Engineering Notes

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Development of 7.62-mm and 30-mm Combustible Cartridge Case Ammunition

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APPLICATION of combustible cartridge case material to small arms ammunition was a natural and logical outgrowth from artillery applications at IIT Research Institute (IITRI). Numerous stub-brass versions of combustible cartridges had been investigated, leading finally to the fully combustible 152-mm Shillelagh system, adopted by the Army and currently undergoing qualification tests.

7.62-mm Ammunition Development

In 1966, under IITRI in-house funding, the application of Shillelagh-type material to small arms was initiated. Later, this effort was taken over by the Maremont Corporation to support a 7.62-mm machine gun based on combustible case ammunition in which the projectile was telescoped into the case. A comparison with a brass-case 7.62-mm round is shown in Fig. 1 illustrating how handling ruggedness is achieved with the projectile unexposed. Further, with the straight cylindrical configuration, misfires can be extracted with the following round. In ultimate designs, this approach should also provide a minimum volume round for reduced storage. Since the maximum use of M-60 machine gun hardware was desired, the maximum case diameter and over-all length were kept the same as the NATO round. This approach permitted the same ramming stroke and essentially the same chamber size to be used.

A potential problem in the telescoped round geometry was blow-by. Another problem was that a great proportion of the total system energy is in the case material which could make obtaining the desired energy release rate difficult. Both of these anticipated difficulties were readily resolved by varying the composition and density to develop the proper energy-density, burning rate and strength.

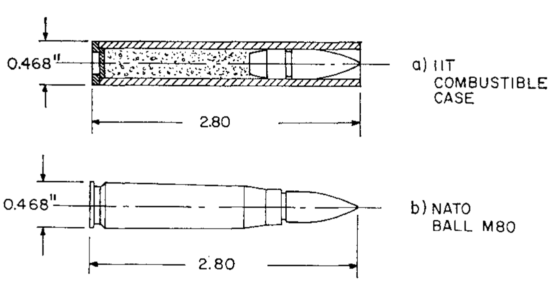

Fig. 1 Comparison of IIT combustible case and NATO M80 7.62-mm cartridge.

Case material fabricated in flat stock form was used to obtain the physical properties shown in Table 1. Limited strand-burner and closed-bomb data were gathered and used in the IITRI interior ballistics computer program to verify the formulation suitability for the 7.62 mm.

A simple test fixture using a 7.62-mm barrel was constructed (Fig. 2). A standard breech was bored-out to accommodate the combustible round geometry.

Evaluation of the blow-by was accomplished with muzzle instrumentation consisting of a photomultiplier tube at the muzzle. Muzzle flash signatures for standard and combustible rounds were compared to obtain an indication of differences in the shape and magnitude. Witness cards were placed ahead of and near the muzzle to detect impacts of unburned residue. A model 607A Kistler pressure gage and a make-screen shadowgraph arrangement were included for monitoring chamber pressure and muzzle velocity.

To establish a base line, a metal sleeve corresponding to the combustible case material in the area of the projectile was inserted into the chamber. This permitted firings without blow-by and provided the base line muzzle signature. The same data on combustible rounds could be taken and compared to obtain a qualitative measure of blow-by. For reference, firings were conducted with a standard chamber using standard 7.62-mm NATO round (Table 2). The velocity difference between the factory-loaded and any of the hand-loaded ammunition is a result of the bullet crimp. Machine crimping was determined to produce a bullet pull force of about 184 lb whereas the best hand crimps yielded only 70-lb force.

The initial firings were made with a metallic sleeve, as shown in Fig. 2, to develop a shot-start system. Duco cement was used initially for this purpose and typical data, using 47 grains of NATO Ball propellant, were a peak pressure P_{max} of 48,000 psi, a muzzle velocity V_m of 2780 fps and a muzzle flash of 6.7 v. Next, a series of firings using various combinations of cutup combustible material and loose propellant was made to select loose propellant compatible with the combustible material. Rounds 1–8, completely combustible, produced P_{max} and V_m very close to those obtained from standard 7.62-mm NATO rounds, as shown in Table 3. It is significant

Table 1 Physical properties of combustible case material[a]

Density, g/cm³	Tensile strength, psi	Modulus of elasticity, ksi	Elongation, %
0.517	920	42	3.8
0.634	1350	68	3.2
0.667	1430	68	3.8
0.754	1700	87	4.0
0.919	1930	109	3.4
1.076	3780	208	3.1

[a]Tests performed per ASTM D638-61T on type III samples. Composition: nitrocellulose, 68.9%; Kraft fiber, 12.1%; Formvar resin 3/95S, 18.0%; diphenylamine, 1.0%.

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Table 2 Standard ballistics evaluation, NATO 7.62-mm M80 ammunition single-shot test fixture

Description	Rounds	$\overline{V_m}$, fps	$\overline{P_{max}}$, psi	Muzzle
A) 47 grains NATO ball powder, hand-loaded; all cases fired once previously.	7	2,660 + 30 −10	44,100	7–8
B) 47 grains NATO ball powder, hand-loaded; gage hole plugged.	6	2,730 + 40	...	4–6
C) Standard M80 rounds, factory loaded.	11	2,830 + 370 −160	...	6–8

that relatively good reproducibility was obtained initially. Their muzzle signatures showed no blow-by evidence and, in fact, indicated less total flash on the average than the NATO round. On the other hand, they were slightly energy-poor for the chamber volume available, and it was obvious that more energy in the case material was required. Furthermore, it was thought that performance improvements could be gained with improved bonding techniques capable of improving the obturation.

With these objectives (higher case energy through higher density and an improved bonding system) in mind, different adhesives and bonding techniques were explored, and a Johns-Manville cement was selected. Gradual improvements in case density were made, and 240 firings were conducted. The final design is represented by the data for rounds 231–237, 240, and 243 in Table 3. These rounds used cases that had densities near 0.75 g/cm^3 and produced no residue in the chamber with no observed blow-by.

A test fixture duplicating the ramming stroke length and acceleration profile of the gun was constructed. Early low-density rounds were damaged at the end which impacted the barrel in this fixture. Also, the bullets pulled away under the impact load, shearing the case material. Twenty combustible case rounds made of 0.75-g/cm^3 dense material were cycled through this fixture (some a number of times) and subsequently fired. They showed no evidence of damage or debulleting (a condition that could occur since, when the round is stopped, it is restrained only by the case), and when fired, performed as expected.

Table 3 Interior ballistic measurements, 7.62-mm combustible cartridge case ammunition

Round number	Power type	Powder weight, grains	Case weight, grains	V_m,[a] fps	V_{max},[a] ksi
1	Ball	26.0	28.7	2630	44.5
2	Ball	36.0	28.2	2650	44.5
3	Ball	35.5	30.0	2700	45
4	Ball	32.4	28.6	2620	44
5	Ball	40.0	21.7	2620	42
6	Ball	41.0	21.7	2660	44
7	Ball	41.0	23.2	2640	41
8	Ball	44.0	20.6	2680	42.5
231	4198	21.1	50.6	2590	50
232	4198	21.1	53.2	2770	50
233	4198	21.6	54.2	2710	52
234	Ball	27.1	53.3	2690	40
235	4198	22	50.7	2490	40
236	4198	22	56.7	2750	55
237	Ball	26.5	52.7	2520	40
240	4198	22.3	54.5	2710	54
243	4198	20.8	51.1	2630	44

[a] Based on 150-grain projectile.

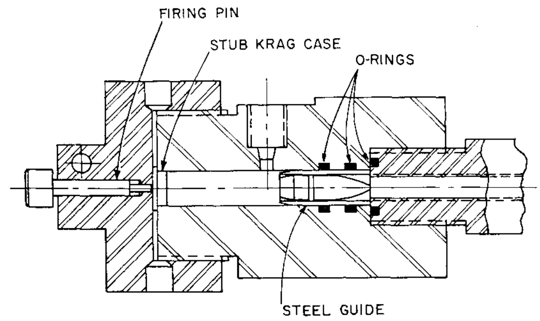

Fig. 2 Breech assembly for combustible cartridge case.

The data in Table 3 show that the conditions of the standard NATO round can be easily met with a number of possible combinations of case and charge weight and loose powder types. Typical pressure-time traces are compared in Fig. 3.

30-mm Ammunition Development

A 30-mm, telescoped, fully combustible round has also undergone preliminary development at IITRI as part of a program to develop a complete automatic weapon system for the VRFWS-S requirement. Nusbaum[1] has described the cartridge which is shown in Fig. 4. The combustible components were made for maximum flexibility with little regard for minimum numbers of components or maximum joint strength. Fabrication dies can be made to provide greater joint strength, easy assembly and producibility. The 7.62-mm case was incorporated in this design as the igniter tube. The combustible components were bonded with Duco and the projectile with Johns-Manville contact cement. The propellant chambers were loaded with various quantities of IMR or Ball propellants. The igniter tube was loaded with various weights of black powder as required for good ignition. This tube also provided a rigid support for the percussion primer. Initially metal primers were used and later, both Frankford Arsenal and IITRI-developed combustible primers were investigated.

Once the firing program was begun, it became apparent that achieving the design velocity goal of 3000 fps for the chosen projectile would be possible at a pressure level much lower than the 50,000 psi specified. Therefore, it was decided that the additional capability would be used in an attempt to obtain higher velocities. This was accomplished after a limited firing program which produced V_m's of 3500 fps at P_{max}'s of 50,000 psi. The loaded weight of this round is approximately 405 g including the weight of the 253-g projectile.

All of the firing produced smooth pressure traces, rising sharply to P_{max}. For the most part, all rounds indicated good obturation (determined from witness cards), however, as the

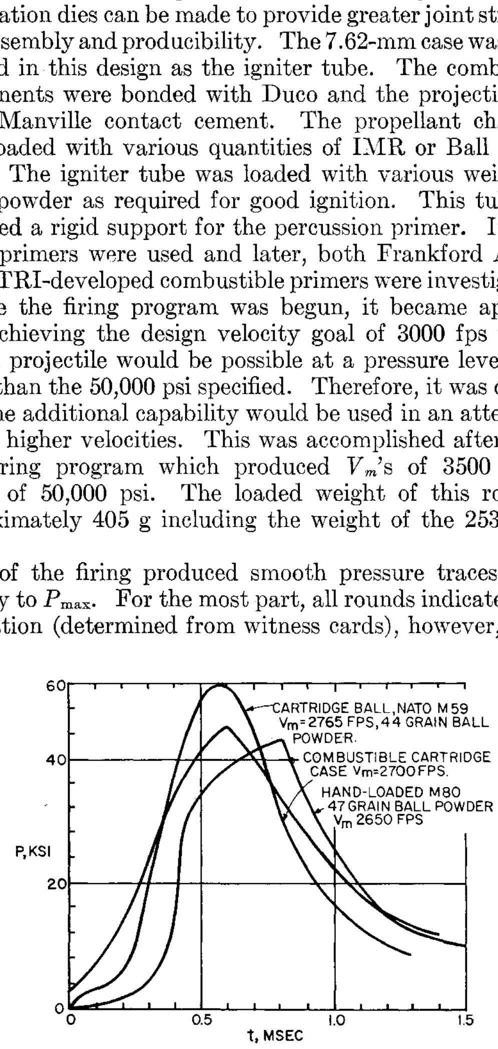

Fig. 3 Traces for 7.62-mm cartridges.

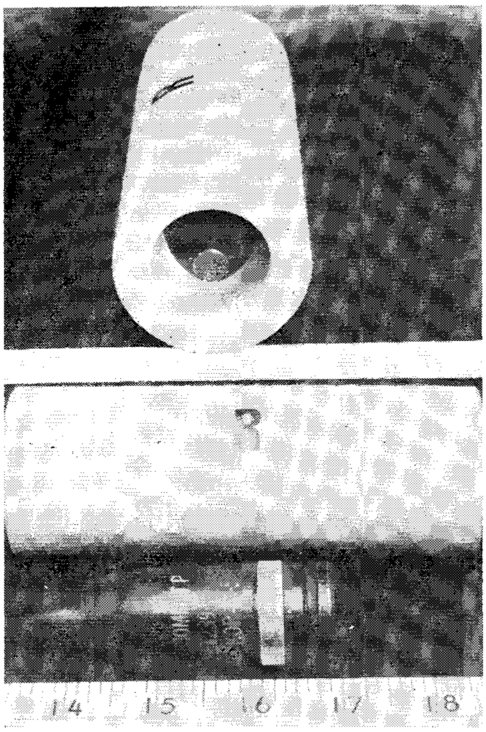

Fig. 4 30-mm folded round with combustible case. (The weight of the empty case is 37 g.)

performance level increased, changes in the loading configuration of the annulus surrounding the projectile were required to prevent blow-by of granular propellant. Firings representative of various loading conditions are shown in Table 4. In all of these firings, metal primers in a shallow metal cup were used.

Flash x-ray techniques were employed on a selected series of tests. The Fexitron model 730, 300-kv unit used had an exposure time of 100 μsec with a nominal penetration capability of 2 in. of steel. Special rounds that incorporated lead foil around both the igniter tube and the case were constructed to ensure sufficient radiographic contrast. The radiographs indicated that, while the igniter tube is still intact, gases vent from the projectile end and the main charge begins to burn. This provides additional pressure to drive the projectile forward. As the projectile leaves the guide tube and enters the launch tube, the guide tube begins to deteriorate. However, this does not seem to occur until the guide tube has served its primary purpose since the round is seen to enter the launch tube perfectly straight. Yaw card data at 9, 15, 50, and 300 ft show stable projectile impacts with no evidence of mal-launch instability. Projectiles recovered were normally rifled with no indication of balloting.

Table 4 Ballistic measurements, 30-mm combustible cartridge case ammunition percussion primer, 7-g FFF black powder igniter—case weight approximately 37 g

Round	Powder type and relative thickness	Loading Front, g	Loading Rear, g	V_m, fps	P_{max}, psi
1	IMR 4996(52)	20	65	2540	20.9
2		20	65	2960	29
3	IMR 5010(70)	20	80.6[a]	2890	34
4[b]		20	77[a]	3150	32
5		20	65	3090	35
6		20	80.6[a]	3350	...
7		20	80.6[a]	3280	56
8	Ball WC857	30	80.6[a]	3290	57
9		25	80.6[a]	3380	50
10		20	80.6[a]	3030	44
11		20	80.6[a]	3330	46
12		20	80.6[a]	3300	47
13		20	80.6[a]	3220	46
14		20	80.6[a]	3360	49.5
15		20	50	2800	...
16	IMR 4350(100)	20	65	3140	42
17		20	77.5[a]	3340	...
18		25	77.5[a]	3470	52
19	IMR 4320(100)	20	50	2810	36

[a] Full loading density—rear chamber.
[b] Case had bulkhead spacer; all other rounds "standard."

Concluding Remarks

Combustible cartridge case material has been tailored to suit the various needs of the two ammunition systems described from both the ballistic and physical properties standpoints. Continued case material improvement is underway on several existing projects which will provide additional strength, density and energy levels.

Reference

[1] Nusbaum, M. S., "A Theoretical Interior Ballistic Investigation of a Fully Combustible Cartridge, Fully Telescoped Round," *Journal of Spacecraft and Rockets*, Vol. 6, No. 1, Jan. 1969, pp. 84–86.

Synthesis of a Guidance System for a Short-Range Infantry Missile

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Nomenclature

$\bar{A},\bar{C}$ = positions of vehicle's center of mass (c.m.) relative to inertial and aiming frames, respectively
A_x,A_y,A_z = accelerometer frame components of vehicle displacements relative to inertial space (for zero initial conditions)
$\bar{B}$ = position of aiming frame origin relative to the inertial frame
D = magnitude of a step change in the second integrator output at $t = 0^+$
$E1,E3,E5$ = platform roll, pitch, and yaw rates, respectively, during boost
$E2,E4,E6$ = platform roll, pitch, and yaw rates respectively, during coast
$\bar{g},g_c$ = gravitational acceleration and constant (32.2 ft/sec²), respectively
g_x,g_y,g_z = components of $\bar{g}$ in accelerometer frame
N_1,N_2,N_3 = accelerometer, first-integrator, and second-integrator output noise, respectively (symbolized as n_1, n_2, and n_3 when the noises are in the form of a bias)
Pr = rth dummy variable
$Q_1,\ldots,Q_4$ = transformations from inertial to geocentric, geocentric to aiming, aiming to accelerometer, and accelerometer to vehicle frames, respectively
S = the LaPlace variable
t,Tr = time and rth time function, respectively
$V_0,\ldots,V_4$ = steady-state gains of compensator network, accelerometers, first-integrators, second-integrators, and the autopilot-actuator-airframe combination, respectively
$\overline{W}_2,\overline{W}_3$ = angular rates with respect to inertial space of coordinate frames 2 and 3, respectively

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