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REPORT NO. 1406

BRL SURVEY OF THE ARMY CASELESS AMMUNITION PROGRAM

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By: B Brunlist
for HERALD H. LAMBERT
Chief, Security Division
Aberdeen Research & Development Center
Date: 6 MAY 1972

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June 1968

[redacted]

U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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DEPARTMENT OF THE ARMY
U.S. ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
U.S. ARMY BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND 21005

DRDAR-TSB

8 March 1978

SUBJECT: Change of Distribution Statement

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A review of the reports listed below has been completed and it has been determined that the distribution limitation can be removed and the Statement "A" be applied:

REPORT	TITLE	DATE	AD NO
BRL Report No. 1406	BRL Survey Of The Army Caseless Ammunition Program.	Jun 68	844887L
BRL Report No. 1756	The Effect Of Muzzle Jet Asymmetry On Projectile Motion.	Jan 75	B002159L
BRL Report No. 1758	Wind Tunnel Magnus Tests Of Cylindrical And Boattail Army-Navy Spinner Projectiles With Smooth Surface And 20MM Equivalent Engraving (Rifling Grooves).	Feb 75	B002628L
BRL Report No. 1793	The Influence Of Muzzle Gasdynamics Upon The Trajectory Of Fin-Stabilized Projectiles.	Jun 75	B005379L
BRL Report No. 1899	Plane Shock - Thermal Layer Interaction.	Jul 76	B013138L
BRL Report No. 1900	The Effect Of Wind On Flat-Fire Trajectories.	Aug 76	B012872L
BRL Report No. 1945	Muzzle Blast Amplification.	Nov 76	B015779L

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REPORT	TITLE	DATE	AD NO
BRL Memorandum Report No. 1864	SPIW Modes Of Fire.	Feb 68	388522
BRL Memorandum Report No. 1919	Accuracy Of Rifle Fire: SPIW, M16A1, M14.	Mar 68	390136
BRL Memorandum Report No. 1953	A Comparative Evaluation Of The 7.62MM And 5.56MM, G-3 Assault Rifles.	Jan 69	849576
BRL Memorandum Report No. 2211	Optimum Projectile Shape For Improving Ammunition.	Aug 72	906481L
BRL Memorandum Report No. 2215	A Computer Program To Calculate The Physical Properties Of A System Of Coaxial Bodies Of Revolution.	Aug 72	904378L
BRL Memorandum Report No. 2225	Determination Of Muzzle Velocity Changes Due To Nonstandard Propellant Temperature Using An Interior Ballistic Computer Simulation.	Sep 72	905714L
BRL Memorandum Report No. 2276	Muzzle Devices, A State-Of-The-Art Survey. Volume I: Hardware Study.	Feb 73	909325L
BRL Memorandum Report No. 2281	On The Misuse Of Field Artillery Firing Tables.	Mar 73	909704L
BRL Memorandum Report No. 2337	Verification Of Ground Test Data By Instrumented Flight Test Of An Artillery Shell.	Oct 73	915842L
BRL Memorandum Report No. 2338	An Investigation Into The Flight Characteristics Of Rotating Discs.	Oct 73	914557L
BRL Memorandum Report No. 2381	Boundary-Layer Studies On Spinning Bodies Of Revolution.	May 74	920069L
BRL Memorandum Report No. 2396	Long Range Dynamics Flight Experiments With The 155MM Projectile, M483.	Jul 74	922181L

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REPORT	TITLE	DATE	AD NO
BRL Memorandum Report No. 2411	Yawing And Balloting Motion Of A Projectile In The Bore Of A Gun With Application To Gun Tube Damage.	Sep 74	923913L
BRL Memorandum Report No. 2456	Effects Of Base Bleed And Supersonic Nozzle Injection On Base Pressure.	Mar 75	B003442L
BRL Memorandum Report No. 2496	Experiments On Wake Optical Properties.	Jul 75	B005619L
BRL Memorandum Report No. 2501	Preliminary Surveys Of The Three Dimensional Boundary Layer On A Yawed, Spinning Body Of Revolution.	Jul 75	B005829L
BRL Memorandum Report No. 2536	The Effect Of A Sub-Caliber Cylinder After-Body On The Behavior Of Spin-Stabilized Projectiles.	Sep 75	B008388L
BRL Memorandum Report No. 2563	Characteristics Of The Sidewall And Floor Boundary Layers In BRL Supersonic Wind Tunnel No. 1.	Dec 75	B008566L
BRL Memorandum Report No. 2573	Three-Dimensional Boundary Layer Research As Applied To The Magnus Effect On Spinning Projectiles.	Dec 75	B008821L
BRL Memorandum Report No. 2646	Muzzle-Blast Influence On Trajectory Of Asymmetrical Fin-Stabilized Projectiles.	Aug 76	B012784L
BRL Memorandum Report No. 2686	Investigations Of Transitional Ballistics In Muzzle Jet Flow Simulators.	Sep 76	B014175L
BRL Memorandum Report No. 2687	A Transient Experiment Using A Multiple-Pulse Laser Light Source.	Sep 76	B014426L
BRL Memorandum Report No. 2688	On The Free-Electron Density In A Nuclear-Blast Environment.	Sep 76	B014240L

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REPORT	TITLE	DATE	AD NO
BRL Technical Note No. 1541	Kinematic Evaluation Of The Special Purpose Individual Weapon Prototypes.	Aug 64	353233
BRL Technical Note No. 1691	Talk To Cadets Of The United States Military Academy, April 1968, Special Purpose Individual Weapon (SPIW).	Apr 68	390618

FOR THE DIRECTOR:

Vernon J. Wyatt

VERNON J. WYATT
Chief
Technical Support Division

BALLISTIC RESEARCH LABORATORY

REPORT NO. 1406

JUNE 1968

BRL SURVEY OF THE ARMY CASELESS AMMUNITION PROGRAM

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RDT&E Project No. 1P014501A33C

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C R E S E A R C H L A B O R A T O R Y

REPORT NO. 1406

ELBannister/BBGrollman/
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Aberdeen Proving Ground, Md.
June 1968

BRL SURVEY OF THE ARMY CASELESS AMMUNITION PROGRAM

ABSTRACT

A review in depth of the Army Small Arms Caseless Ammunition Program was conducted by a committee designated by the Commanding Officer of the U.S. Army Ballistic Research Laboratory. The Review Committee visited 17 contractor and Government installations during the term of the review. The results of the review, determined from interviews with contractors and Government personnel, and from reviews of progress reports prepared by contractors show the current status of the Caseless Ammunition Program. The results of this study show that the Caseless Ammunition Program has not reached the concept formulation phase as defined by AMCR 70-30.

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I. INTRODUCTION

The Ballistic Research Laboratory was directed by AMC Message 84442, (Appendix I), dated 19 November 1967, to conduct a review in depth of the Small Arms Caseless Ammunition Program. Visits to development facilities were required, and were to be cleared through Mr. W. A. Luukkonen at Army Weapons Command, Rock Island Arsenal, Illinois. At the conclusion of the review, Headquarters, USAMC was to be advised as to the extent BRL can participate in the supporting research effort, including a cost estimate.

The Commanding Officer of BRL requested the Chief of the Interior Ballistics Division to appoint a committee to carry out the small arms caseless review. Figure 1 shows the composition and assignment of the review committee.

The Review Committee was organized under its chairman and a plan for conducting the small arms caseless review was established.

The objectives of this plan were the following:

1. Determine, in detail, the technical objectives of each program and/or caliber round on which work is being done.

2. Determine, in detail, the technical status of each program.

3. Define problem areas as to:

   a. are they peculiar to that particular weapon, and/or,

   b. are they fundamental problems which occur independent of the weapon or its particular design?

4. Are there alternate approaches, e.g., semi-caseless, liquid, fluid bed, etc., which could be taken to achieve the objectives of each program?

5. Show that present approach is (or is not) best of all alternate approaches.

6. What could (or should) BRL be doing to aid the programs?

On 29 January 1968, the Commanding Officer of BRL, by AMC Message 12704, (Appendix II) was requested to expand the small arms ammunition review to include the state-of-the-art with respect to AMCR 70-30 on concept formulation. This request will be discussed later.

The work which follows will show the results of the requested review, the conclusions reached, and the recommendations.

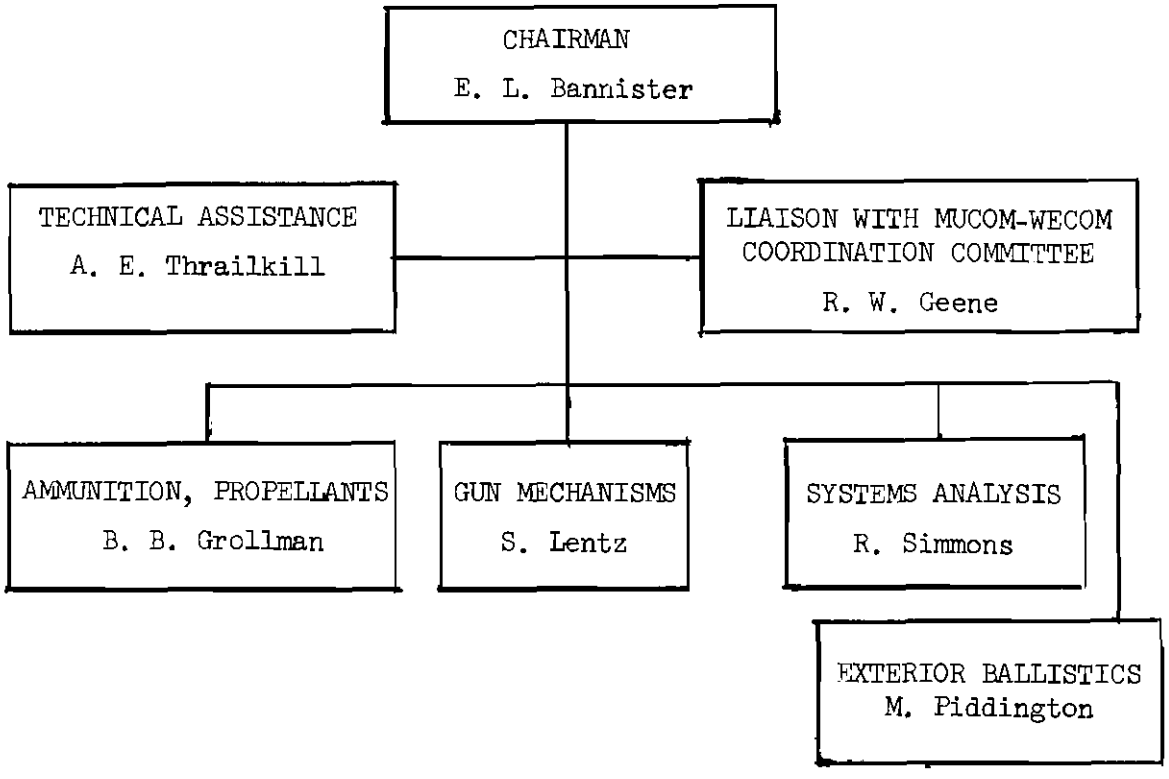

FIGURE 1. Review of the Small Arms Caseless Ammunition Program

II. HISTORICAL BACKGROUND OF CASELESS AMMUNITION

Work on caseless ammunition began at Frankford Arsenal in 1959, and, until quite recently, was supported with limited annual funding under the Small Arms Ammunition Applied Research Project; first, as a part of the supporting investigations task, and later as a discrete task within the same project. Through this work it was possible to demonstrate, with modified cased-ammunition weapons as test vehicles, that a 7.62mm caseless cartridge could be fired in single shot, semiautomatic, and fully automatic modes using both magazine and link feeds.

Figure 2 shows the research models of the 5.56mm and 7.62mm caseless cartridges. The cartridge consists of a compression-molded propellant cylinder composed of individual granules of IMR 4895 single-base propellant and a combustible nitrocellulose lacquer binder, a propellant plug of the same composition as the cylinder, a combustible support of M8 double-base propellant, and a standard 5.56mm or 7.62mm ball projectile. The combustible percussion primer consists of a molded primer cup of IMR 4809 containing a lead styphnate (961) primer mix and a nitrocellulose paper disc seal. All components are assembled using a combustible adhesive or nitrocellulose cement.

This early work succeeded in identifying many problems which required solution before a caseless ammunition approach could be selected for application to a specific weapon system. It was recognized that the ammunition research had progressed to the point where intensive effort, specifically on caseless weapons, was required to move forward with a balanced program.

As a result, a joint U.S. Army Munitions Command and Weapons Command proposal was prepared through the efforts of Frankford Arsenal and Springfield Armory outlining the objectives, problem areas, and dollar and time considerations required to demonstrate feasibility of a caseless ammunition weapon. This joint program was submitted to the U.S. Army Materiel Command in early 1966. It recommended a 3-year exploratory development effort and a total expenditure of 2.6 million dollars.

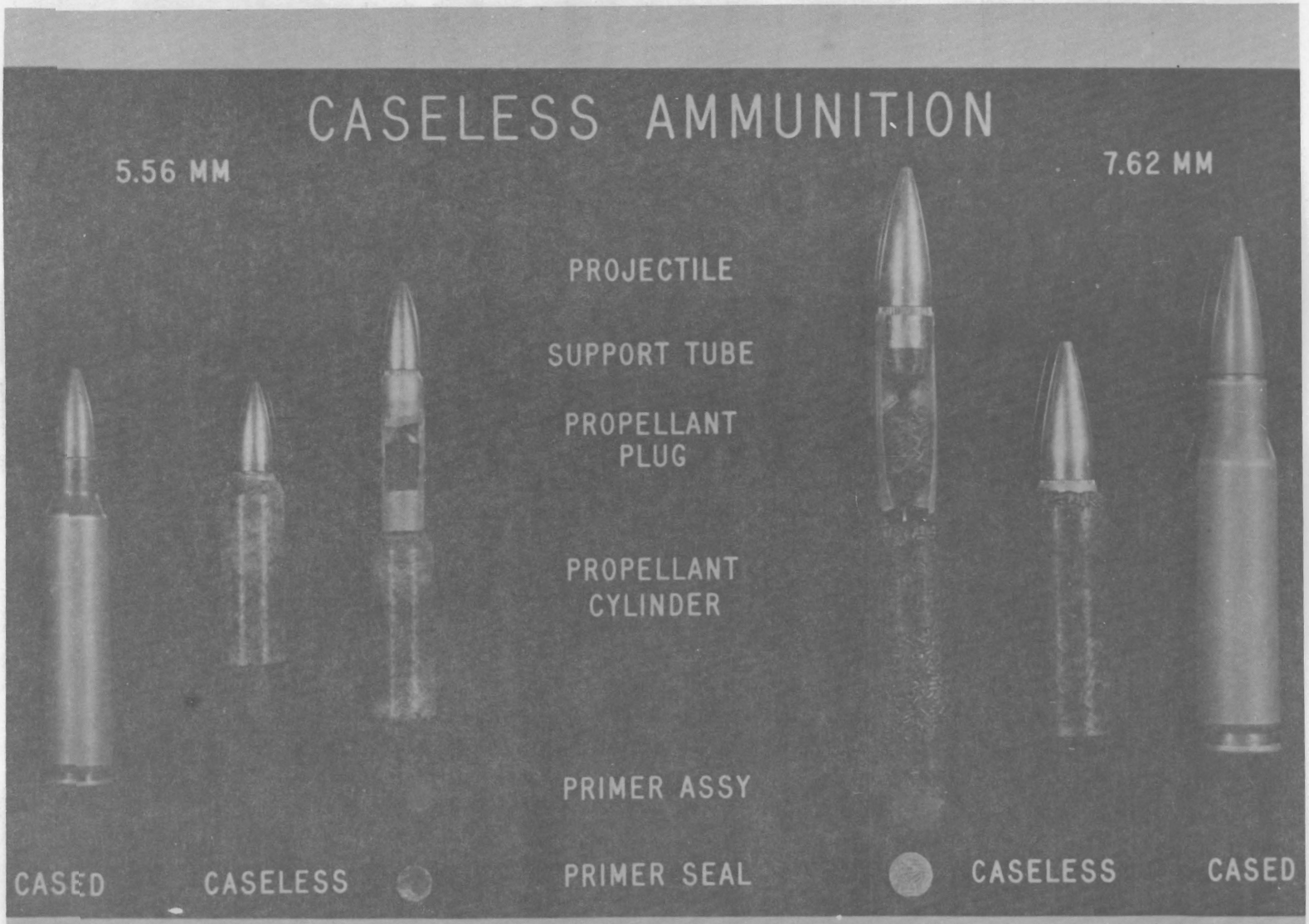
CASELESS AMMUNITION
5.56 MM
7.62 MM
PROJECTILE
SUPPORT TUBE
PROPELLANT PLUG
PROPELLANT CYLINDER
PRIMER ASSY
PRIMER SEAL
CASED
CASELESS
CASELESS
CASED

FIG. 2

Concurrent with the refinement of this joint program, two other matters were under review within the Department of the Army which have had a major impact on the present situation. First, the concern over the shortage of copper for small arms cartridge cases led to a series of briefings during the Spring of 1966. An important recommendation forthcoming from these briefings was that a major emphasis should be placed on caseless ammunition as a long term solution to eliminate our dependence on critical metals for small arms ammunition. From this came a decision within the U.S. Army Materiel Command to concentrate the 3-year program on Infantry Weapon Systems and to establish as a goal, the demonstration of caseless ammunition in a shoulder-fired rifle and a machine gun.

Secondly, the staffing of the Qualitative Materiel Requirements (QMR) for the Successor Vehicle Rapid Fire Weapon System (VRFWS-S) reached a decision point within the Department of the Army. One of the requirements cited was that the ammunition be of the caseless type. This matter was considered by the Materiel Requirments Review Committee in September, 1966. This review led to the decision that there would be a dual approach for the system - a conventional cased ammunition development and a Parallel Exploratory Development Program to demonstrate the feasibility of a caseless ammunition/weapon combination. Based upon this decision, a plan for the exploratory development effort was submitted on 19 September, 1966 for a total of three million dollars over three years. The initial increment of this program - $745,000 was released by the U.S. Army Materiel Command to the field commands in October, 1966.

The Army Caseless Ammunition program is being conducted by a joint U.S. Army Weapons Command - U.S. Army Munitions Command Project Team composed of personnel at Rock Island Arsenal and Frankford Arsenal. Management guidance and periodic review is furnished by a Joint Command Review Board having membership from WECOM, MUCOM, and AMCRD-W.

The Joint Command Review Board developed a "Management Plan for Caseless Ammunition and Weapons Exploratory Development Program for Small Caliber (Rifle and MG), and Large Caliber (Vehicle Rapid Fire Weapons System - Successor) (VRFWS-S)," dated October, 1967. The Management Plan gives the objective of the program as . . . "To achieve a state-of-the-art capability sufficient to prove the feasibility of three types of caseless ammunition-weapons viz., a shoulder fired rifle, a machine gun, and an automatic vehicle-mounted rapid fire weapon. This will include the fabrication of sufficient weapon hardware and ammunition for demonstration."

Appendix 28 of this plan (Appendix III of the report) shows the caseless ammunition contractual effort for FY 67. Contractors listed in this appendix, with the exception of Cornell Aeronautical Laboratories, were visited by members of the BRL Survey Committee. The findings and recommendations of the BRL Committee are based on these visits, and on visits to Government installations.

The program and funding for the Caseless Ammunition/Weapon Exploratory program for FY 68 is shown in Appendix IV. The planned program for FY 68 was scheduled for funding at 2.465 million dollars, but the level was reduced to 1.125 million dollars. The tasks showing zero funds reflect the changes in the program due to the reduced budget.

III. PROBLEM AREAS

The early research work on the small caliber caseless ammunition identified the major problem areas which require solution before engineering development could be recommended. The problem areas are listed below. These problems apply to combustible case ammunition as well as the caseless molded type.

1. Durability and environmental protection of ammunition.
2. Heat transfer and cook-off.
3. Obturation.
4. Producibility of the desired ammunition.
5. Erosion and fouling.
6. Ignition techniques.
7. Misfires.

Problem 1 - This problem must be considered from three aspects.

1. Environmental durability or the capability of the ammunition to withstand extreme temperature, humidity, solar radiation, and fungi attack.

2. Mechanical durability or strength to withstand the forces and acceleration of feeding into a weapon, from linking and delinking, transportation, and field handling.

3. Hazards of accidental ignition of ammunition outside of the weapon and propagation of burning from one cartridge to another in magazines and feed systems.

Problem 2 - The next problem area is that of increased heat transfer to the weapon with the elimination of the metal cartridge case.

Problem 3 - Obturation for combustible ammunition is the most serious weapon problem area since it will have a decided effect on the overall configurations of the weapon and ammunition. With the elimination of the cartridge case which performs the breech sealing function, new

self-obturating mechanisms within the weapon, ammunition, or the link will be required.

Problem 4 - Production facilities must be developed to produce large quantities of ballistically reproducible ammunition in order not to bias the tests of the various weapons.

Problem 5 - The erosion problem arises from not having a metal case and therefore, will be limited to the components such as the breech, chamber and obturators. The barrel bore erosion will be similar to that experienced with cased ammunition except where higher velocities are required. The fouling problem arises from incomplete combustion of the primer and propellant charge.

Problem 6 - Combustible percussion primers have been made for the 7.62mm ammunition which provide reliable ignition, handling safety, sensitivity and reaction time; however, the constituents have a severe erosive effect on the weapon and leave slag or residue in the chamber. Primer compositions must be developed which produce all gaseous products or have a decided reduction in the amount of ash and still not be reactive with metallic components of the weapon. In addition, combustible primers, both percussion and electric, should be designed for the 5.56mm ammunition as well as for the rounds being considered for the VRFWS-S.

Problem 7 - The weapon designer must consider the possibility of a misfire and the problem of clearing the weapon since the caseless ammunition does not lend itself to extraction by conventional means.

There is little doubt that other problems exist in the Caseless Ammunition Program, but the problems above appear to be the most fundamental ones existing at this time. When these problems have either been solved or at least characterized, then the state-of-the-art for caseless ammunition will have reached a point where it can be used as an alternate for cased ammunition.

What is being done to solve these problems?

The Joint USWECOM-USMUCOM Project Team has developed a plan, covering the time frame FY 66 to FY 70 to provide solutions to these problems. The plan has four primary activities.

1. Caseless Ammunition Research Studies
2. Weapon Concept Studies
3. Feasibility Demonstration Phase
4. Cost Effectiveness Studies

The ammunition research studies are designed to answer problems 1, 2, 4, 5, and 6.

Frankford Arsenal is conducting some tests on the environmental durability of 7.62mm caseless ammunition by exposing rounds to tropical environments in Panama, then returning the rounds to Frankford Arsenal for test firings. These tests have not been completed, hence, any judgement on the effect of tropical atmospheric conditions would be premature. Frankford has temperature cycled rounds between $-65^{\circ}F$ and $+ 170^{\circ}F$ and successfully fired them in their test fixture.

No environmental testing has been done on the large caliber ammunition, because the rounds have not reached this state of development.

No durability test procedure has been developed for caseless ammunition, either small or large caliber. It is doubtful whether caseless ammunition would survive many of the durability tests designed for cased ammunition.

Cornell Aeronautical Laboratory has been conducting research on heat transfer and cook-off problems relating to caseless ammunition. They are using an experimental-analytical approach in which theoretically determined heat transfer rates and barrel temperatures are compared with experimentally determined values. CAL has reached a number of conclusions from the work they have done so far, the more definite ones are stated below.

1. Heat transfer at the neck and within the barrel is relatively the same for both cased and caseless 7.62mm ammunition. This should be expected since the bore surface and origin of rifling or forcing cone of a gun is the same whether used for cased or caseless ammunition.

2. CAL has measured the heat input per round for a 7.62mm caseless gun chamber, and found the value to be less than 9 BTU/ft^2/round. This value cannot be compared directly with a 7.62mm cased gun because of the heat insulation generated by the metal cartridge case. The chamber of a cased ammunition gun is heated by the conduction of heat back from the fore part of the forcing cone. The value of the heat input at this position, for both 7.62mm cased and caseless ammunition, is approximately 20 BTU/ft^2/round. Although the heat input per round to the chamber for caseless ammunition is relatively low when compared to that of the rifle forcing cone, the heat goes directly into the chamber wall. This direct heating enhances the caseless ammunition long term cook-off problem.

3. Propellant cook-off temperature-time characteristics are such that both long and short time cook-off can present problems in weapon operation.

4. Generally, short time cook-off will occur in the first 50 msec or not at all for open bolt operation. Insulative coatings or air gaps to prevent direct contact of the propellant with the chamber walls can be very effective in overcoming short time cook-off.

5. With respect to the M60 caseless machine gun, short time cook-off due to hot chamber or stop-shoulder walls would not be expected in a single burst of less than 100 rounds.

6. Long term cook-off is the main area of concern in continuous weapon operation using caseless ammunition. Short term cook-off may be eliminated with a proper insulative coating or air gap. Long term cook-off, without the assurance of an open breech between every burst, can not be easily prevented if the chamber area is allowed to reach high temperatures during long burst operation. Since the thermal conductivity of caseless ammunition is similar to an insulator, it is doubtful whether an insulative coating would provide a significantly greater barrier to long term cook-off than the caseless ammunition itself.

7. Chamber temperatures of 400°F or above can present long time cook-off hazards.

8. Although the temperature rise in the chamber area per round is low, (approximately 2°F/rd) in the M60 caseless weapon, cooling is also low. Thus, firing schedules in which continuous operation without cook-off is desired result in rather low rates of fire.

The following recommendations were made by CAL to solve the short and long-term cook-off problems of caseless ammunition.

1. Heat transfer studies of caseless ammunition should continue, with efforts directed toward larger and smaller calibers and different geometrical configurations.

2. Additional evaluations of the cook-off characteristics of the individual round components should be made.

3. Insulative coatings and prevention of direct contact between the propellant with the chamber wall and the stop shoulder should be examined for elimination of short time cook-off. Methods of reducing the net heat flow to the chamber should be studied as a means of eliminating long term cook-off.

4. Weapon designs should be examined from the standpoint of decreasing the cook-off hazard of caseless ammunition, e.g., providing an air gap between the hot gun and the round of ammunition.

The cook-off problem which exists with caseless ammunition, whether small or large caliber has not been solved. A solution does appear to be feasible within a reasonable time.

The next problem area which must be considered for caseless ammunition is obturation. The metal case, whether brass, steel, or other metallic material, provides obturation in conventional small arms weapons. This method of sealing the gun chamber does not exist with caseless ammunition. The round must be sealed in the gun chamber by some method which will remain intact for a reasonable number of rounds.

A number of obturation systems have been devised by a number of gun contractors during the current caseless ammunition program.

Frankford Arsenal and AC-DRL have fired several thousand rounds of caseless 5.56mm rounds, both single-shot and burst-fire with reasonably good results from their obturation systems. AC-DRL has experienced difficulty in their current obturation system, and at present are developing a different type obturation method for their model 67 gun. Other small caliber contractors, Hughes Tool Company, AAI, and General Electric are working on obturation devices for their respective weapons but have not fired enough rounds to evaluate the effectiveness of their obturation system.

Obturation systems are being developed for large caliber weapon systems by several large caliber gun contractors. All of the obturation tests by these contractors have been in single shot test fixtures. There is no experimental evidence at present to show the effectiveness of any of the obturation systems under automatic firing conditions.

All of the caseless ammunition, except some 5.56mm, up to this time has been made by hand on a single round basis.

AC-DRL has developed a semiautomatic device for making molded 5.56mm caseless ammunition propellant charges. At present, the projectile and primer are inserted in the round by hand. The machine is designed to produce 10 charges per minute or approximately 4000 rounds per eight hour day. AC-DRL has compared their machine made 5.56mm rounds with those made by hand by Frankford Arsenal, and the comparison demonstrates a high degree of repeatability and ballistic quality for the AC-DRL machine made rounds.

A pilot line to automatically produce 5.56mm caseless ammunition is being built at Frankford Arsenal. This line will be completed in May 1968. The pilot line can be converted to make 7.62mm caseless ammunition with a minimum of modification. The pilot plant will be able to produce several thousand rounds per day when it becomes operational. Experience gained in the operation of the pilot plant will be useful when a requirement develops for the design and operation of a caseless ammunition production facility.

At present all large caliber caseless, combustible case, and monolithic ammunition is being handmade on an individual round basis.

Hercules, Incorporated, has conducted a study for Frankford Arsenal to determine the feasibility of building a pilot line to manufacture large caliber molded caseless ammunition. Their study shows that such a production facility is feasible. No work on a large caliber pilot plant is planned at this time.

Although Hercules, using their own funds, has designed a pilot plant for making large caliber caseless ammunition, they are, at present hand-making their large caliber rounds. Their production capability is limited to a few rounds per day.

Frankford Arsenal is hand-making large caliber caseless rounds, and like Hercules, their production rate is low.

IITRI is exploring the possibilities for machine manufacturing their combustible case large caliber rounds, but at present, they are hand-making their rounds. Their production rate is only a few rounds per day.

Aerojet-General, under their own funding, has made less than 100 rounds of their monolithic large caliber round, and again these rounds are handmade. At present the proper web structure has to be hand-machined in their round after it is cast.

The current production capability of all of the organizations making large caliber caseless rounds (including combustible case and monolithic) is not sufficiently developed to make but a few rounds per day. With this low production rate it will be quite difficult to properly test any large caliber automatic gun without introducing ammunition bias.

There is little reason to believe that the erosion of a gun bore firing caseless ammunition, whose ballistics are similar to cased ammunition, would differ from one firing cased ammunition. On the other hand the erosion of other weapon components such as bolt, firing pin,

and chamber could differ quite drastically in a caseless ammunition gun system.

Little work has been done on studying the erosion of caseless guns. Firing pin erosion appears to be the main cause of concern, especially in the automatic small arms weapons.

AAI has had trouble with the erosion of firing pins in their automatic caseless ammunition test fixture. Some reduction in firing pin erosion has been obtained by using higher melting metals, by changing the shape of the firing pin head, and by modification of primers.

AC-DRL has experienced similar firing pin troubles. In addition they have been troubled with metallic materials, obstensibly from the primer mix, used in the round. This material deposits on the chamber seal, and after several rounds, prevents proper functioning of the seal, which in turn allows the hot, high pressure chamber gases to escape across the seal surface. The flow of these gases quickly erodes the seal.

The assessment of gun fouling is not possible at this time because of the small number of rounds fired to date in small caliber weapons.

Little can be said at this time regarding the erosion and fouling of large caliber caseless guns, because of the small number of rounds fired to date.

One of the advantages of caseless ammunition is complete combustion of the round. To completely exploit this advantage, the round must be initiated by an ignition system that is completely consumed as the round burns. Priming systems can be of several types, percussion, electric, and adiabatic. All of these have been made to work with some type of caseless ammunition. They can be quite simple or quite sophisticated, depending on the use. Smith & Wesson paint a conductive primer mix on their propellant charge, which they initiate by means of a very small 12 volt battery. Aerojet-General Corporation

used a squib which initiated a ring of pyrophoric material around the forward end of their caseless round.

All of the small caliber rounds made by Frankford Arsenal and AC-DRL use combustible percussion primers similar to primers used in cased ammunition. Frankford Arsenal is currently having little difficulty in firing their ammunition in their test weapons, however, other agencies have experienced considerable difficulty in getting Frankford Arsenal small caliber, 5.56 and 7.62mm, to fire in their test guns. Frankford Arsenal personnel insist that differences in chamber volume between their weapons and others is the cause of these malfunctions. This may be true, but differences in firing pin shape and force, differences in head space adjustment, or perhaps round to round differences in primer mix could be the cause of the malfunctions. None of these factors has been studied to any great extent.

AC-DRL has not reported any great difficulty in making their 5.56mm round fire. They use a priming system similar to Frankford Arsenal.

Large caliber caseless rounds are initiated with percussion primers similar to those used in small caliber. There is a study being carried out by the Franklin Institute to determine the feasibility of combustible electric primers for caseless ammunition. These primers, if successful, may be considered for use in large caliber ammunition.

None of the techniques for extracting a misfired or unfired round appears to be completely satisfactory. These techniques require more extensive testing before a judgement can be made of their adequacy.

IV. SMALL CALIBER WEAPONS

To carry out the objectives of the Army Caseless Ammunition Program, four contractors and one Government installation are currently conducting design studies on a small caliber shoulder-fired rifle and a machine gun. The contractors for the rifle are AAI Corporation, Hughes Tool Company, and AC Electronics-Defense Research Laboratories, along with Rock Island Arsenal. The General Electric Company, Armament Dept. of Burlington, Vermont, is currently conducting a design study on a machine gun for caseless ammunition. With the exception of the AC Electronics-Defense Research Laboratories design study, all of the contractors are primarily dependent upon the Frankford Arsenal for supplying either 5.56mm or 7.62mm caseless ammunition for use in test firing of the particular test fixture or the design weapon.

The objective of the individual shoulder-fired rifle studies is to develop a rifle concept capable of firing 5.56mm molded caseless propellant cartridges at the maximum rate of 750 rounds per minute. The concept is to be developed through a detailed design and engineering analysis which will provide information for design of a test fixture.

The objective of the machine gun study concept is to develop a machine gun capable of firing 7.62mm molded caseless propellant cartridges at the maximum rate of 650 rounds per minute. The concept is to be developed through a detailed design and engineering analysis which will provide information for design of a test fixture.

AAI, Incorporated has designed and fabricated a firing fixture which employs the firing pin blow back operating principle to recoil the operating slide, to unlock a rotary bolt, cock the hammer, etc. Over 100 rounds have been fired with no difficulty in obtaining satisfactory parts function. Firing has been in single shot and 3 round burst sequences. The mechanism cycles at a natural rate of about 1600 rounds per minute. AAI estimates that a reduced firing pin of 0.140 inch to 0.100 inch dia. will reduce the rate to 1200 rounds per minute. An inertia wheel can also be added to the trigger mechanism for extending the hammer sear

release dwell time. Ignition delay times have been recorded to be as high as 207 ms and as low as 7 ms. The delayed ignition problem is being investigated in both the weapon and the primer of the ammunition. AAI has mounted, but not tested, an aluminum heat sink around the outside of the barrel chamber. Tentative estimates indicate firing complements up to 550 rounds with the heat sink. The weapon was not fired with a functional extractor or rate controlling device. The breech has been designed to open in 2.7 ms at 2500 psi chamber pressure.

The bolt obturator consists of a thin metal lip extending around the O.D. of the bolt with a similar arrangement being investigated for the firing pin. There is some evidence that the flexible lip can be eliminated from the face of the firing pin. Both seals are backed up with elastomeric "O" rings as secondary seals. This sealing arrangement is performing satisfactorily in both single shot and burst firings and appears to be acceptable at this time; however, long firing cycles have to be performed to evaluate the seal's ability to obturate completely over the entire chamber pressure range.

The feed system for the AAI rifle requires a lip type magazine and a ramp for the round from the magazine to the chamber. High-speed movies have illustrated that the round is being fed from the magazine into the chamber with no damage to the propellant cylinder.

The AAI rifle is designed to fire the Frankford Arsenal 5.56mm molded caseless round and most tests have shown long ignition delays. Work is being done to increase primer impetus and to decrease weapon chamber volume in the bolt face area.

Hughes Tool Company has fabricated single shot test fixtures and has conducted firings to obtain barrel pressures and to experiment with obturators. More than 50 5.56mm Frankford Arsenal molded propellant caseless rounds were fired. During the concept phase of the contract, a three chamber revolver concept was considered and then revised to a vertical shuttling single chamber rifle concept. The shuttle chamber concept uses a telescoped round which offers reduced length and ease of

extraction. The shuttle chamber also provides a thinner silhouette and simplicity in the feeding mechanism. The weapon is gas-operated with an unlocking time sufficient to allow a low unlocking chamber pressure. The firing mechanism is hammer operated for full or semiautomatic modes of fire. Feeding occurs near the end of the recoil stroke. The weapon design has the magazine located in front of the chamber and slightly below the gun barrel. The use of shuttle chambers has not been tried in shoulder-fired weapons. The up and down motion of the chamber may result in a turning action and may have an effect on the weapon accuracy. The concept features simplicity, ruggedness, and light weight components.

Obturation is accomplished by the use of metal "L" section ring type seals. The seals have given satisfactory obturation during firing in the single shot fixture. To assist in completely obturating the rear of the chamber, a large diameter firing pin has been used,approximately the size of the "L" seal, to bear aginst the "L" seal throughout the ballistic cycle.

A linear feed system is planned that will operate from the front of the chamber. The round will be rammed from the magazine rearward into the weapon chamber. The feeding is not initiated at the beginning but toward the end of the recoil stroke of the operating rod. A drum type magazine is also considered for use with this concept.

The Hughes concept requires no separate round ejection device since the round coming into the chamber will perform that function.

Initial firings in the test fixture have been with the non-telescoped molded 5.56mm Frankford Arsenal rounds. Some firings have been made with telescoped 5.56mm caseless rounds supplied by Hercules, Inc. and Frankford Arsenal.

The AC-DRL has designed and fabricated, with company funds, two firing fixtures capable of firing 5.56mm molded caseless rounds of a design similar to those of Frankford Arsenal. The gun employes a laterally split chamber arrangement where one half of the chamber is in the bolt face and the other half is in the barrel. A metal obturator exists

between the two halves. The bolt is locked to the barrel by rotating its two lugs into abutments provided in the receiver. The fixtures, of bull pup design, are gas operated and have a cyclic rate of about 1000 rounds per minute. It can fire full automatic and semi-automatic from either a closed bolt or an open bolt position. The fixtures have been fired about 1000-1500 rounds each and have been demonstrated to DA elements. AC-DRL has developed the fixture to be capable of shoulder firing.

The latest obturator devised for the AC-DRL split chamber is metallic and has functioned for at least 1000 rounds. The firing pin is obturated by piston ring type seals.

Two feed systems have been investigated by AC-DRL, a conventional spring energized magazine and a gun actuated drum magazine. Feeding ammunition is accomplished by a forward moving bolt which ramps the round from the magazine into the chamber. The path of the cartridge being fed is aligned by a spring loaded movable ramp. The ramp angle of the cartridge is severe because of the large lateral distance between the magazine lips and the chamber as governed by the type of obturator and split chamber design.

Round ejection is accomplished by manually opening the receiver, retracting the bolt, and pivoting a wishbone shaped spring extractor into engagement with the outside diameter of a misfired round or a round to be ejected. The round is then ejected through the magazine channel or the receiver top cover.

AC-DRL has produced 5.56mm caseless ammunition to support their weapon development program. The AC-DRL caseless ammunition is similar in design to the Frankford Arsenal rounds and indeed is based on the Frankford Arsenal early development.

A similar firing fixture has been made by AC-DRL to fire single-flechette caseless ammunition. A small number of these rounds has been fired through this fixture.

Two concepts have been developed by Rock Island Arsenal. One concept utilizes open-bolt firing and the second concept utilizes a closed-bolt sequence.

In the open-bolt concept there are only five moving parts in the weapon; the locking portion of the bolt, the bolt piston and firing pin part of the bolt, the trigger, the sear, and the recoil and counter-recoil spring. In preparation for firing, the bolt is seared in the open position. When the trigger is pulled, the sear rotates releasing the bolt. The spring accelerates the bolt forward picking up a round, chambering it, and continuing into battery until locking lugs strike the end of the grooves in the barrel extension. The bolt piston travels a short distance after locking the bolt and strikes the primer, firing the round. Gas pressure acts on the firing pin and bolt piston resulting in rearward movement and unlocking the bolt. The chamber pressure is quite low by the time unlocking is completed. The bolt continues its rearward movement back to the sear position and will repeat the firing cycle until the trigger is released.

Obturation of the breech is accomplished by a series of piston rings and circumferential turbulance inducing grooves on the bolt.

The feed system considered for this rifle is a double row spring energized magazine.

The closed-bolt concept is similar to the open-bolt concept with the exception of the locking system and the actuation of the firing pin. In preparation for firing, a round is pushed out of the magazine feed lips and ramped into the chamber by the bolt. The bolt face is stopped in the chamber and the bolt piston continues forward camming locking blocks into a locked position. The trigger releases a hammer which rotates through a groove in the bolt and the bolt piston strikes the firing pin overcoming the force of the spring between the piston and firing pin. The firing pin travels forward striking the primer of the round. Gas pressure forces the firing pin to move back against the bolt piston and the piston assembly. The bolt piston moves rearward to allow unlocking blocks to cam down into the bolt and the entire bolt

assembly moves rearward. A recoil spring and buffer stop the rearward movement and returns the bolt forward to pickup and chamber another round. The trigger actuates the repeat cycle.

Extraction of a round is accomplished by a tang, which is an extension of the bolt, and reaches forward to the front shoulder of the round in a recessed groove in the chamber. As a result of this extraction technique the chamber has been enlarged. RIA has had difficulty firing the Frankford Arsenal Ammunition and a limited number of rounds has been fired to date.

The General Electric Company has designed a 7.62mm "Tilting Chamber" - Telescope Round - Gun Actuated Machine Gun concept. The concept is an open-bolt gas operated weapon. The gas is taken from the bore of the barrel to drive a piston which acts on a drive link. Through a series of links and cams the chamber is tilted downward, the firing pin cocked, and a round stripped from a magazine. The round is then fed into the tilted chamber, the chamber tilted back into position and the round fired.

Obturation of the tilted chamber is obtained with "L" type metal rings between the barrel and chamber and chamber and breech. The seals are in the tilting chamber.

A gun actuated type of feed system is considered. A pawl feeds tape by engaging holes in the tape and pulls rounds from the magazine.

A single shot test fixture has been fabricated and fired to test the obturation of tilting chamber concept. The rounds fired to date have been the Frankford Arsenal molded caseless rounds. G.E. is considering fully telescoped rounds for this concept.

V. PROPOSED VEHICLE RAPID FIRE WEAPON SYSTEMS (VRFWS-S)

Brief descriptions of the weapons proposed by each company visited and the operations of the various mechanisms are given in the following order.

AAI
GE
Aeronutronics
Hughes
IITRI
Rock Island
TRW

Aircraft Armaments, Inc.

Aircraft Armaments is proposing either a 22 or 27mm self-powered, gas-operated, automatic weapon for the caseless VRFWS which is the same basic mechanism that was developed by them for the Special Purpose Individual Weapon System (SPIW). In the firing cycle, the pressure first acts on the face of the firing pin to unlock the bolt from the barrel extension and then the remaining pressure acts on the base of the chamber to carry the bolt through the rest of the recoil cycle. This mechanism can be designed to fire from either an open or closed bolt.

Two problems are inherent in the system which they are proposing:

1. Extraction and ejection of misfired rounds will be a problem. The two proposed plans for using a small cable attached to an extractor or the pressure from a CO_2 cartridge acting on the shoulder of the round do not appear to be very feasible.

2. Sealing of the gases around the firing pin may well be as important as sealing of the gases in the chamber since the firing pin effectively becomes the operating rod in the mechanism.

AAI is not an active contractor in the caseless VRFWS-S.

General Electric

General Electric is proposing a 27mm self-powered, gas-operated, automatic weapon for the caseless VRFWS-S. In the model, which was displayed, the gas system is located on the left side of the weapon. As the gas operating rod moves rearward a series of cams and rollers translates the chamber from the firing position to the loading position and the firing mechanism to the sear position. In the counter-recoil portion of the cycle, the energy from the driving spring and moving components feeds the round into the chamber, translates the chamber back to the firing position and unsears the firing mechanism.

It is anticipated that fully telescoped rounds being developed by Hercules, Inc. will be used in the system. This will enable the rounds to be prepackaged without links, like items in a vending machine, and feed directly from the feed tray into the chamber by a simple longitudinal translatory motion. It also will simplify the ejection of misfired rounds by having the fed round push the misfired round out the front of the chamber.

Floating ring seals are being considered for both the front and the rear of the chamber. These have proved to be successful in the 20mm, M39 gun. To determine the effectiveness of the seals in this system an investigation is being conducted to measure gas leakage at the seals and variation in muzzle velocity.

The non-symmetrical motion of the oscillating chamber may introduce vibrations into the barrel. If this is the case, it will be necessary to have sufficient damping in the barrel so that the accuracy will not be degraded.

General Electric is not an active contractor for the Army VRFWS-S System. Although General Electric's proposed large caliber weapons concept was rated favorably in the technical evaluation, efforts to negotiate a contract were not fruitful and a contract did not materialize.

Aeronutronics Division of the Philco-Ford Corporation

Aeronutronics is developing a 27mm self-powered, recoil-operated, cam-driven automatic weapon for the caseless VRFWS-S. In the system the barrel recoils one inch to unlock the bolt from the barrel extension. After unlocking, the residual pressure acting on the face of the bolt carries the bolt and bolt carrier through the remainder of the recoil travel. Other functions in the mechanism cycle are controlled by cam slots cut into the bolt carrier.

The proposed length of the barrel is 95 to 100 inches and the weight is estimated to be 60 lbs. with the muzzle brake. By permitting the barrel to recoil along with an additional 40 lbs. of recoiling parts, the trunnion forces will be reduced over a system having a fixed barrel.

The weapon is designed to fire a partially telescoped round of molded double-base propellant and with a reduced diameter forward of the base for extraction. Misfired rounds extracted from the chamber will be ejected forward underneath the barrel. In addition, it is proposed that consumable links be molded into or banded directly to the rounds. These will consist of either a wire-like material or a flat flexible plastic band.

No decisions have been made by Aeronutronics on the type of chamber seals that will be used. At present, they are investigating four types of high pressure, high temperature seals which they estimate should provide a seal life of 4000 rounds.

It is anticipated that problems, other than those inherent to all caseless systems will be encountered in the following areas:

1. The non-symmetrical camming actions taking place below the center line of the bore will probably introduce large amplitude vibrations into the long, unsupported, region of the barrel. This will tend to degrade the weapon accuracy in the full-automatic fire mode.

2. The consumable links will require additional guidance and control of the ammunition in feeding, reliable cutting of the link prior to chambering, and elimination of all residue resulting from cutting the link material.

3. The knob-like base of the round provided for extraction of misfired rounds may not reliably withstand the forces required for extraction after reasonably rough handling or chambering of the round.

Hughes Tool Company

The Hughes Tool Company proposed a self-powered system for the VRFWS-S in the form of an artist's concept. The weapon consists of a barrel with a slot cut through the breech and a sleeve which slides over the slot to seal the chamber during the ballistic cycle. Ammunition for the system was pictured as a fully-telescoped projectile in an octagon-shaped bar of molded propellant. To feed the weapon the individual cartridges would be rammed from the side directly into the chamber and if the previous cartridge misfired the new cartridge would merely eject it out the opposite side of the chamber.

Two basic questions of feasibility are introduced by this concept.

1. Can the cartridge be made into configurations other than modified cylinders without introducing additional problems in sealing, erosion, and residue build-up?

2. Can reliable seals be provided for the sliding breech sleeve which will seal the propellant gases in the chamber?

IITRI

IITRI has considered six design concepts of 27mm contenders for the VRFWS-S. A concept using external hydraulic power to drive the mechanism has been chosen for development. The weapon will fire fully-telescoped rounds from a double chamber shuttle. The chamber will be sealed with floating ring seals similar to those used in the front of the chambers in the 20mm, M39 gun. Rounds will be fed from a cradle in front of the shuttle by hydraulic rammers. The chambers will be loaded

alternately, feeding from one side and then the other as the shuttle moves back and forth between rounds. The weapon will have a dual feed capability with the cradle being fed at the top or bottom. Misfires will be ejected out the back of the chambers by the next round being fed. The feed cradle will be ratcheted into position by the shuttle which will be operated hydraulically. The hammer will be spring loaded but will be cocked hydraulically. The first firing fixture will have a single feed capability and no provision for ejecting misfires. Detailed design of the firing fixture is near completion.

Care will have to be taken in controlling acceleration and deceleration of the shuttle to avoid setting up vibration of the barrel.

Rock Island Arsenal

Rock Island Arsenal is fabricating a 27mm firing fixture to investigate the feasibility of using caseless ammunition. The mechanism is driven by an electric motor and has a revolving cylinder with four chambers sealed with floating ring seals similar to those used in the M39 gun. Fully-telescoped rounds are fed pneumatically through either of two flexible feed tubes into the front of the two horizontal chambers. The top chamber is aligned with the barrel for firing while misfires are pneumatically ejected out of the front of the bottom chamber. The fixture is near completion but problems have been encountered with the camming surfaces in the "Geneva" mechanism used to index the cylinder containing the chambers.

In the present design the round in the chamber is in contact with the next round to be fed. Dimensions of the rounds would be very critical to prevent shearing of the front of the round in the chamber or the back of the next round to be fed as the cylinder turns.

TRW

TRW has designed a 27mm contender for the VRFWS-S which will fire fully-telescoped rounds from a sleeve chamber with "U" type low pressure seals and dynamic flexure type high pressure seals. The gun is operated

by recoil with the sleeve and operating rod being carried rearward by inertia after the receiver is stopped by dual recoil mechanisms. No locking mechanism is used because the rear of the chamber, on which the chamber pressure bears, is attached to and recoils with the receiver. Rearward acceleration holds the sleeve and operating rod in battery until after the projectile leaves the barrel and the receiver is stopped. Dual feeders attached to the side of the receiver are operated by cams on the operating rod. Fingers from both feeders guide the rounds into position where the sleeve encompasses the round. An ejector operates from below the chamber by pushing the rejected round through the top of the receiver when a new round is charged into the weapon.

The design has been completed and an operational automatic firing fixture is expected to be completed in six months.

The non-symmetrical forces produced by motion of the operating rod which is below the barrel, will produce barrel vibration. The feed fingers may not have sufficient control of the round being translated from the feeders into the receiver.

VI. RESUME' OF THE ADVANTAGES AND DISADVANTAGES OF PROPOSED CASELESS VRFWS-S

Ammunition:

In handling and storage the full-telescoped rounds have advantages over other configurations. They have better fuse protection, better viscoelastic qualities, better balance, and provide better round control.

Link Configuration:

The optimum system is offered in a sealed, prepackaged, linkless feeding system. The second best is the consumable link.

Power:

Self-powered weapons are less vulnerable because the weapon will continue to fire after loss of vehicle power. These weapons depend on reproducible interior ballistics for proper functioning. Externally-powered weapons have better timing control and ejection of misfires without stoppage.

Seals:

There is a definite advantage in using the floating ring seal since its effectiveness and durability have been demonstrated in the 20mm M39 gun. There will be some initial leakage as the pressure builds up. The reliability and durability of non-floating flexure type seals is unknown at this time for automatic weapons.

Feeding & Ramming:

Caseless ammunition will be more vulnerable to external damage than cased ammunition. Therefore better control will be required to avoid harsh accelerations and impacts during feeding and ramming. The systems which use well controlled lateral or longitudinal translations will have an advantage over systems using harsh ramping and ramming of the rounds.

Firing Condition:

The weapon should be designed so that the round is chambered after triggering and so that when the trigger is released the chamber or

chambers are empty to avoid cook-off or damage of the round from heat.

Ejection:

Self-powered weapons should automatically eject misfires upon charging.

Externally-powered weapons should eject misfires automatically without stopping.

VII. CASELESS AMMUNITION RESEARCH

Currently Frankford Arsenal, IITRI, and Aerojet-General Corporation are conducting a Caseless Ammunition Research and Development program with Government funds. Hercules, Inc. under sub-contract and with company funds, is also conducting research and development in both large and small caliber caseless ammunition. AC-DRL with their own funds developed a 5.56mm round for use in the AC-DRL firing fixture.

Smith & Wesson, Inc., demonstrated for the press and more recently for the BRL Caseless Committee a combustible 9mm round. Recently Remington Arms Company disclosed to the BRL Caseless Committee a non-metallic disposable round for the 5.56mm.

The following is the technical status of the caseless ammunition research and development program.

Frankford Arsenal has designed 5.56mm ammunition with IMR 4809 and 4475 as well as 4895 propellant in order to obtain acceptable performance in chamber configuration of the various weapon concepts; 5.56 and 7.62mm rounds in telescoped projectile configurations have also been fabricated and fired.

Recently, Frankford Arsenal has been studying the design of a primer which is more effective in the larger chamber volumes. Frankford states that free volume differences in firing fixtures are the cause of round malfunctions. Differences in free volume may contribute to the failure of a round to fire, but other factors such as amount and type of primer mix, force generated against the primer by the firing pin, and the firing pin shape may also contribute to the failure of rounds. To resolve this problem, Frankford Arsenal is experimenting with double cup primers, each cup containing a pellet of 3.5 grains of styphanate. Symmetry of the primer will simplify assembly into the cartridge. A number of propellants for the primer cup are being tried, each with a different relative quickness.

Frankford is experimenting with encapsulating techniques to heat-seal the primer pellet between two sheets of plastic film having good resistance to moisture transmission.

Recently an in-house task was assigned to Pitman-Dunn Laboratory of Frankford Arsenal, to conduct an interior ballistic study of the 5.56mm caseless cartridge. The objectives of this study are to:

1. formulate an interior ballistic model that simulates experimental firings of caseless ammunition.

2. pin point the parameters that influence the burning mechanism of caseless ammunition.

3. establish guide lines for the future design of caseless ammunition. This work is just starting and will continue for one year.

IITRI is developing a combustible cartridge case round for the VRFWS-S. To date they have only made rounds to be fired in a 30mm gun. IITRI has been funded by the VRFWS-S Project Manager to continue work on their combustible case work. This work will be directed toward the development of a 27mm combustible case round. The work consists of the following tasks:

1. Modify present 30mm single shot test fixture to fire 27mm ammunition.

2. Redesign cartridge to achieve a 4800 fps velocity for a 2300 grain (150 gram) projectile at a pressure not to exceed 60K psi. The combustible cases will be of acrylic fiber/resin composition.

3. Design and fabricate combustible cartridge case forming dies and fixtures.

4. Fabricate a maximum of 150 27mm cartridges.

5. Design and fabricate an automatic test fixture capable of firing ammunition of above design at a rate of 550 shots per minutes.

Aerojet-General Corporation has developed a large caliber monolithic (monobloc) caseless round. The propellant is cast from a double-

base propellant. The proper web is obtained by drilling cylindrical perforations in the grain after casting. Twenty to 30 of these rounds have been fired in a 27mm smoothbore single shot test fixture.

At present this type of round does not lend itself to a telescope mode. It is claimed that the heat transferred to the gun chamber and erosion of the bolt face will be reduced.

Hercules, Incorporated, Kenvil, New Jersey has made a number of different types of caseless rounds, 5.56mm, 7.62mm, 20mm, and 30mm. The rounds are molded IMR or Reloder propellant, with semi-telescoped, telescoped, and conventional configurations. Hercules has ballistically tested some of their rounds, but have not made enough firings of one configuration to determine the ballistic uniformity of the round. Hercules has demonstrated an ability to tailor large caliber caseless rounds to fit a variety of gun chambers.

Hercules has made a rather detailed study of the caseless ammunition field, and has concluded that the manufacture and use of both small and large caliber caseless ammunition is within the state-of-the-art.

In addition to the caseless ammunition discussed above, two contractors, Olin-Mathieson and Remington Arms Company are currently working on caseless primers.

Olin-Mathieson is developing a reduced ash primer using their patented materiel Stabnate. Remington is developing an ashless primer (tetrazine/PETN) for use with both small and large caliber caseless ammunition.

VIII. CONCLUSIONS

1. It is the judgement of the BRL Caseless Review Committee that the Joint MUCOM-WECOM Caseless Ammunition Project Team is to be commended for the manner in which they have conducted the Caseless Ammunition Exploratory Development Program; a program which sought to solve those fundamental problems facing the development of weapon systems utilizing caseless ammunition.

2. The committee concludes that more effort should go into the caseless ammunition development portion of the program to insure that sufficient quantities of ballistically reproducible small and large caliber rounds will be available for unbiased testing of the various weapon concepts.

3. The committee concludes that the current Caseless Ammunition Program has no guidance as to what portion of the total effort should be directed to the large caliber program and what portion should be directed to the small caliber program. The current emphasis on caseless VRFWS-S could reduce the small caliber effort below that required to achieve planned goals. Further, present Army committment to the M16 rifle minimizes the Army requirement for the immediate application of caseless ammunition to rifles.

4. The committee concludes that the small caliber effort should go into the small caliber machine gun program. The great potential of space and weight savings for caseless ammunition would be used to the greatest advantage in the Army Aircraft Weaponization program.

5. The committee concludes that alternate approaches to the Caseless Ammunition Program, such as liquid propellants, gelled propellants, fluidized beds, etc., are not sufficiently developed to be considered in the current Caseless Ammunition Exploratory Development Program.

IX. RECOMMENDATIONS

Based on the review of the Caseless Ammunition Program, the committee has recommended to the Project Manager of VRFWS-S, that the Army Caseless Ammunition Program, at this time, is not ready to enter engineering development in that not all of the six prerequisites as per AMCR 70-30, have been satisfied. It is further recommended that the current Caseless Ammunition Program continue in the exploratory development phase as provided for in the Management Plan.

X. BRL PARTICIPATION

The committee has concluded that more effort should be directed to the development of caseless ammunition. To this end it is recommended that the program of work be directed toward the solution of the technical problems of caseless ammunition manufacture. Such problems should be defined by the WECOM-MUCOM Joint Committee. This requires however, that the committee address primarily technical matters rather than administrative. In such a program BRL should participate as a regular member to define the details of investigations to be carried out.

BRL should participate as a regular member of caseless ammunition/weapons proposal and contract evaluation groups. BRL can offer aid and knowledge in the field of ballistics and the reactions of gun mechanisms.

BRL should study the interior ballistic characteristics of different types of caseless ammunition as they become available.

BRL should study the dynamics (kinematics and kinetics) of prototype automatic caseless ammunition weapons systems.

BRL should study the exterior and terminal ballistics of projectiles developed for use in caseless ammunition weapon systems.

BRL should always maintain a cooperative attitude toward other Government agencies, contractors, and other organizations working in the field of caseless ammunition/weapons systems.

The estimated cost of BRL participation in the current Caseless Ammunition Program is 100K dollars.

Involved in this cost will be the fabrication and instrumentation of caseless ammunition test fixtures to be used to characterize the interior ballistics of both Government and contractor developed ammunition. If possible, some of these test fixtures will be applicable to exterior ballistic studies, if required.

It is not clear at this time what terminal ballistic studies will be required for caseless ammunition/weapon systems.

In addition to ballistic studies, dynamic studies of prototype automatic weapons will have to be made to determine the effect of gun motion on accuracy, effect of recoil on the performance of supporting vehicle, and a general characterization of the overall efficiency of the weapon-vehicle system.

It is estimated that BRL participation in the Caseless Ammunition/ Weapons Program will require 2 man years/year.

XI. AIR FORCE CASELESS AMMUNITION/GUN PROGRAMS

7.62 Minigun/Caseless Ammunition Study

Work on the AF 7.62 Minigun has been completed by GE, and a final report is being drafted.

GE experienced considerable difficulty in getting the Frankford 7.62 ammunition to fire in the Minigun. After considerable testing and evaluation, the areas of firing pin protrusion, firing pin geometry and free volume were determined to be the causes of improper primer ignition. After five failures to fire, an investigation revealed that the primer had burned but had not ignited the combustible round. An inspection of the test fixture showed an enlargement of the rear end of the base to accommodate an extractor. The extractor filled the lower portion of the cut but the upper volume was open. When a thin metal strip was used to fill this open space, three out of the next five rounds fired.

25mm Caseless Ammunition/Gun Study

Two contracts, one to Philco-Ford/IITRI, the other to General Electric Company/Hercules, Inc. were awarded by the Air Force in January 1968 to conduct feasibility studies for 25mm caseless ammunition/gun systems. No report is available on the progress of these contracts.

The Air Force has joined the Army in a joint effort with Aerojet General Corporation to investigate their monolithic grain approach to caseless ammunition.

APPENDIX I

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WECOM ATTN V A LUUKKONEN: FOR RIA ATTN MR SPROTT

CONFIRMING DISCUSSION WITH COL RAAEN, IT IS REQUESTED THAT THE BRL CONDUCT A REVIEW IN DEPTH OF THE SMALL ARMS CASELESS AMMO PROGRAM. VISITS TO DEVELOPMENT FACILITIES ARE REQUIRED AND ARE TO BE CLEARED THROUGH V A LUUKKONEN. UPON COMPLETION OF STUDY, REQUEST THIS HQ BE ADVISED AS TO THE EXTENT BRL CAN PARTICIPATE IN THE SUPPORTING RESEARCH EFFORT INCLUDING COST ESTIMATE.

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APPENDIX III

APPENDIX 28

CONTRACT SUMMARY

CALIBER	ACTIVITY/TASK	CONTR. AGENCY	COMPANY CONTR NO.	COST	PLANNED PLACE-MENT	DATE PLACED	DURA-TION	REPORT PERIOD
Both	Ammo Coating Study B1201	FA	Cornell Aero Labs DAAA-25-67-C0781	$23,372	May 67	5 May 67	8 Mos	B
Both	Primer Comp Stdy (Gaseous) B1601	FA	Remington Arms Co. DAAA-25-67-C0903	$30,430	Apr 67	30 Jun 67	12 Mos	B **
Both	Primer Comp Stdy (Red Ash) B1603	FA	Olin Mathieson Co. DAAA-25-67-C0904	$27,093	Apr 67	23 Jun 67	12 Mos	B **
Both	Obturation Study B2101	FA	AAI DAAA-25-67-C0763	$35,577	Apr 67	28 Apr 67	8 Mos	M
Both	Heat Transfer Study B2401	RIA	Cornell Aero Labs DAAF01-67-C0544	$24,784	Mar 67	27 Mar 67	6 Mos	M
Both	Heat Transfer Study B2404	RIA	Cornell Aero Labs Supplement	$40,000	Sep 67	---	9 Mos	M
Small	Mfg & Process Study S1702	FA	Hercules Inc. DAAA25-67-C0658	$25,603	Mar 67	22 Mar 67	6 Mos	Q
Small	Rifle Concept Study S2005 (SPIW Type)	RIA	AAI DAAF01-67-C0724	$31,633	Apr 67	9 Jun 67	5 Mos	M
Small	Rifle Concept Study S2005 (Revolver)	RIA	Hughes Tool Co. DAAF01-67-C0723	$38,409	Apr 67	13 Jun 67	5 Mos	M
Small	Rifle Concept Study S2005 (Lat Split Breech)	RIA	G.M. - ACDRL	$64,930	Apr 67	---	5 Mos	M
Small	Machine Gun Concept Study S2006 (Pivoting Breech)	RIA	G.E. DAAF01-68-C0004	$37,605	May 67	Jul 67	5 Mos	M

CALIBER	ACTIVITY/TASK	CONTRACTING AGENCY	COMPANY CONTR NO.	COST	PLANNED PLACE-MENT	DATE PLACED	DURA-TION	REPORT PERIOD
Large	Electric Ignition Study L1602	FA	Franklin Institute Research Lab DAAA-25-67-C0742	$ 9,882	May 67	22 Jun 67	4 Mos	M
Large	Mfg & Process Study L1701	FA	Hercules Inc. Supplement DAAA-25-67-C0658	$28,827	Jun 67	29 Jun 67	6 Mos	Q
Large	Weapon Concept Study L2001(Sliding Chamber)	RIA	TRW, Inc. DAAF01-68-C0009	$87,829	Jun 67	24 Jul 67	3.5Mos	M
Large	Weapon Concept Study L2001(Split Drop Chamber)	RIA	G.E.	$85,841	Jun 67	Cancelled	3.5Mos	M
Large	Weapon Concept Study L2001(Firing Pin Actuated)	RIA	Philco-Ford DAAF01-68-C0008	$69,845	Jun 67	15 Aug 67	3.5Mos	M
Large	Weapon & Ammo Concept Stdy L2001(Combustible Case)	FA	IITRI, Phase I DAA-25-67-C0415	$54,902	Dec 66	2 Dec 66	6 Mos	M
Large	Weapon & Ammo Study L2001(Combustible Case)	FA	IITRI, Phase II Supplement DAAA-25-67-C0415	$59,350	Jun 67	27 Jun 67	6 Mos	M

* Monthly - M
Bi-monthly - B
Quarterly - Q
** Limited Distribution - Propriety Information

Installations and contractors visited are shown in the following table.

DATE	INSTALLATION
13-14 Dec 67	AC-Defense Laboratory of General Motors Corp. (AC-DRL) Firing Demonstrations at Lorton, Va.
18 Dec 67	Frankford Arsenal, Phila. Pennsylvania.
12 Jan 68	Hercules, Inc., Kenvil, N.J.
19 Jan 68	AAI, Inc., Cockeysville, Md.
23-24 Jan 68	General Electric, Burlington, Vt.
25 Jan 68	Smith & Wesson, Inc., Springfield, Mass.
25 Jan 68	Olin-Winchester Co., New Haven, Conn.
30 Jan 68	Philco-Ford, Irvine, California
30 Jan 68	Aerojet-General Corp., Downey, Calif.
31 Jan 68	Hughes Aircraft Div., Hughes Tool Co., Culver City, California
1 Feb 68	AC/DRL, Santa Barbara, California
15 Feb 68	IITRI, Colt's Fire Arms Div., Colt Industries, & Northrup Corp., Nortronics, Wash., D. C.
16 Feb 68	Frankford Arsenal, Phila., Pa.
19 Feb 68	IITRI, Chicago, Ill.
20 Feb 68	Rock Island Arsenal, Rock Island, Illinois.
21 Feb 68	TRW, Port Clinton, Ohio
12 Mar 68	Remington Arms Co., Bridgeport, Conn.

APPENDIX IV

Program & Funding for FY 68

The Caseless Ammunition/Weapon Exploration Program as approved by AMC and managed by the Joint Command Management Review Board now includes work on two programs namely Small Caliber (5.56-7.62mm) and Large Caliber (20-30mm). The FY 68 planning is for work to continue on both programs at a total estimated cost of $2.465 million. These funds are broken out as follows: $1.125 million and $1.340 million for the Small and Large Caliber Programs respectively.

1. Ammunition Research (Small Caliber) (405K)

a. In-house (335K)

(1) (100K) Ammunition design and testing of 5.56mm and 7.62mm will continue with testing to include ballistic, environmental and physical. Laboratory fabrication of ammunition will continue and will be as follows: 6300 caliber 7.62mm and 5100 ea. 5.56mm cartridges.

(2) (0) Percussion ignition studies will continue with further work on sensitivity and elimination of moisture vapor transmission. Work has been started on two approaches for keeping moisture out of the primer. In addition, consideration will be given to applying the ashless or minimum ash mixes developed for the large caliber program.

(3) (0) Studies will be performed directed toward eliminating or reducing the possibility of accidental ignition in the magazine or belt during the feeding cycle as a result of heat in the weapon or rough handling in the field or feeding cycle. Cook-off in the chamber is not a part of these studies; however, the ammunition being used during the studies will be coated with the material recommended by the coating development contractor.

(4) (150K) The remainder of equipment and tooling for the pilot line will be completed; installed and de-bugged. Wherever possible, without delaying completion of the pilot line, the pilot line will reflect the recommendations resulting from the manufacturing and

process study.

(5) (O) Fabricate 5000 ea. 5.56mm and 4000 7.62mm cartridges on the pilot line along with special ammunition to support Rock Island Arsenal weapon concept contracts for the rifle and ground mounted machine gun mechanisms.

(6) (85K) Project management and engineering support.

b. Contract (70K)

(1) (70K) An interior ballistic study will be performed to determine the mechanics of propellant ignition and burning in the chamber. One facet of the study will be photographs of the ballistic cycle through chamber apertures.

(2) (O) The coating development contract for the large caliber ammunition will be supplemented to include work on small caliber ammunition. The purpose of the coating is to reduce heat transmission from the chamber to the ammunition and increase the number of rounds that can be fired before cook-off occurs.

2. Weapon Concept Studies (Small Caliber) (210K)

a. In-house (90K)

(1) (90K) Rock Island Arsenal will provide engineering support during the rifle and machine gun concept contracts by performing mechanism feasibility studies, and fabrication and testing of mechanism.

b. Contract (120K)

(1) (20K) The contract for heat transfer studies will be supplemented for additional studies on small caliber weapons using caseless ammunition. The purpose of this contract is to develop formula that will be helpful to the weapon concept designers for chamber and mechanism heat transmission away from the ammunition and evaluation of contractor's weapon mechanisms.

(2) (O) An erosion and fouling study will be performed to determine the magnitude of the problem, effect on weapon components

and ammunition feeding and chambering. It is expected that conclusions will be made on methods of defeating or easing erosion and fouling through ammunition design and component compositions and weapon chamber configurations.

(3) (O) An obturation study will be conducted on methods of obturating the chamber and firing pin of small caliber weapon mechanisms. The study will include mechanisms that are integral with the weapon, ammunition or link. Although a similar study is being performed in the Large Caliber Program it is expected the large difference in caliber will require special consideration and different mechanisms. This effort will also support the weapon mechanisms under the contract.

(4) (100K) Upon completion of the first phase of the rifle concept contracts and the associated evaluation, the most feasible and acceptable concept contracts will be supplemented to prove feasibility of the mechanism. The supplement will be for fabrication and testing of the breadboard firing mechanism. It is conceivable that more than one contract will be supplemented.

(5) (O) Only one contract is being finalized for the ground mounted machine gun concept. The review of the first phase will result either in a continuation of the effort along the lines as originally proposed or a redirection of the design along lines suggested by the Government.

3. Feasibility Demonstration Phase

a. Contract (O)

The funds required for the following contracts or supplements are for the third phase of the demonstration weapon mechanism design and fabrication contract effort. These funds must be available in June 1968 if the weapon portion of the program is to remain on schedule.

(1) (O) The contract for the prototype rifle feasibility mechanism will be supplemented to provide for final design, fabrication and testing of the mechanism to be used for the demonstration tests.

(2) (O) The contract for the prototype feasibility demonstration mechanism of the ground mounted machine gun will be supplemented to provide for final design, fabrication and testing of the mechanism that will be used for the demonstration tests.

4. Ammunition Research (Large Caliber) (190K)

a. In-house (165K)

(1) (80K) Ammunition design including ballistic environmental and physical testing will be continued, along with in-house coating development activities. Ammunition fabrication during this phase will include sufficient quantities for development testing and 1000 cartridges to support weapon mechanism contracts.

(2) (O) Percussion and electrical ignition studies will be continued with the results of the contracts for development of ashless primer compositions being phased into the development and testing of the ammunition. The electrical ignition studies will be continued using the 152mm electric ignition element. Work will also continue on electrical conductive coatings for the propellant.

(3) (O) Studies will be performed to determine methods of eliminating or reducing the possibility of accidental ignition during firing of the weapon or between bursts. It is expected accidental ignition is possible as a result of hot gases or burning propellant leaving the rear of the chamber and impinging on the cartridge as the bolt is opened. This program will be combined with the small caliber accidental ignition study because of the similar nature of the problems and for economy.

(4) (O) The initial actions will be taken to have installed a large caliber pilot line for fabrication of ammunition. The equipment having the longest lead time will be ordered or fabricated.

(5) (85K) Program management and engineering support.

b. Contract (25K)

(1) (25K) The electric ignition study now underway will be expanded to include more refined methods of ignition and ignition elements.

(2) (0) An interior ballistic study will be performed to determine the mechanics of ignition and propellant break-up and burning. One of the purposes of the study will be to determine optimum propellant cylinder configurations, burning temperatures and the effect of propellant cylinder break-up or lack of break-up.

(3) (0) Fabricate 5750 rounds for support of demonstration weapon designers.

5. Weapon Concept Studies (320K)

a. In-house (50K)

(1) Rock Island Arsenal will continue to provide engineering support to the weapon concept contractors. As a supplement to this support RIA will perform weapon mechanism studies and tests of in-house designed mechanisms.

b. Contract (270K)

(1) (250K) Supplement weapon concept contracts for initial detail design, fabrication of firing mechanism and testing.

(2) (20K) The present heat transfer contract will be supplemented to include work on heat transfer in large caliber weapon mechanisms using caseless ammunition.

APPENDIX II

RTTUZYUW RUEOBHA3647 0292148-UUUU--RUEOEAA.

ZNR UUUUU

R 292134Z JAN 68

RM CGUSAMC WASHDC

RUEOEAA/CO BRL APG ABERDEEN MD

INFO FUEOEKB/CGUSAMUCOM DOVER NJ

RUEOPUA/CO FA PHILA PA

RUCIRRA/CGUSAWECOM ROCK ISLAND ILL

RUCIRRA/CO RIA ROCK ISLAND ILL

BT

UNCLAS AMC 12704 FROM AMCRD-W

MUCOM FOR W CARSON FA FOR G BORNHEIM WECOM FOR V A LUUKKONEN

RIA FOR MR SPROTT

REFERENCE OUR MESSAGE NO 84442 DATED 20 NOV ON CASELESS AMMO. CONFIRMING DISCUSSIONS WITH COL RAAEN. REQUEST SCOPE OF STUDY BE EXPANDED TO INCLUDE STATE-OF-THE-ART WITH RESPECT TO AMCR 70-30 ON CONCEPT FORMULATION. SEVERAL COMMERCIAL ORGANIZATIONS HAVE ADVISED DOD AND OCRD THAT STATE-OF-THE-ART NOW PERMITS IMMEDIATE ENTRANCE INTO ENGINEERING DEVELOPMENT STAGE

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
U.S. Army Aberdeen Research & Development Center
Ballistic Research Laboratory
Aberdeen Proving Ground, Maryland

2a. REPORT SECURITY CLASSIFICATION
Unclassified - [redacted]

2b. GROUP

3. REPORT TITLE

BRL SURVEY OF THE ARMY CASELESS AMMUNITION PROGRAM

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

5. AUTHOR(S) *(First name, middle initial, last name)*

E. L. Bannister B. B. Grollman R. W. Geene S. S. Lentz

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1968	60	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. RDT&E 1P014501A33C	Report No. 1406
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Materiel Command Washington, D. C.

13. ABSTRACT

A review in depth of the Small Arms Caseless Ammunition Program was conducted by a committee designated by the Commanding Officer of the U.S. Army Ballistic Research Laboratory. The Review Committee visited 17 contractor and Government installations during the term of the review. The results of the review, determined from interviews with contractors and Government personnel, and from reviews of progress reports prepared by contractors show the current status of the Caseless Ammunition Program. The results of this study show that the Caseless Ammunition Program has not reached the concept formulation phase as defined by AMCR 70-30.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ammunition						
Caseless [redacted]						
Small Caliber						
Combustible Cartridge Case						