specified in paragraph B, Article I, of RFQ DAAF01-67-Q-1662, will be incorporated into the design of the machine gun.

In the development of the concept, TRW will make use of, where applicable and reasonably available, results of previous or current research, development studies and investigations bearing upon or related to the work from both Government and non-Government sources.

TRW will develop the concept based upon a link-belt laterally fed machine gun utilizing the basic TRW gun mechanism concept of a sliding chamber providing for obturation by use of plastic or metallic seals coupled with a dynamic sealing technique.

The machine gun design will be applicable to the three caseless ammunition concepts as presented in this proposal. The three concepts are:

A. Modified Frankford Arsenal "telescoping" round
B. Currently designed Frankford Arsenal Caseless Ammunition

C. TRW Saboted Bullet Caseless Ammunition.

5.0 STATEMENT OF WORK (Cont.)

During the course of the design concept phase, TRW will:

A. Investigate and analyze basic modes of gun operation to determine and recommend the best method readily adaptable to the gun mechanism. These modes of operation will include:

1. Gas operated
2. Firing pin operated
3. Recoil operated
4. Free gas operated

B. Identify the problem areas related to gun functioning associated with each of the three ammunition concepts and determine practical methods of solution.

C. Conduct a trade-off analysis to determine which of the three ammunition concepts most readily integrates with the weapon mechanism.

D. Upon completion of the trade-off evaluation, TRW will recommend which of the weapon/ammunition designs warrant further consideration in a subsequent hardware development phase.

5.0 STATEMENT OF WORK (Cont.)

In the development of the machine gun concept, TRW will conduct engineering design studies to determine:

A. Gun kinematic and design data to include:

1. Recoil velocities of the reciprocating and rotating parts.
2. Travel-time relationship of the reciprocating and rotating parts.
3. Total cyclic time analysis.
4. Energy and force levels associated with the gun mechanisms.
5. Stress analysis of critical components.
6. Spring design analysis, where applicable.
7. Weight analysis.
8. Center of gravity analysis.
9. Obturation by dynamic sealing analysis.

B. TRW will investigate the use of special materials and provide material specification recommendations based upon the results of these investigations. The special material usage is related to:

1. Gun parts subjected to highly erosive conditions, such as the sliding chamber and firing pin.
2. Plastic and metallic seals to provide for obturation in the gun mechanism.

5.0 STATEMENT OF WORK (Cont.)

C. TRW will determine, by numerical analysis, the heat transfer phenomena associated with the gun concept in light of such things as:

1. Minimization of cook-off.
2. Chamber and barrel heat build-up.

In the development of the caseless ammunition concepts, and simultaneously with the development of the machine gun concept, TRW will:

A. Conduct research survey and obtain all available data related to the Frankford Arsenal Caseless Ammunition design and any available data related to the TRW modified version of the Frankford Arsenal concepts.

B. The available data obtained will be analyzed and evaluated in light of its relationship to the TRW machine gun concept.

C. Conduct preliminary interior ballistics analyses in relation to the TRW folded round and the saboted bullet concepts in order to define pertinent characteristics of the ammunition concept such as:

5.0 STATEMENT OF WORK (Cont.)

C. (Cont.)

1. Chamber pressure.
2. Muzzle velocity-time-bore travel relationship related to:
   a) Type/quantity of propellant
   b) Propellant burning rates
   c) Chamber volume/expansion ratio parameters.
3. Primer ignition characteristics.

D. The results of the analyses as stated above will be considered in the trade-off evaluation to determine the recommended weapon/ammunition design.

In the development of the machine gun concept, human factors engineering principles will be considered in the design to include:

A. Design for all environmental conditions.

B. Design for compatibility of mechanism with the operator.

C. Design for simplification of maintenance.

D. Design for ease of manufacture.

E. Design for safety in operation and meaintenance.

5.0 STATEMENT OF WORK (Cont.)

TRW will produce and furnish all engineering design calculations compiled during the course of the development, as well as one (1) complete set of reproducible TRW facility standard engineering layouts, and engineering drawings to include:

A. Complete weapon assembly.

B. Section views of complete weapon assembly.

C. Individual detailed drawings of the major weapon assemblies to include:

1. Barrel Assembly
2. Breech-sliding chamber assembly
3. Firing mechanism
4. Gun action mechanisms
5. Feed assemblies to include both link feed and a magazine feed.
6. Ejection mechanism
7. Charger mechanism
8. Link designs

D. Envelope drawings of the complete weapon assembly to include dimensions of length, width, height. The envelope drawings will also include the adaptation of the machine gun to various applications such as:

5.0 STATEMENT OF WORK (Cont.)

D. (Cont.)

1. Tripod mounted
2. Bipod mounted
3. Provision for shoulder firing
4. Remote firing, vehicle mounted

E. Detailed drawings of the ammunition concepts.

TRW will furnish monthly progress reports in accordance with instructions contained in Article I, paragraph E (1) and (3) of RFQ DAAF01-67-Q-1662.

TRW will furnish a Final Technical Report in accordance with instructions contained in Article I, paragraph E (2) and (3) of RFQ DAAF01-67-Q-1662.

6.0 PROGRAM PLAN

The technique employed at TRW which has been met with a high degree of success, is to plan, conduct and complete a program based upon an integrated approach to a final complete system.

This integrated approach, as related to the development of a machine gun capable of firing caseless ammunition, is to utilize the specialized skills of the TRW Weapons Design Group and the TRW Ammunition Group, which combine their efforts to produce a complete weapon system.

The inter-relationship of these two groups by mutual cooperation in research, design, development and testing enhances the objective of successful completion of this weapon system program.

6.0 PROGRAM PLAN (Cont.)

6.1 MAN-POWER PROJECTIONS

	Man Months						
	1st	2nd	3rd	4th	5th	6th	TOTAL
Project Engineer	.35	.35	.35	.60	.50	1.00	3.15
Weapons Design Engineer	1.00	1.00	1.00	1.00	1.00		5.00
Weapons Design Engineer	1.00	1.00	1.00	1.00	1.00		5.00
Ammunition Eng.	.35	.60	.60	.25			1.80
Materials Eng.	.25	.25	.50				1.00
TOTALS	2.95	3.20	3.45	2.85	2.50	1.00	15.95

NOTE: The consultant services of E. M. Stoner and key senior technical management personnel will be applied to the program as required.

8.0 PROGRAM MANAGEMENT

TRW has assigned to the proposed program a management team experienced in analysis, design and development involving all aspects of weapons and weapon systems. Every activity required is incorporated into the program schedule with the Program Manager responsible for project guidance and control. This project team has access to all staff services required to expedite work on the contract. Such organization of responsibility provides shorter lines of communication and thus more sensitive response to program requirements.

A program management network technique has been used for planning, costing and scheduling the entire proposed program. This same network will be used for controlling and monitoring the program.

The prime function of the Program Manager is planning, leadership and guidance of the total program assigned to him.

To aid the Program Manager in this responsibility, other components of the Jet and Ordnance Division establish records and controls as guides for efficient managing techniques.

Project Planning and Control with the Accounting organization continually monitor and feed back to the Program Manager information of importance such as budget data, etc. This allows the

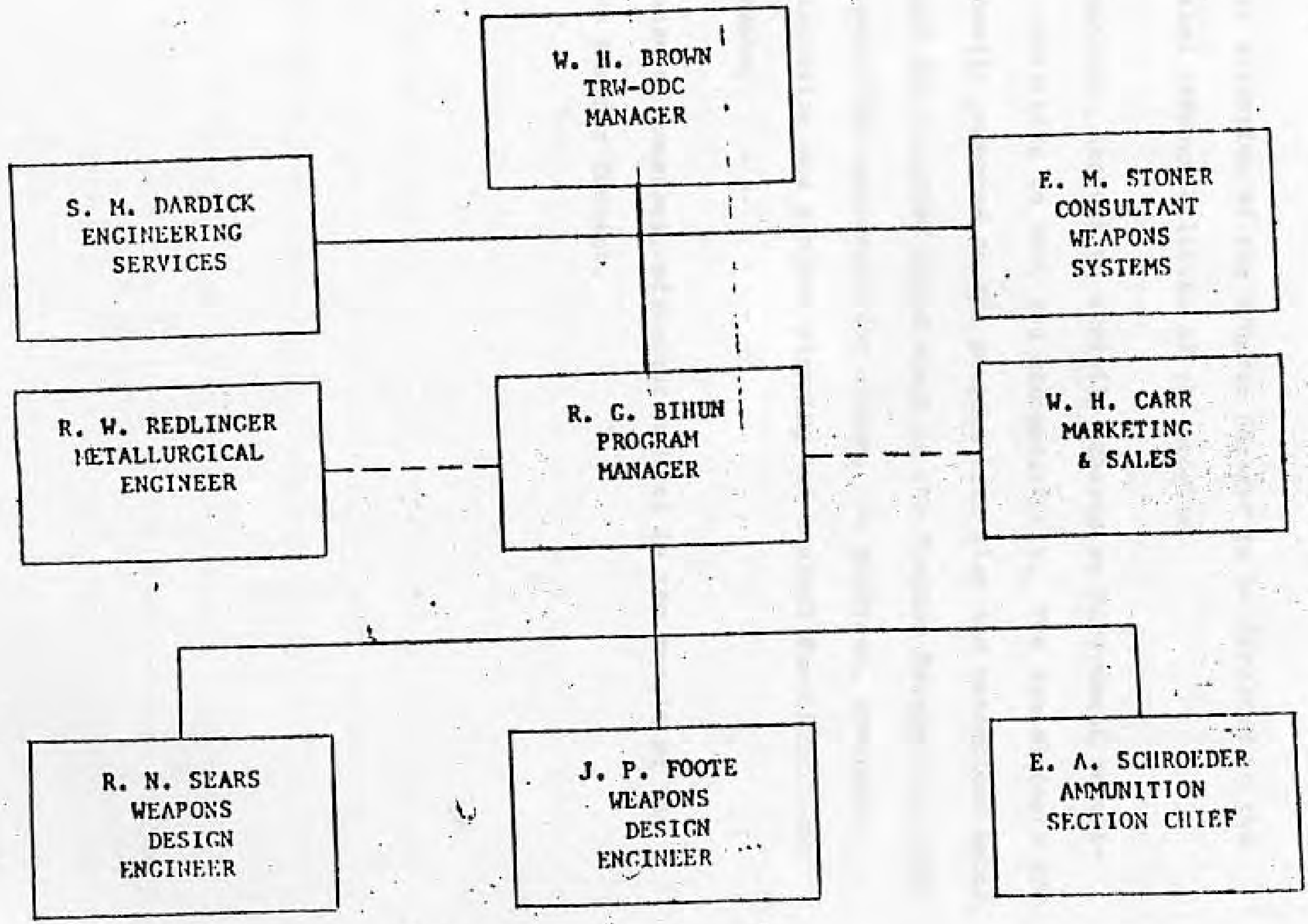
8.0 PROGRAM MANAGEMENT (Cont.)

fullest attention of the Program Manager to be directed to the technical responsibilities of the program.

For instance, accounting strictly adheres to Government regulations pertaining to cost and accountability. The acutal costs are continually compared to the porgram cost plan and exceptions noted, analyzed and reported immediately to the Program Manager and other interested TRW components for action. In addition, contracts administration and project planning and control function in the same manner.

Insurance of constant, efficient control is the result of the Project Manager Concept.

8.1 PROJECT ORGANIZATION



STEVEN M. DARDICK, Section Chief - Engineering Services

PRESENT POSITION: Responsible for supervising the administrative services functions at the Ordnance Development Center, including the cost estimating, contract coordinating, program planning, and cost control reporting of scheduled programs.

Supervises test services function, including range operations and field services liaison. The test services group provides firing capability in support of both development and contractor programs.

EDUCATION: B.S. Industrial Management, Lehigh University, 1960

EXPERIENCE: Program Planner, TRW Inc. 1965 - 1966

Engineering Assistant, TRW Inc. 1964 - 1965

Facilities Manager, Dardick Corporation 1963 - 1964.

First Lieutenant, U.S.A.F. 1960 - 1963

Ballistic Technician, Dardick Corporation 1957 - 1960

HIGHLIGHTS: As Section Chief of the Engineering Services Group, Mr. Dardick has been active in planning, budgeting and scheduling all programs at the Ordnance Development Center.

STEVEN M. DARDICK, Section Chief - Engineering Services (Cont.)

HIGHLIGHTS: (Cont.)

This effort has ranged from use of PERT and CPM techniques to digital computer work for manpower and inventory control.

Prior to advancing to an administrative function, Mr. Dardick served as an engineering assistant in ammunition development. These duties included assignment as project engineer on an advanced small arms ammunition concept, and optimization studies of ammunition in the medium caliber range.

As facilities manager for Dardick Corporation, Mr. Dardick acted as liaison between Mr. David Dardick and the licensees under the latter's open chamber patents. Duties included coordinating with Frankford Arsenal in charge development experimentation, and firing fixture testing to analyze ammunition performance. Other efforts involved materials development for tround ammunition.

STEVEN M. DARDICK, Section Chief - Engineering Services (Cont.)

HIGHLIGHTS (Cont.)

Mr. Dardick served as Launch Control Officer on a Thor missile site with the U.S. Air Force for two and one-half years.

As ballistic technician for Dardick Corporation, Mr. Dardick assisted in the testing and development of Dardick Handguns. These duties included test firing of weapons, experimental loading and fixture firing of ammunition.

ASSOCIATIONS: Lambda Mu Sigma

National Rifle Association

American Ordnance Association.

ERT W. REDLINGER, Principal Engineer

PRESENT POSITION: Mr. Redlinger is the engineer in charge of Air Force programs for precision forging turbine wheels and development of improved bomb suspension lugs. His recent assignments include the responsibility for development programs relating to ordnance requirements and direction of liaison with the TRW Ordnance Development Center. He currently serves as program manager for the development of improved processing techniques for experimental warheads.

EDUCATION: B.S., Metallurgical Engineering from Carnegie Institute of Technology.

EXPERIENCE: He joined the Westinghouse Atomic Power Laboratory where he was concerned with the development of fabrication techniques for hafnium and zirconium and the process development of ceramic fuel wafers and alternate control materials for nuclear reactors. This work provided the background for his contributions to the Metallurgy of Hafnium and Neutron Absorber Materials for Reactor Control.

ROBERT W. REDLINGER, Principal Engineer (Cont.)

HIGHLIGHTS: Since joining the Materials and Processes Department in 1961, Mr. Redlinger had assisted in programs for the development of tungsten nozzle inserts and conducted forging programs for the fabrication of experimental and commercial columbium-base alloys into jet engine components. He was responsible for the installation and evaluation of a high velocity metalworking machine and subsequent development programs relating to high velocity deformation.

ASSOCIATIONS: American Society for Metals

American Ordnance Association.

JOHN P. FOOTE, Development Engineer

PRESENT POSITION: Mr. Foote is responsible for the design, development and testing of weapons currently under development.

EDUCATION: B.S.M.E., University of Texas, 1962 Austin, Texas

EXPERIENCE: Project Engineer, KOBE Inc., Huntington Park, California.

Assistant Project Engineer, AVCO Ordnance, Richmond, Indiana.

Jet Test Engineer, Pratt & Whitney Aircraft, West Palm Beach, Florida.

HIGHLIGHTS: While at KOBE Inc., Mr. Foote was responsible for design, testing and field installation of High Pressure Oil Well Control Valves. With AVCO Ordnance, Tactical Weapons Group, Mr. Foote assisted in the development and testing of the AVROC 15-40, a 40mm gas operated rocket firing machine gun, also responsible for design and testing on the AVROC 2-15, a 15mm gas operated rocket firing pistol. As a Jet Test Engineer with Pratt & Whitney, Mr. Foote was responsible for coordinating and running sea level and high altitude tests on J-58 Jet Engines.

ROBERT N. SEARS, Senior Design Engineer

PRESENT POSITION: Mr. Sears is responsible for the design, development and testing of weapons and ammunition currently under development at the TRW Ordnance Development Center.

EXPERIENCE: Mr. Sears has had twenty years' of experience in ordnance and is thoroughly acquainted with the aspects of the business from original concept to field use. He was intimately connected with the design and development of the TRW 6425-25mm Automatic Cannon.

HIGHLIGHTS: Before joining TRW, he was a consultant for Savage Arms and Marlin Firearms and was involved in the design and development of the following Springfield Armory projects:

1. SPIW
2. Roman Candle Concept
3. Alpha Systems Weapons
4. XM 75 Grenade Launcher
5. XM 122 Spotting Machine Gun
6. XM 144 Machine Gun
7. Test Fixture for SPIW Ammunition
8. Original concept and design of grenade launcher for SPIW.
9. XM 9 Helicopter Armament Subsystem

ROBERT N. SEARS, Senior Design Engineer (Cont.)

PUBLICATIONS: Mr. Sears has written numerous technical reports and was technical editor of Guns and Hunting Magazine in 1961. Precision Shooting Magazine published two of his papers entitled, "Telescopes and Sighting Errors", and "Mirage".

EUGENE A. SCHROEDER, Senior Ammunition Engineer

PRESENT POSITION: Mr. Schroeder joined TRW in 1966. In his present position, Section Chief, Ammunition, his responsibilities lie in the analysis, design, test and evaluation of advanced ammunition and fuzes. He is responsible for all ammunition developments for the TRW 25mm Weapon. Also, he is responsible for fuzing concepts for 25mm and 20mm ammunition.

EDUCATION: B.S.M.E., Bradley, University, 1954

EXPERIENCE: Prior to joining TRW, Mr. Schroeder was an engineering manager for AVCO Ordnance Division. There he was responsible for advanced design of weapons, warheads and artillery ammunition. Among the studies and developments achieved were 2.75" Target Marking Warhead, Repeating Anti-Personnel Mine, Cluster Munitions for Aircraft Dispensers, XM 70 Artillery Munitions, SPIW preliminary design and analysis and other classified ammunition developments.

Prior to his joining AVCO in 1962, Mr. Schroeder was associated with the Bermite Powder Company as a Senior Engineer and Project Manager. He was

EUGENE A. SCHROEDER, Senior Ammunition Engineer (Cont.)

EXPERIENCE: (Cont.)

responsible for design and development of power cartridges, all types of pyrotechnic delays, small rocket motors, destruct devices and shaped charges. He further participated in development of A & A devices, Sofar bombs, thrusters, and ejection assemblies.

As a Project Engineer for the Magnavox Company from 1954 to 1960, Mr. Schroeder was responsible for design and development of fuzes, both rocket and artillery, missiles S & A devices, and acceleration integrating devices. He also participated in various electronic programs in solenoids and data processing machines.

HIGHLIGHTS: Various programs he participated in were: Redeye fuzing, XM 32 S & A device, T 1409 fuze, T 1405 fuze, FMU/3B fuze, 2-inch rocket, 1 1/2 inch rocket and others.

ROBERT G. BIHUN, Development Engineer

PRESENT POSITION: Project Engineer for the design and development of a 35mm light-weight, anti-aircraft automatic cannon. Responsible for testing and analysis of weapons currently under development at the TRW Ordnance Development Center.

EDUCATION: B.S.M.E., university of Michigan, Ann Arbor, 1961

EXPERIENCE: Theoretical analysis of numerous proposed TRW weapon systems. Design and performance analysis of the TRW 6425-25mm Automatic Cannon; chief test engineer for the TRW 6425-25mm development program; complete analysis of test results. Development engineer for proposed TRW tank-mounted machine gun. Ammunition development engineer for current and proposed ammunition concepts; conducted propellant development porgram for 25mm ammunition.

Commanding Officer, Explosive Ordnance Detachment, U.S. Army Ordnance Corps, October 1961 to 1964.

Research Engineer, Research and Development Department, Ingersoll-Rand, Phillipsburg, New Jersey 1961.

ROBERT G. BIHUN, Development Engineer (Cont.)

EXPERIENCE: (Cont.)

Research Assistant, Heat Transfer and Thermodynamics Laboratory, University of Michigan 1960-1961.

HIGHLIGHTS: Analysis of weapon systems included complete kinematic, dynamic and stress analysis of weapons presently under development and future weapons concepts.

First Lieutenant, U. S. Army Ordnance Corps, specialized training and experience in weapons and ammunition including special and nuclear weapons.

As research engineer with Ingersoll-Rand, conducted analysis of "Thermodynamics of Non-Ideal Gases."

ASSOCIATIONS: Associate Member, American Society of Mechanical Engineers.

American Ordnance Association

Tau Beta Pi and Pi Tau Sigma, National Honorary Engineering Societies.

Registered "Engineer-in-Training", Professional Engineers, State of Michigan.

EUGENE M. STONER, Consultant, Weapon Systems

PRESENT POSITION: Mr. Stoner is available in a consultant capacity on all projects undertaken by TRW.

EXPERIENCE: Mr. Stoner joined TRW early in 1964, as a key member of its ordnance engineering staff. His vast experience as a designer of many shoulder-fired, aircraft and vehicle mounted weapons has necessitated frequent consideration of the human factors problem and of working closely with human factors engineers.

HIGHLIGHTS: Most recently, Mr. Stoner has been responsible for designing the following weapons on which he holds many patents:

1. MA-1 Air Force Survival Rifle
2. AR-7 Commercial Version of survival rifle now being manufactured by Armalite Inc.
3. AR-9 Automatic Shotgun - 12 gage
4. AR-10 Automatic NATO Caliber Rifle now being manufactured by AI of Holland.
5. AR-11 High Velocity 22 Caliber Automatic Military Weapon
6. AR-15 High Velocity .223 Caliber Automatic Rifle now being manufactured by Colt. Designed the .223 round of ammunition for this rifle.

EUGENE M. STONER, Consultant, Weapon Systems (Cont.)

HIGHLIGHTS (Cont.):

7. AR-16 .30 Caliber NATO Automatic Rifle utilizing all stampings for low cost production.

8. Stoner "62" and "63" Weapon Systems.