20mm AMR – New Use for Unused Ammo

Harnessing the Power of Technology for the Warfighter

US Special Operations Command

FOREIGN COMPARATIVE TESTING (FCT) PROGRAM

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20mm AMR – New Use for Unused Ammo

- **Anti Material Rifle Concept Dates to WWI (Mauser)**
  - **Developed in Response to British Tank Threat**

Lt. - 13.2 X 92 SR
Ctr. - .55 Boys
Rt.- .50 BMG

British MK 1 Tank

M1918 @ 41 lbs

M1918 Mauser T-Gewehr

Boys AT Rifle @36 lbs (1937)

The .50 Browning Machine Gun (BMG 12.7X99mm) is the only one of these 3 similar performance rounds still in use today. The .55 cal Boys AT round is also known as 13.9X99B.

20mm AMR – New Use for Unused Ammo

- **Anti Tank Rifle Applications Continue into WWII**

Lahti L-39 20X138B @ 109 lbs Brake cut Recoil Energy 44% and Recoil Operation cut it another 25% (reportedly)

Solothurn S18-1000 20X138B "Long Solothurn" (Reinmettal) – Recoil Op. Semi-Auto @ 118 lbs

PTRD 14.5X114mm Single Shot w/ Long Recoil Mech. @ 38 lbs

Japanese Type 97 20X125mm @ 130-140 lbs rear monopod dug in for felt recoil reduction

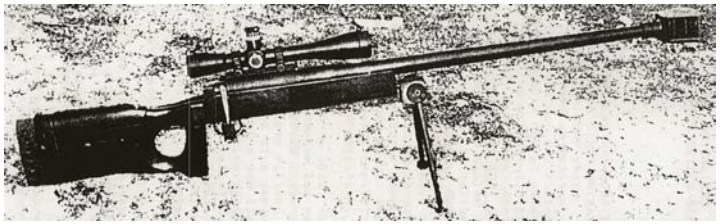
PTRS 14.5X114mm Semi-Auto (5 shot) @ 46 lbs

20mm AMR – New Use for Unused Ammo

1980's .50 caliber rifles for Material Targets

RAI "Haskins" M500 circa 1983 at 35 lbs, fielded in support of 1981 NAVSPECWAR Op. Req.

M107 – started as M82 in 1982 approx. 33 lbs



McMillan M88 SASR (Special Applications Sniper Rifle) at 24 lbs fielded in 1988 by NAVSPECWAR

Pauza P-50 available 1989 approx. 30 lbs

MK 15 MOD 0 SASR @ 28.2 lbs Naval Special Warfare Current Issue

20mm AMR – New Use for Unused Ammo

Recent Foreign .50 caliber AMR efforts with some integrating recoil mechanisms along with brake.

DSR 50 from DSR-Precision GmbH
- hydraulic buffer in stock (.50 BMG)

Chinese 99 (avail. In .50 BMG)
- buffering in stock

Czech OP-96
Falcon 12.7X99mm
- spring in stock

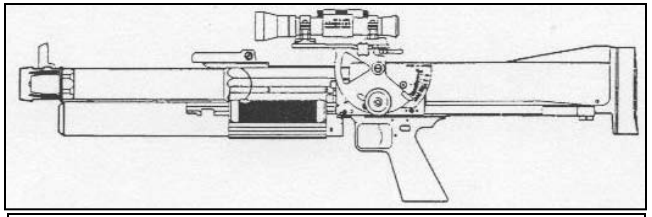
Accuracy International
AS-50 (UK) 12.7X99mm

Russian ASVK 12.7X108mm
(aka KSVK & SVN-98)
- novel combo. muzzle device

Russian OSV-96
12.7X108mm
(& .50 BMG)
Semi-Auto with
hinged barrel

Current US Anti-Materiel Efforts

XM109 AMPR – Anti-Material Payload Rifle (25mm OICW / OCSW "Grenade") 35 lbs w/ 17.6 in. barrel)



FN Herstal 40mm HV Grenade Launcher (17 lb threshold)

NOS Louisville also had a similar 1990's 40mm effort EX41 prototype @ 21 lbs & 500 fps (M430 projectile)

XM500 AMR .50 Caliber 26 lbs (Gas Op. Semi) – Lighter / Shorter than M107 at 46 inches long

U.S. Army also has lightweight M107 project with specified weight of 23.7 pound at 57 inches long (M107 is same length but at approx 33 pounds).

20mm AMR – New Use for Unused Ammo

US “Commercial” Offerings (Anzio Iron Works)

20X102mm Bolt Action (3 shot) 49 inch barrel (advertised @ 59-130 lbs)

20mm Takedown Single Shot (39 lbs)

- **Currently chambered for 20X102mm (Vulcan / M61). Cases converted to percussion priming (from electric).**
- **Other known U.S. Companies working with 20mm include Serbu Firearms and Pioneer Machining & Weapon Systems.**

20mm AMR – New Use for Unused Ammo

Current catalog prices per round for 20mm rounds for Vulcan Cannon M61 (20X102mm).

DODIC AA24	**PGU-27A/B 20mm TP**	**$5.58**
DODIC AA28	**PGU-30A/B 20mm TP-T**	**$10.00**
DODIC AA22	**PGU-28A/B 20mm SAPHEI**	**$14.29**

Based on recent 20X102mm SAPHEI pricing and only looking at available HEI/APT (M210/M95) A862 quantity of **1.4 Million rounds** that equates to a cost savings of over **20 Million Dollars**. Not Counting the 250K of M204 TP (Practice) Ammunition also available (Linked with APT). Based on AA24 20X102mm TP value that is another **$1.4 Million** in Free Issue Ammo.

20X102mm M61 / M39 Gun Systems

<<20X110HS vs .50 BMG, .300 Win Mag, 7.62 & 5.56 mm NATO

20mm AMR – New Use for Unused Ammo

General AMR / Heavy Sniper Rifle (HSR) Requirements Background

- 1992 USSOCOM Directive 70-2
- HSR JORD Approved 16 March 1994
- Special Operations Weaponeering Manual 61 JTCG/ME-83-8 Target Defeat Goal of 5 shots or less at ranges from 50 to 1200 meters
- 1.5 MOA accuracy goal to 1500 meters 2 MOA threshold (32 ft-lb recoil threshold)
- 5 second TOF (Time of Flight) to 2000 meters Goal
- PSR CDD Increment 4 Anti-Material Capability
  - Allows for AM focused Supplemental Weapon System

20mm AMR – New Use for Unused Ammo

Foreign 20X110mm HS (Hispano-Suiza) Rifles Procured for Evaluation

RT-20 M1 (RH Alan - Croatia)
43.4 lbs – 36 in. barrel – 52.5 in. OL

SR-20 (Truvelo – South Africa)
Approx. 55 lbs – 39 inch barrel – 72 inch OL
(20X82mm as shown, aka 20X83.5mm)

20X110HS NTW-20 Rifle
DENEL – South Africa
70 lbs – take down capable
39 inch barrel – 70.5 inch OL

Other Available Chamberings:
20X82mm (MG151Round)
14.5X114 Russian and .50 BMG

20mm AMR – New Use for Unused Ammo

DENEL NTW 20X110HS AMR

NTW 20X110HS AMR Data

Weight	70 lbs
Barrel Length	39 inches
Overall Length	70.5 inches
Projectile Mass	2030 grain
Projectile Velocity	2600 fps
Recoil Vel. (Bench)	6.4 fps

MK 15 MOD 0 SASR – Caliber .50 BMG

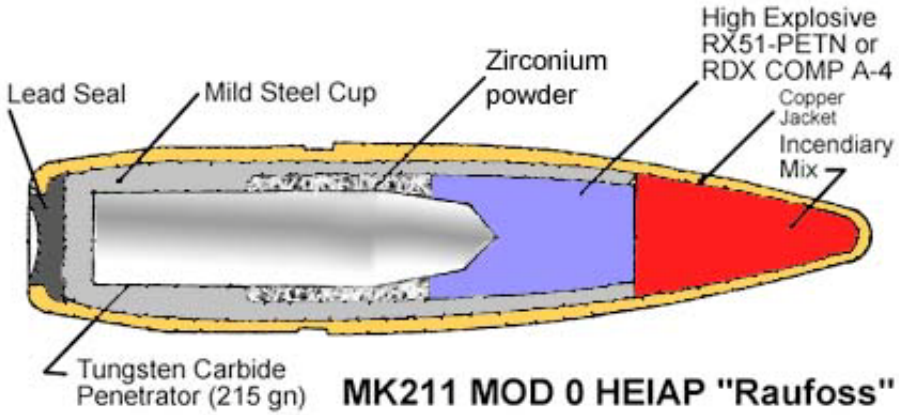
MK 15 MOD 0 Data

Weight	28.2 lbs
Barrel Length	27.5 inches
Overall Length	55.5 inches
Projectile Mass	660 grain
Projectile Velocity	2700 fps
Recoil Vel. (Bench)	6 fps

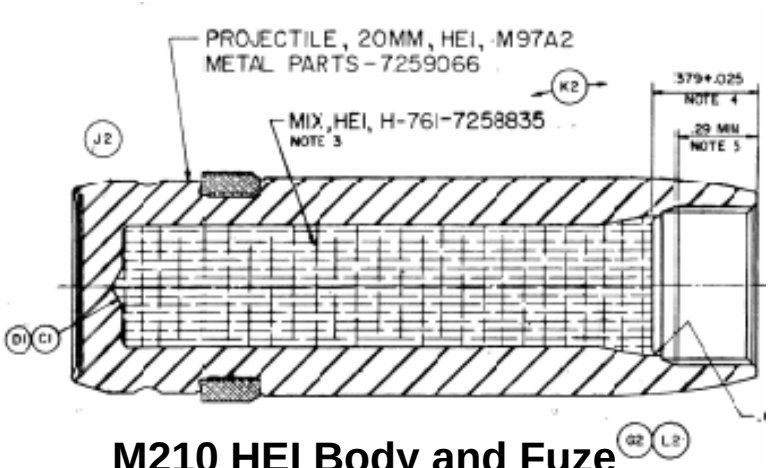
Felt Recoil Velocities Achieved during Bench Shoulder Firing

20mm AMR – New Use for Unused Ammo

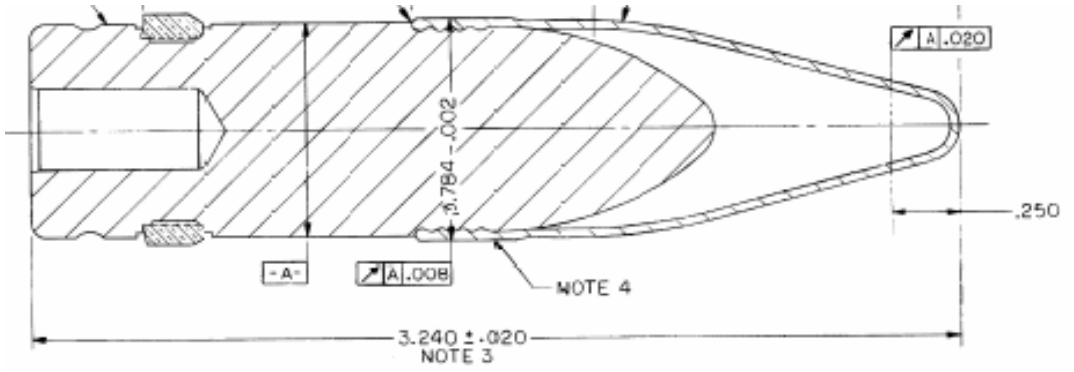
.50 cal. MK 211 Current Baseline Projectile Construction vs. 20mm M95 APT and M210 HEI



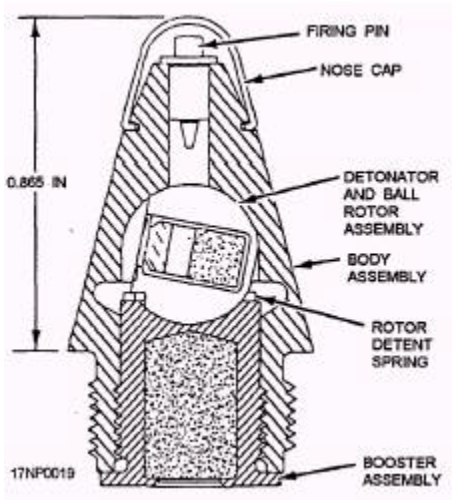
MK211 MOD 0 HEIAP "Raufoss"



M210 HEI Body and Fuze



M95 Armor Piercing Tracer Projectile

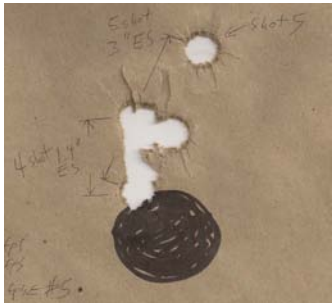


M505A3 Fuze

20mm AMR – New Use for Unused Ammo

.50 BMG Cartridge top vs.
20X110mm Hispano Suiza

M204 TP & M95 APT



First 5 shot group of M204 TP
100 yds from bench 3 in. ES –
First 4 shots in 1.4 in. ES

.27 cal MK 211
.43 cal M2 AP
.77 cal M95 APT

Cartridge	.50 caliber MK 211	20mm M210 HEI	M2 AP	20mm M95 APT
Explosive	Comp A4 (RDX)	Comp A4 (RDX)	None	None
Incendiary	Zirconium + Incendiary Mix	Aluminum Powder	None	Tracer Comp.
Penetrator	.27 cal. 215 grain Tungsten-Carbide	No Penetrator	.43 cal. steel @ 425 grains	.77 caliber steel @ 1750 grains
Fuze	Pyrotechnic Train Activation	M505A3 – Arms at 10-35 ft	No Fuze	No Fuze

Note: Mass of Incendiary / Explosive for M210 HEI @ 120 grains is approx. 3.3 times that of MK 211.

20mm AMR – New Use for Unused Ammo

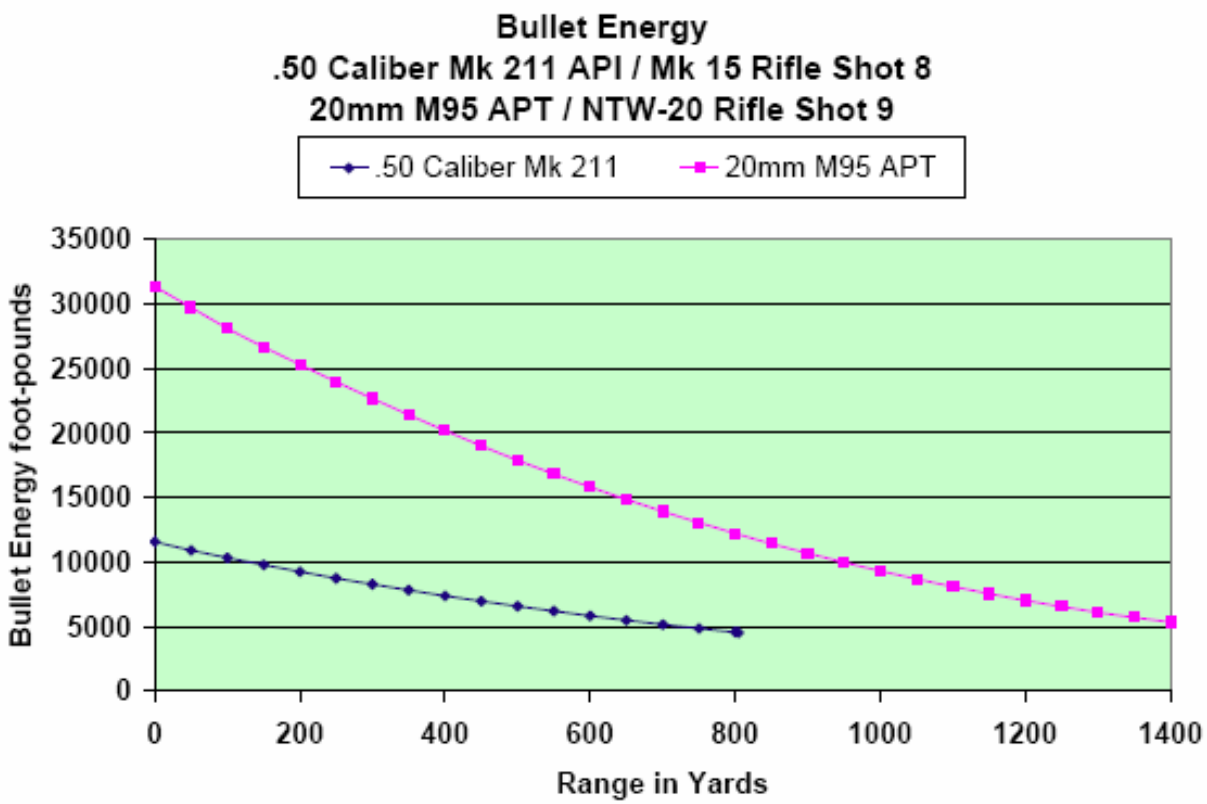
All groups are 3 shots each			1 MOA at 600 yds is 6.3 inches			
Data compiled from 5 different days			1 MOA at 1000 yds is 10.5 inches			
Rifle	"Shooter"	Range (yds)	# Groups	Ammo	Avg. ES (in.)	Avg.ES (MOA)
RT-20	Fixture	600	4	APT	9.4	1.5
NTW-20	DA	600	6	TP&APT	8.6	1.4
MK15	DA&DS	600	2	AP	9.5	1.5
NTW-20	DA&OC	1000	5	TP&APT	17.3	1.6
MK15	DA&OC	1000	3	AP	19.8	1.9
NTW-20	SEAL	1000	1	TP	21.5	2.1
MK15	SEAL	1000	1	MK211	23.5	2.24
NTW-20	SEAL(BS)	1400	1	TP	10.5	0.72

Acoustic Target - 1000 yards @ NSWC Crane

SEAL shot groups were documented during familiarization firing – Camp Atterbury, IN
Their Recoil Comments:

1. **Recoil at Max – cannot use non-standard shooting positions (overpressure minimal, recoil sufficient).**
2. **Recoil is spread over more time but compresses body more (than other weapons). Need to allow for more than 25 shots a day to get accurate dope.**
3. **Recoil Near Max – Similar to MK 15 but longer/deeper.**
4. **Recoil Excessive – Hardest hitting gun he has shot.**
5. **Recoil at Max – Imagine Push and Overpressure is like 25mm on Hard Mount.**
6. **Recoil Excessive – Training and Employment issues (Size and Config. as well).**

20mm AMR – New Use for Unused Ammo



Doppler Radar Velocities (fps)		
Range (yards)	MK 15 MK211	NTW-20 M95 APT
MV	2607	2638
200	2332	2370
400	2082	2117
600	1853	1874
800	1639	1647
1000		1438
1200		1248
1400		1091
NTW-20	M210 HEI	
0	2648	
400	2086	
800	1610	
1200	1210	

.50 cal. MK 211 lost 968 fps over 800 yds versus 991 fps for 20mm M95 APT and 1038 fps for M210 HEI.

Burning tracer reduces drag on the 20mm APT projectile. The MK 211 available had lower than expected velocities.

20mm AMR – New Use for Unused Ammo

MK 15 MOD 0 firing MK 211 multi-purpose .50 caliber against simulated Heavy Vehicle Door with 18 gage (0.043”) witness panels @ 21 and 33 inches to rear of target face.

Shot 1

Entry

Exit

W1- 4 Complete Pen.
5 Partial Pen.

W2- 6 Complete Pen.
11 Partial Pen.

Shot 2

Entry

Exit

W1- 8 Complete Pen.
5 Partial Pen.

W2- 3 Complete Pen.
13 Partial Pen.

20mm AMR – New Use for Unused Ammo

NTW-20 firing M210 HEI against simulated heavy vehicle door made up of 2 layers of 18 gage steel (0.043”) spaced 3.5 inches with 18 gage steel witness panels @ 21 and 33 inches back (2x2 ft).

“Door” Entry 9.5 in. dia.

“Door” Exit 13.5 in. dia.

W 1 –

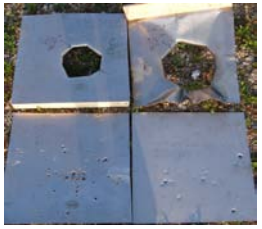
35 Complete Penetrations

167 Partial Penetrations

W 2 –

9 Complete Penetrations

40 Partial Penetrations



“Door” Entry 9 in. dia.

“Door” Exit 13 in. dia.

W 1 –

32 Complete Penetrations

197 Partial Penetrations

W 2 –

4 Complete Penetrations

36 Partial Penetrations

20mm AMR – New Use for Unused Ammo

More views of 100 yard Simulated Vehicle Door Damage along with other material target damage (MK 211 penetrator did penetrate concrete & wood & both W1 & W2).

Shot 1 of M210 HEI -100 yd "Car Door" as Found

Stacked Solid Concrete Block was breached by 20mm HEI but no damage to 18 gage steel Witness Panel – need APT for deep penetration of fortified targets.

Shot 2 of M210 HEI - 100 yd "Car Door" Exits

As Found Post-Fire

Pine Boards – 6 inches thick (4 boards) 18 gage steel W1& W2 were penetrated completely

20mm AMR – New Use for Unused Ammo

200 yard Car Door - MK 211 vs. 20mm HEI. Data not yet available at further ranges but effects should be similar out to max. range of approx. 2000 meters.
M505A3 Point Detonating Fuze acts immediately upon impact versus the slower MK 211 pyrotechnic train.

HEI Car Door Exit

HEI Car Door Entry

MK 211

½ inch dia. in & out

W1 @ 11.5" .02 alum.

W2 @ 36.5"steel 5 CP

20mm HEI Entry

20mm HEI Exit

W1 @ 11.5" 142 CP

W2 @ 36.5"steel 20 CP

20mm AMR – New Use for Unused Ammo

MK 15 fired MK 211 & NTW 20 fired M95 APT at High Hard Armor (HHA) Gun Mount Protective Plate at 100 yards (W1 at 18.5 inches and W2 at 29.5 inches behind target plate) **MIL-A 46100 Spec. 0.4 inch**

MK 211 .50 caliber

MK 211 vs. HHA Exit

W1: 4 CP / 33 PP

W2: 6 CP / 11 PP

M95 APT 20mm

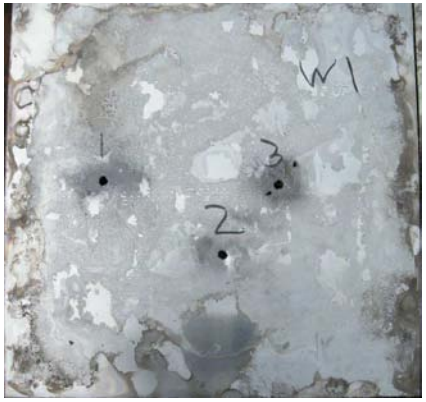
M95 APT vs. HHA Exit

W1: 15 CP / 67 PP

W2: 18 CP / 65 PP

20mm AMR – New Use for Unused Ammo

100 yards .50 cal M2 AP & 20mm M95 APT vs. 0.5 in. AR400 Steel Plate (simulated RHA) (per Mil-A 12560)



.50 caliber M2 AP

.020" Alum. Witness Panels W1 @ 6" and W2 @ 14"

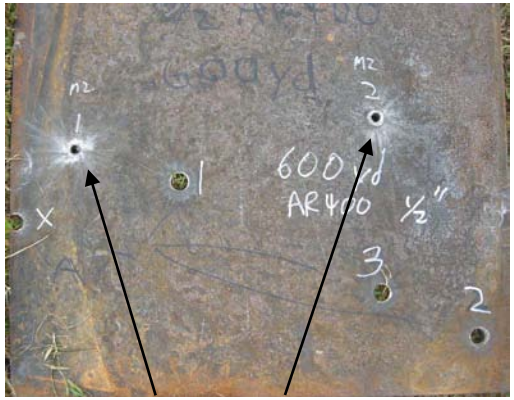
20mm M95 APT

Rear of W1 & W2

.020" Alum. Witness Panels W1 @ 6" and W2 @ 14"

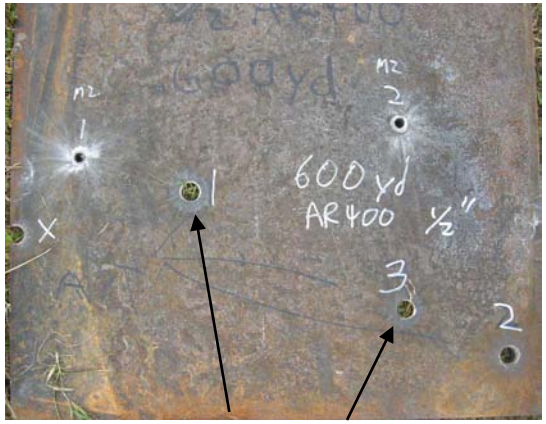
20mm AMR – New Use for Unused Ammo

600 yards .50 cal M2 AP & 20mm M95 APT vs. 0.5 in. AR400 Steel Plate (simulated RHA)



.50 cal M2 AP at 600 yds

.020" Alum. Witness Panels W1 @ 6" and W2 @ 14"



20mm M95 APT at 600 yds

.020" Alum. Witness Panels W1 @ 6" and W2 @ 14"

20mm AMR – New Use for Unused Ammo

1000 yard "Vehicle Target" - This represents a general Vehicular Target Engine Defeat: ½ inch 65-45-12 Ductile Iron behind 2 layers of ¼ inch Aluminum Plate (5052H32).

Proj.	Shot-Pen.	MuzV (fps)	RemV (fps)
M2AP	2-CP	2734	1748
M2AP	6-PP	2692	1706
M2AP	12-PP	2690	1704
M2AP	13-CP	2664	1678
M95	2-CP	2661	1518
M95	3-CP	2676	1533
M95	6-CP	2586	1443

RemV estimated based on prior test Avg. Velocity Loss @ 1000 yards. See next slide for Iron Plate Hits.

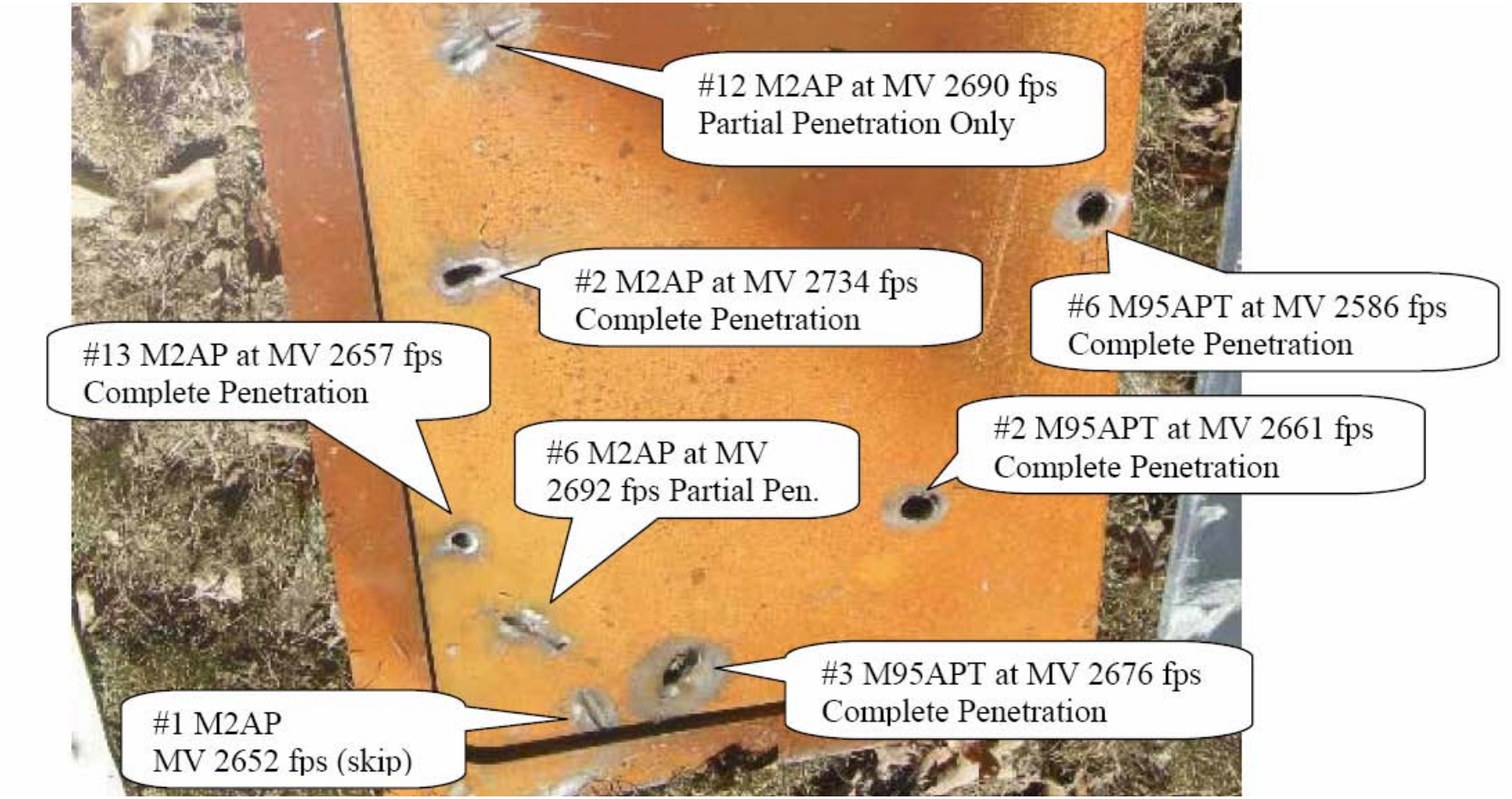
¼ inch Alum. ¼ inch Alum. ½ inch Iron ¼ inch W1

1000 yard "Vehicle Target"

M95 APT vs. M2AP Penetrators

20mm AMR – New Use for Unused Ammo

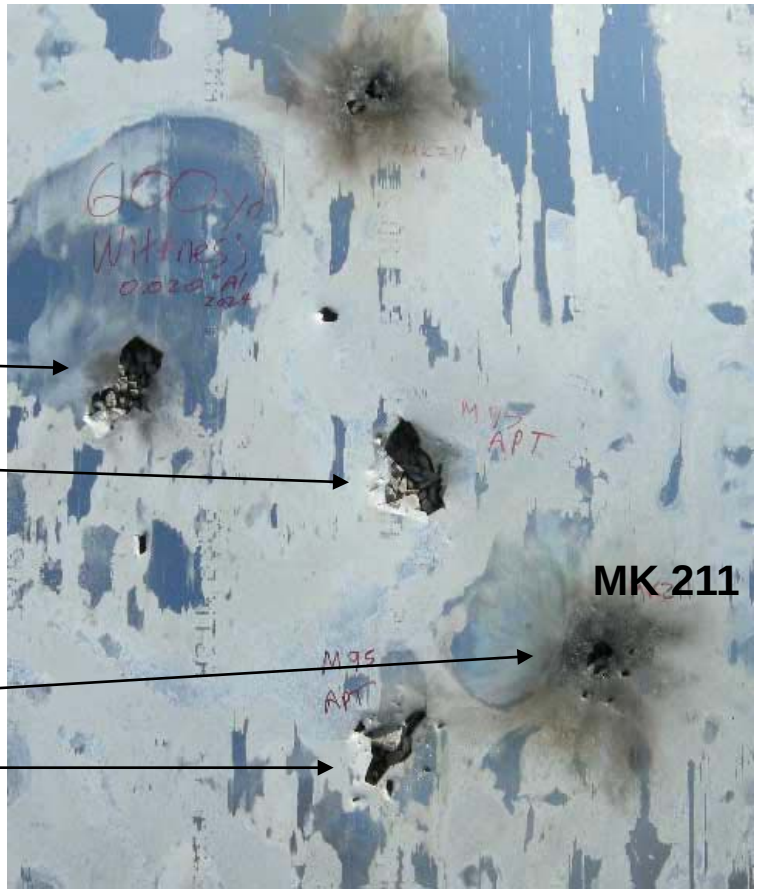
Ductile Iron Target Plate @ 1000 yards (set 48 inches from front alum. plate)



M95 APT Average 1500 fps Impact Velocity at 1000 yards (all 4 Complete Penetrations, 3 seen here)

20mm AMR – New Use for Unused Ammo

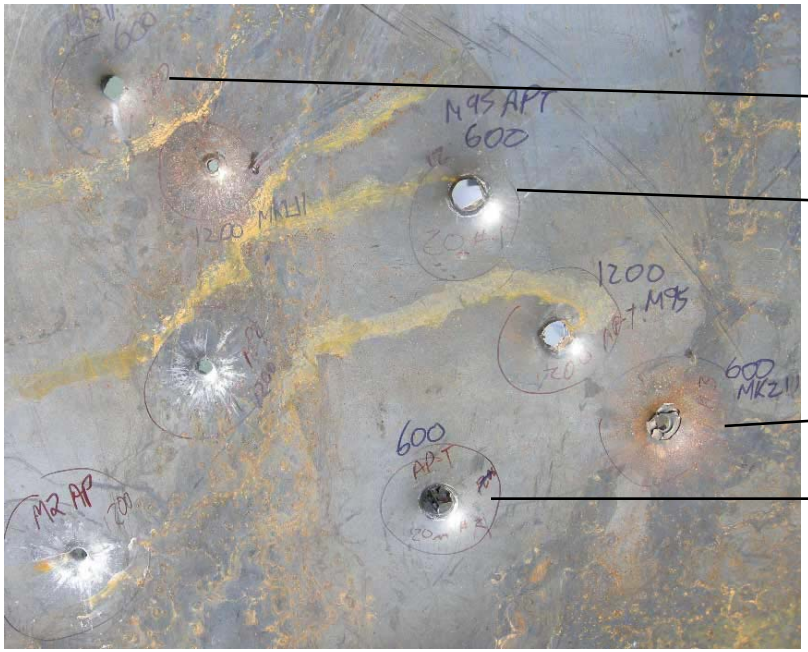
600 yards MK 211 against 20mm Ammo Can with other empty ammo cans inside (blew off lid) - for 20mm HEI expect major damage to all.



3 hits M95 APT

and

1 hit MK 211



¼ inch A36 Steel @ 600 yards

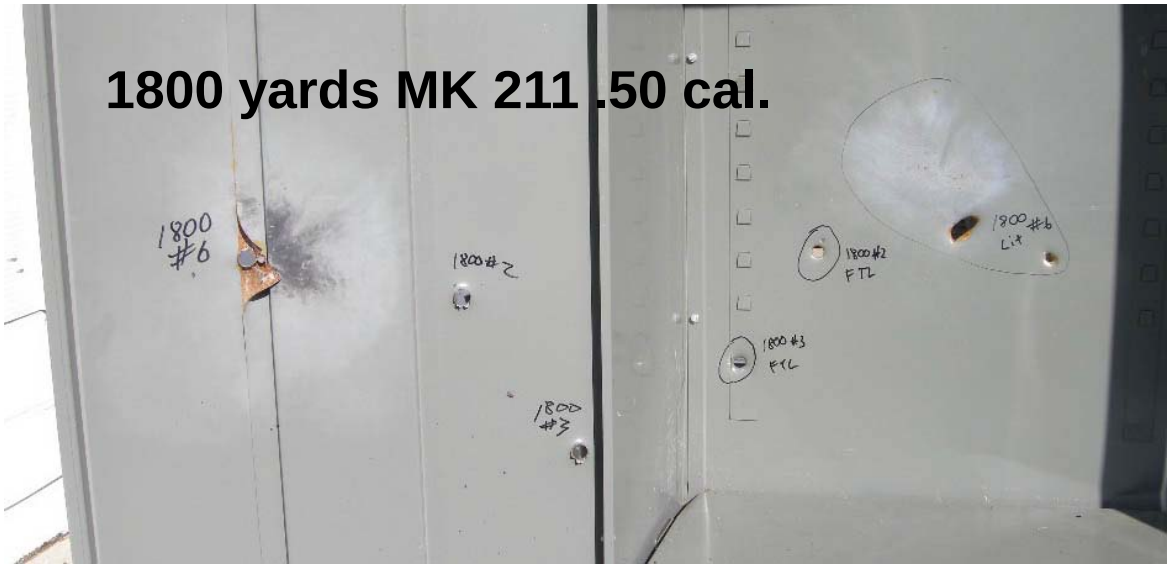
¼ inch mild steel "Behind Target Effects" are more significant for M95 APT 20mm than for exploding MK 211 rounds at 600 yards.

20mm AMR – New Use for Unused Ammo

At 1800 yards majority of MK 211 projectiles Failed to Light (activate / explode) designated FTL.

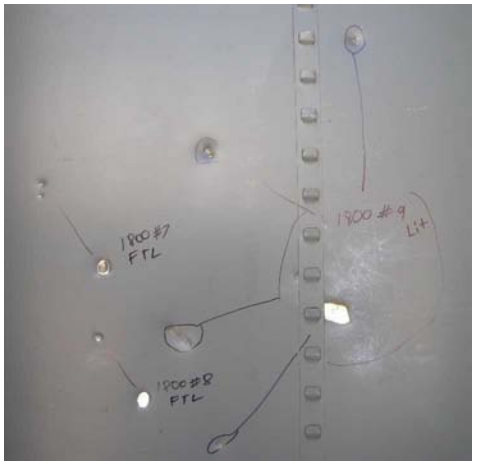
Surrogate Light Material Targets were Steel Office Fixtures as well as ¼ inch A36 mild steel plate.

MK 211 damage is also significantly reduced at this range even when it activates.



Inside view of open door and back wall of target - 2 of 3 FTL

Another 2 of 3 FTL - #9 activated on latch plate



MK211 Pen. lodged in A36 mild steel FTL

20mm AMR – New Use for Unused Ammo

1800 yard MK 15 - MK 211 Impacts on 20/23 gage target lengthwise (Failed to Light) and 19/20 gage profile (Lit). Damage Marginal, even when activated remaining velocity under 1000 fps at 1800 yds.

1800 yard MK 211 into target face and completely penetrated without activation

MK 211 at 1800 yards that did activate – perhaps due to heavier 14 gage layer just past entry

20mm AMR – New Use for Unused Ammo

Vehicles and Dismounted Machine Gun and Mortar Teams are most probably hit / defeated during the initial contact before they can react. Rapid Target Acquisition, Engagement, and short Time of Flight are critical to Hit Probability – especially for ”dumb” (unguided) munitions. A rifle based weapon system can provide this combination. Probability of Kill is then enhanced by the blast and fragmentation available in a 20mm HEI projectile.

20mm AMR – New Use for Unused Ammo

20X110HS AMR is well suited for Modern Material Targets:

(M210 HEI for thin skinned / light targets and M95 APT for hard / lightly armored)

& **E**xplosive **O**rdnance **D**isposal

Potential VBIED

20mm AMR – New Use for Unused Ammo

BATF Explosive Standards

ATF	Vehicle Description	Maximum Explosives Capacity	Lethal Air Blast Range	Minimum Evacuation Distance	Falling Glass Hazard
	Compact Sedan	500 pounds 227 Kilos (In Trunk)	100 Feet 30 Meters	1,500 Feet 457 Meters	1,250 Feet 381 Meters
	Full Size Sedan	1,000 Pounds 455 Kilos (In Trunk)	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	Passenger Van or Cargo Van	4,000 Pounds 1,818 Kilos	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	Small Box Van (14 Ft. box)	10,000 Pounds 4,545 Kilos	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	Box Van or Water/Fuel Truck	30,000 Pounds 13,636 Kilos	450 Feet 137 Meters	6,500 Feet 1,982 Meters	6,500 Feet 1,982 Meters
	Semi-Trailer	60,000 Pounds 27,273 Kilos	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

Vehicle Borne Improvised Explosive Devices

VBIED's

Goal:

Disrupt or Detonate @ Safe Stand-off w/ min. Collateral Damage

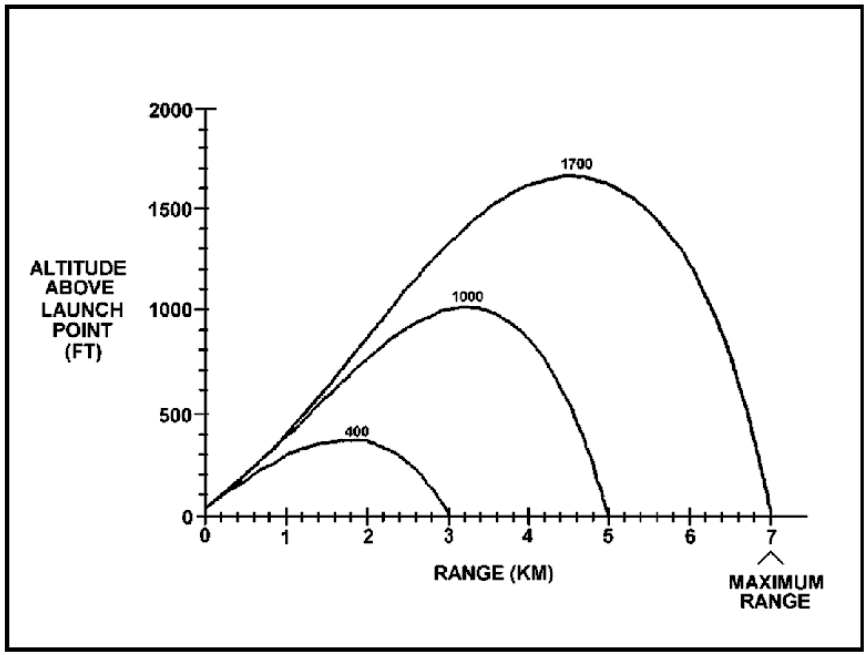
Plus Water and Aircraft

20mm AMR – New Use for Unused Ammo

A few current alternative threat response options - all with time / precision & / or cost trade-offs vs. AMR for Material Targets (up to light armor).

20mm AMR – New Use for Unused Ammo

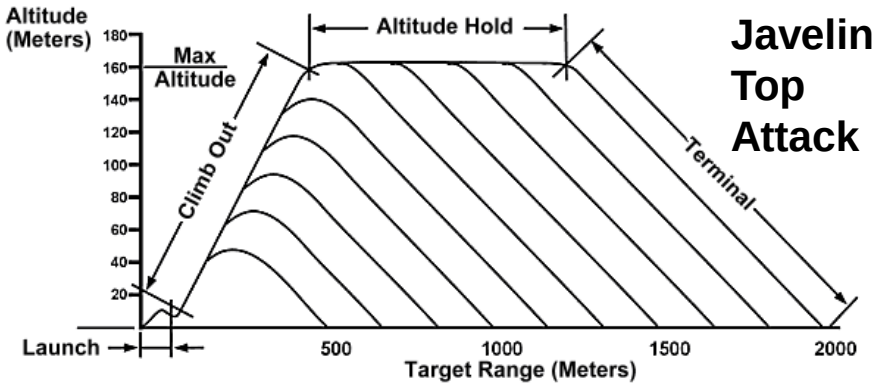
High Trajectory / Max. Ordinate requires Air Space Coordination.



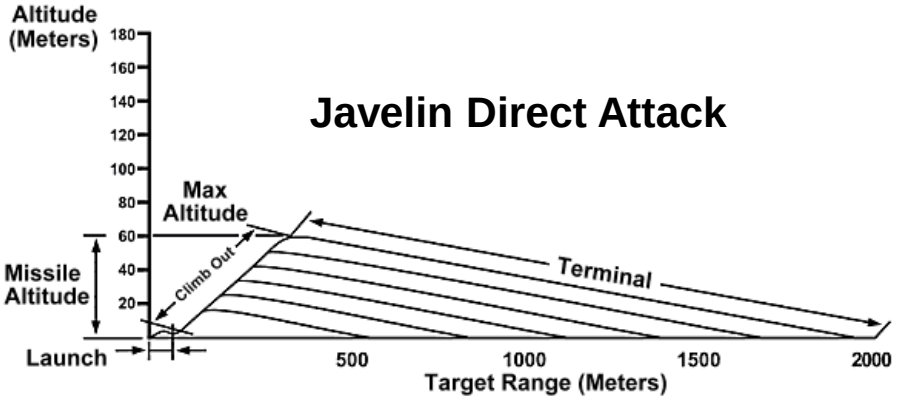
LOBL Trajectories (AGM-114A)

Hellfire Missile Trajectory - current AGM-114C alternate trajectory is 40% lower.

Javelin – Minimum Engage Distance of 65m Direct Attack or 150 meters Top Attack to maximum of 2000 meters.



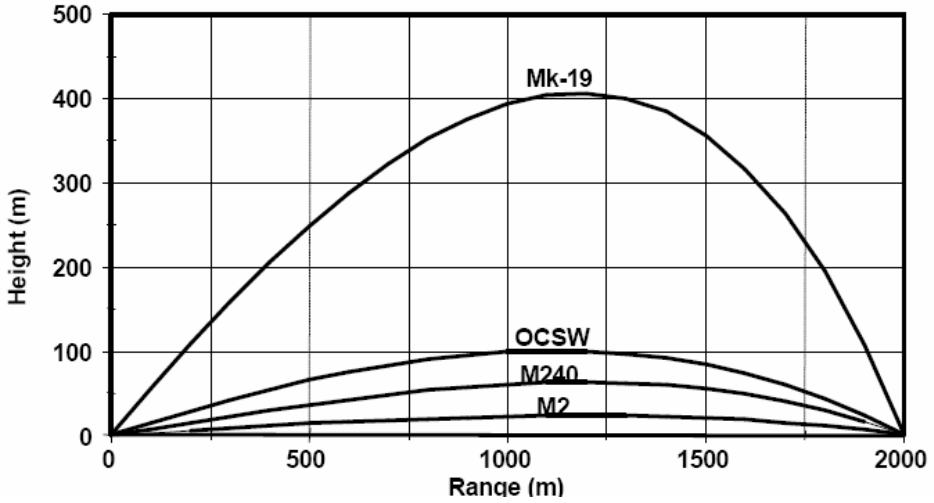
Javelin Top Attack

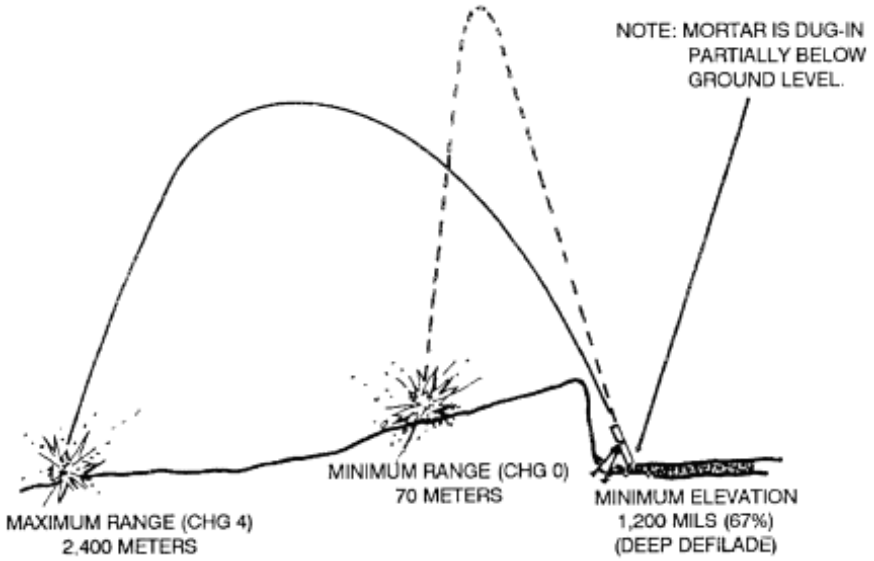


Javelin Direct Attack

20mm AMR – New Use for Unused Ammo

60mm M720 Mortar Bomb Bursting Radius is 15m and 40mm Grenade Lethal Radius is 5 meters (20 m Hazard) vs. 2 meter Lethal Radius for 20mm HEI Cannon Shell (6 m Hazard)





TOF (sec)	500m	1000m	1500m	2000m
OCSW	1.55	3.55	5.97	8.89
M2	0.62	1.47	2.65	4.24
Mk-19	2.78	6.49	11.39	17.99
M240	0.77	2.19	4.18	6.68
20X110mm	.7	1.8	3.2	< 6

While the M224 60mm Mortar is fairly light weight and covers 70m to well beyond 2000m (3500m) it has poor first round hit probability and has a Max. Ordinate of 6825 ft along with associated Long Time of Flight (near 30 seconds). Also, collateral damage is an issue.

TOF & Trajectory Data from 2000 Gun & Ammo Symposium JSSAP Brief

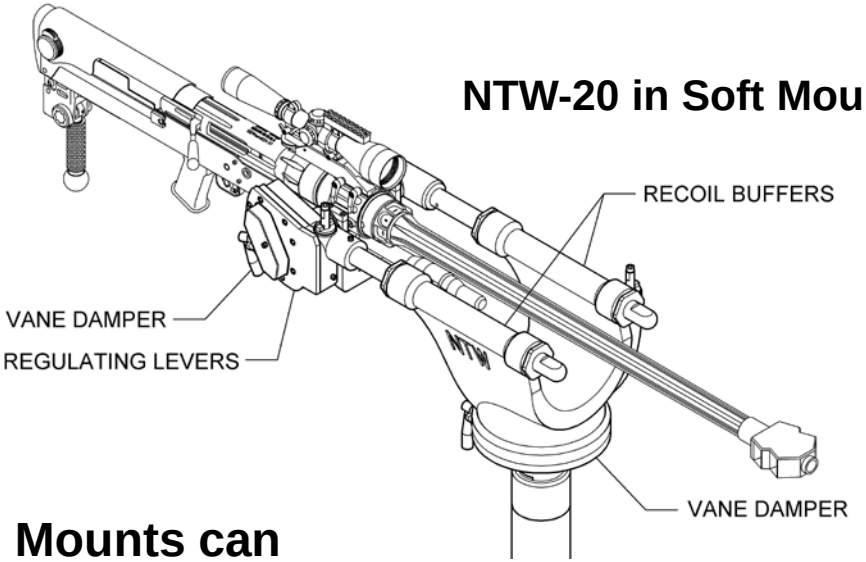
20mm AMR – New Use for Unused Ammo

The Below Chart is an example of how Weapon Systems can be compared using a Matrix – (%'s only estimated). Colors (Red/Amber/Green) would be used given requirement based MOE % ranges. A 60%+ effective (1-3 shots) 20mm AMR at 35 pounds capable of delivering perhaps 20 rounds in 2 minutes @ 2 MOA, could prove highly effective & efficient versus alternatives. Machine Guns / Mortars / Artillery / TOW / M3 Carl Gustav. etc. could also be added.

MOE / MOP One Shot	.300 Win Mag	MK15 w/ MK211	AMR 20mm HEI	Shoulder GL 40mm HEDP	JDAM "smart-bomb"	Hellfire	Javelin
Stop Vehicle/ Boat (Mobility Kill)	5%	25%	75%	60-80%	100%	100%	100%
Incapacitate Driver	15%	25%	75%	60-80%	100%	100%	100%
Detonate on Board Explosives	1%	30%	75%	60-80%	100%	100%	100%
Range	1200m	1500m	2000m	2000m	NA	3000m+	2000m
Accuracy / ES	1.5 moa	2 moa	2 moa	8 moa	10 m	3 m	3 m
TOF to 1500m	3 s	2.9 s	3.2 s	11.4 s	~30 s	~12 s	~10 s
Round Weight	1/10 lb	1/3 lb	0.57 lb	0.75 lb	500 lbs	100 lbs	35 lbs
System Weight	16 lbs	28 lbs	35 lbs	40 lbs	500 lbs	100 lbs	50 lbs
SOF Materiel Targets (typical)	1%	40%	75%	85%	100%	100%	100%
Cost per Shot	$ 1	$12	$15	$20-30	$10K	$60K	$80K

20mm AMR – New Use for Unused Ammo

NTW-20 Bipod



NTW-20 in Soft Mount

Mounts can remove nearly all Felt Recoil

NTW-20 bipod digs in and transfers a portion of recoil energy into the ground when prone. Adding a spiked rear monopod – forming a reversed tripod- could also help reduce felt recoil considerably.

Navy MK 125 Tripod at 7 lbs (alum.) vs. original steel M122 at 15 lbs.

20mm AMR – New Use for Unused Ammo

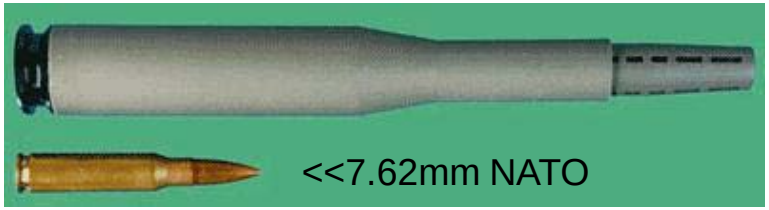
Advanced AMR Concepts with Recoil Management

Steyr IWS 2000 15.2mm @ 39.5 lbs

HK WSG 2000 9X90mm MEN @ 17.6 lbs (assumed w/o fire control included)

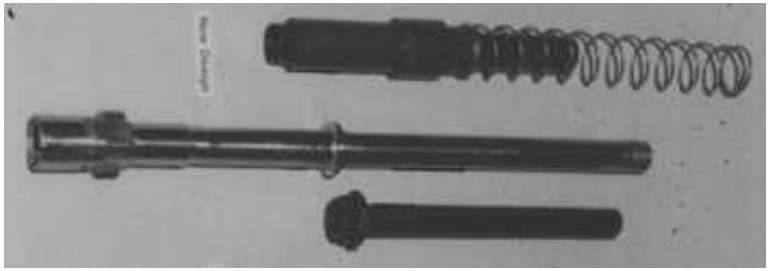
.50 BMG left 9X90mm ctr.

Long Recoil Operation – Barrel recoils in a Hydro-Pneumatic Sleeve. System also includes a Howitzer style Muzzle Brake. This Smoothbore System fired a sub-caliber 308 grain Tungsten Dart @ over 4700 fps. Barrel recoiled nearly 10 inches to spread energy transfer over time.



Projectile Weight with Sabot is 540 grains

This HK system did not need a muzzle brake to have only 5.29 lb-sec of recoil impulse. It used a hydro-mechanical long recoil mech. - like the HK - CAW system shown below.

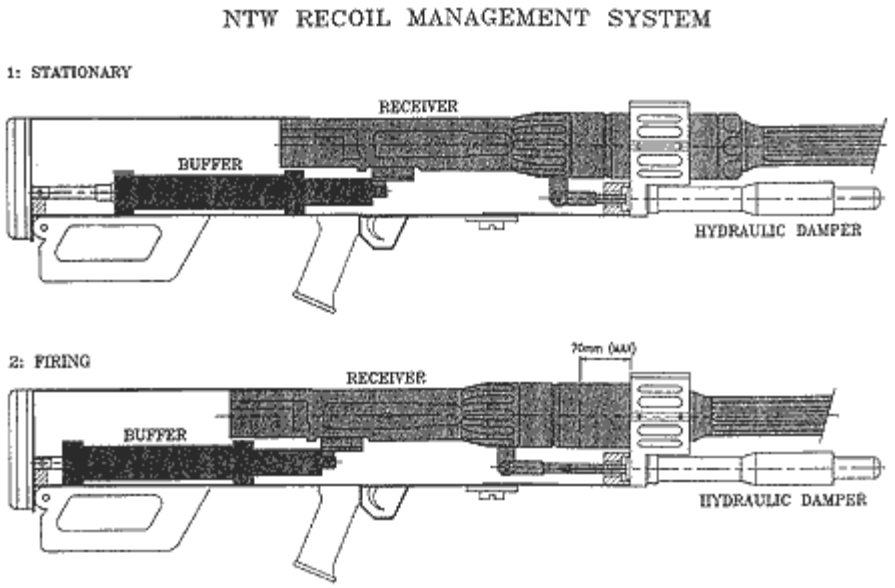


20mm AMR – New Use for Unused Ammo

Undesirable Recoil Handling Technologies would include anything adding mass inefficiently:

Use of rearward venting (RT-20) or counter-mass (Davis Gun), which limits system versatility (avoid).

Use of an "out of battery" firing system with mass moving forward prior to and during primer ignition, which would tend to degrade accuracy potential (use as last resort).



V Below is Rifle "Free" Bench Velocity

MK 15 Free Recoil: (V=8.44 fps)
31.2 ft-lbs KE / 7.4 lb-sec Impulse
Peak Shoulder Force = 230 lbs

NTW-20 Free Recoil: (V=10 fps)
109 ft-lbs KE / 22 lb-sec Impulse
Peak Shoulder Force = 140 lbs

<u>Spreading Recoil Transfer Over Time</u> is key to decreasing Felt Recoil by lowering Peak Shoulder Force, which in turn can allow for a lighter System Overall Weight, necessary for a Highly Mobile AMR. The ideal situation is "Constant Recoil" where no "Bottoming" occurs.

Comparative "Free Recoil" Data Table

Weapon System	Cartridge	System Wt. (lbs)	Bullet (grains)	Muzzle Vel. (fps)	Powder (grains)	Bullet KE (ft-lbs)	Recoil Vel. (fps)	Recoil KE (ft-lbs)	Recoil Impulse (lb-sec)	Recoil Data Source
Rem870 12 gage	#4 buck						21.60	50.70	4.69	Pendulum Test 1987
Rem870 12 gage	#4 buck	8	600	1250	27	2079.64	14.21	25.07	3.53	Calc. K=1.35
M16A2	5.56mm	8	62	3100	26	1321.69	5.38	3.59	1.34	Calc. K=1.35
M14 K=1.35	7.62mm	9.5	147	2800	46	2556.52	8.80	11.43	2.60	Calc. K=1.35
M14 Pendulum	7.62mm	9.5	147	2800	46	2556.20	8.80	11.50	2.60	Pendulum Test 1989
M14 Crane Brake	7.62mm	9.6	147	2800	46	2556.20	6.00	5.65	1.87	Pendulum Test 1989
M14 Crane Brake	7.62mm	% Reduction in Data Element Due to Brake >>					32%	51%	28%	Pendulum Test 1989
.338-.416 RAP	.338-416	15.9	250	2950	95	4826.14	10.06	25.09	4.99	Pendulum Test Crane
.338-.416 K=1.35	.338-416	15.9	250	2950	95	4826.14	10.03	24.82	4.95	Calc. K=1.35
Win Mag Sniper	.300WM	13.9	190	2950	72	3667.87	8.76	16.64	3.80	Crane Pendulum Test
Win Mag Sniper	.300WM	13.9	190	2950	72	3667.87	8.71	16.37	3.76	Calc. K=1.35
Win Mag (calc.)	.300WM	13.9	190	2950	72	3667.87	7.39	11.78	3.19	www recoil calc.
Win Mag K=1.75	.300WM	13.9	190	2950	72	3667.87	9.58	19.81	4.14	TOP 3-2-504 calc.
MK 13 MOD 5	.300WM	16	190	2950	72	3667.87	7.20	12.73	3.58	Crane Accel. Shoulder
MK 13 MOD 5	.300WM	16	190	2950	72	3667.87	7.56	14.22	3.76	Calc. K=1.35
T-Gewehr M1918	13.2X92SR	41	795	2550	210	11467.36	9.58	58.46	12.20	Calc. K=1.35
Boys .55 cal ATR	13.9X99B	36	735	2600	225	11021.74	10.72	64.21	11.98	Calc. K=1.35
MK 15 MOD 0	.50 BMG	28.2	660	2750	235	11071.98	13.61	81.16	11.92	Calc. K=1.35
Russian PTRD	14.5X114	38	990	3250	470	23196.26	19.85	232.46	23.42	Calc. K=1.35
NTW 20	20X110	70	2030	2600	490	30440.99	14.28	221.69	31.05	Calc. K=1.35
20mm RT-20	20X110	43.4	2030	2500	490	28144.41	22.15	330.60	29.85	Calc. K=1.35
Solothurn S18-1000	20X138B	118	2270	2725	570	37391.68	10.03	184.24	36.75	Calc. K=1.35
Lahti L-39	20X138B	109	2270	2650	570	35361.75	10.56	188.62	35.74	Calc. K=1.35
Note: Most calculated data is from "Winchester" equations using K=1.35 found to correlate well with prior NSWC Crane Pendulum Test Data										
(TOP 3-2-504 uses same formula but with K=1.75 - gas velocity factor - predicting higher results)										

As seen with "M14 Crane Brake" above – Muzzle Brake Recoil Reduction is not included in any of the calculated recoil characteristics (counter recoil tube effect for the RT-20 also not included). Even if a particular system had a 60% KE reducing brake, several systems have been fielded with over the U.S. 60 ft-lb limit for free recoil energy. PTRD also has a long recoil mech. (even though single shot).

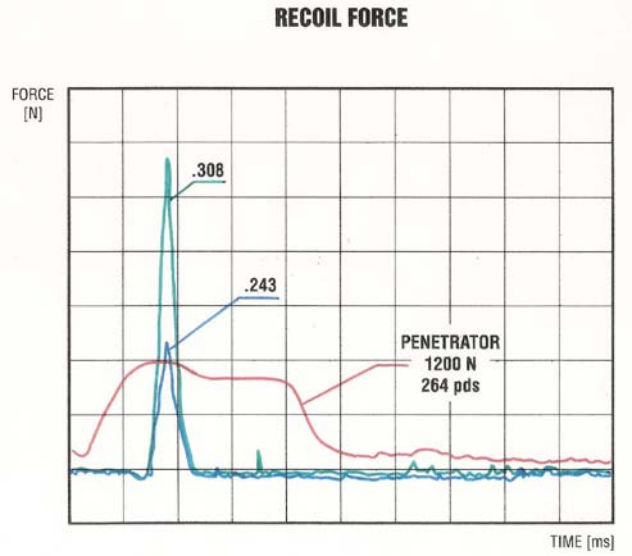
20mm AMR – New Use for Unused Ammo

A 20mm AMR System Configuration Optimized for Lightest Practical Weight with Long “Action Travel” and Cannon Style Breech (compact and rapidly reloaded by team mate) should be considered. Barrel length could be reduced to balance weight & range. Light Weight / High Strength Materials would be combined with a mix of Recoil Attenuation Technologies:

- Muzzle Device – Try to Combine Blast and Flash Reduction with Recoil Compensation / Brake Effects – Balanced Device.
- Hydraulic / Magneto-Rheological Damping System – Integrate into design to absorb some energy and slow the energy transfer to shooter / mount – be aware of any temperature sensitivity issues.
- Pneumatic Damping / Spring Buffering – Per Ron Sugg 1994 Patent Concepts. Spread Recoil Energy over large time duration and store some using the spring for release over more time (long recoil effect).
- Friction or Magnetic Braking – Sugg 1994 Patent includes Friction. Eddy Current Braking (using permanent magnet) could also be applied.
- Spiked Bipod & Rear Monopod plus Mounting Capabilities.

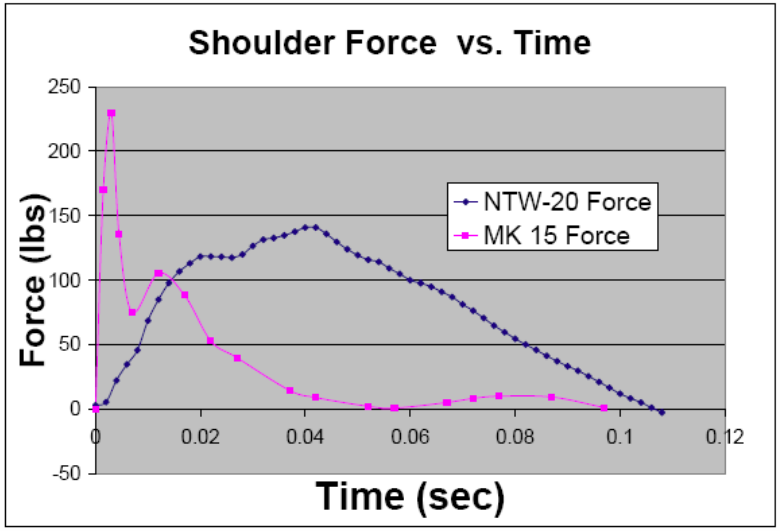
20mm AMR – New Use for Unused Ammo

Recoil Force / Acceleration, and High Speed Video Test Setups



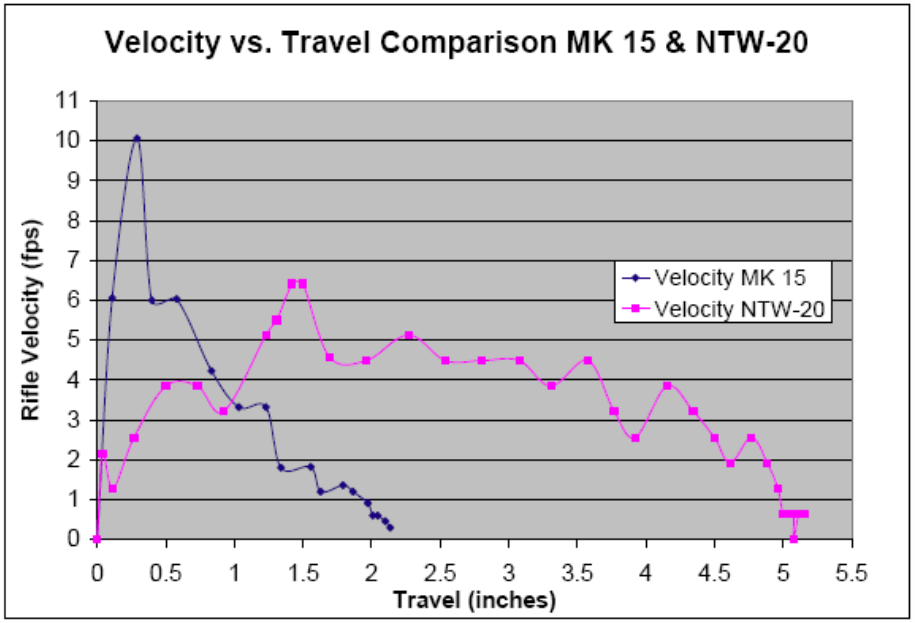
<< Steyr IWS 2000 Recoil Force Compared to .308 Win. and .243 Win.

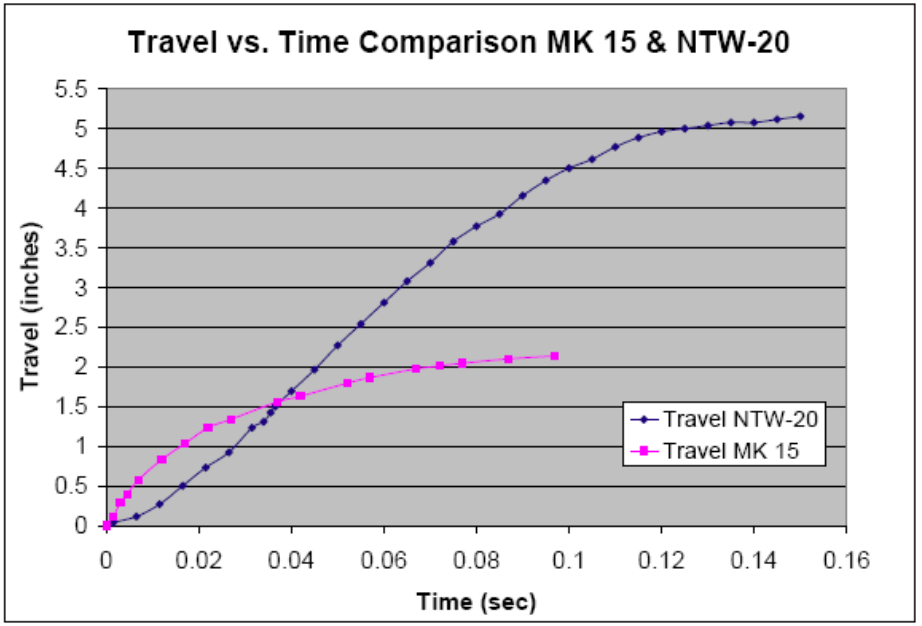
MK 15 versus NTW-20 Force >>



20mm AMR – New Use for Unused Ammo

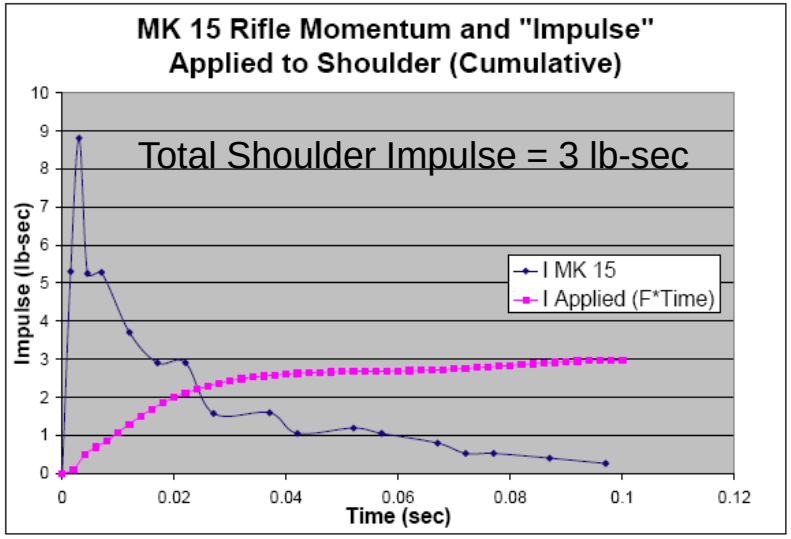
- **Extending Recoil Duration by Storing Energy with Spring and Damping with Hydraulics Reduces Felt Recoil by Reducing the Peak Force Felt by the Shooter.**





Peak Forces from prior slide plot occur at approx. 0.5 inches and .0045 sec for MK 15 @230 lbs and at 1.5 inches and .045 sec for NTW-20 @ 140 lbs. Also notice the "effective" shoulder fired velocity (post muzzle brake effect) is 6 fps for MK 15 and only 6.4 fps for the NTW-20. The significant momentum of the NTW-20 along with the return of stored energy from its buffer spring result in more than 2 times the travel (at shooting bench) compared to the MK 15.

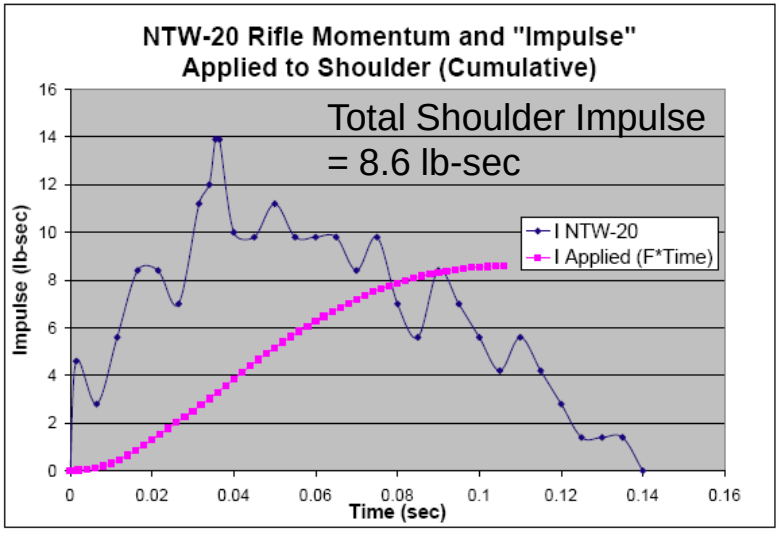
20mm AMR – New Use for Unused Ammo

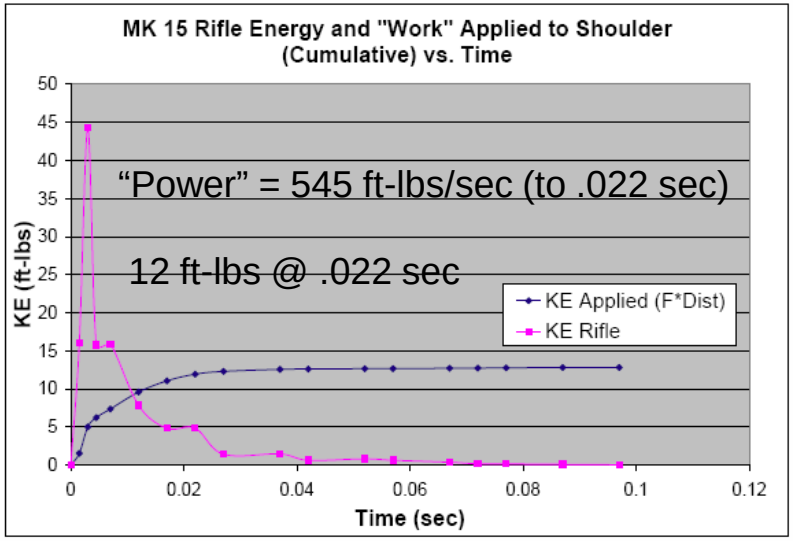


Impulse – << MK 15 NTW-20 >>

Rifle (M*V) & Shooter (F*T)

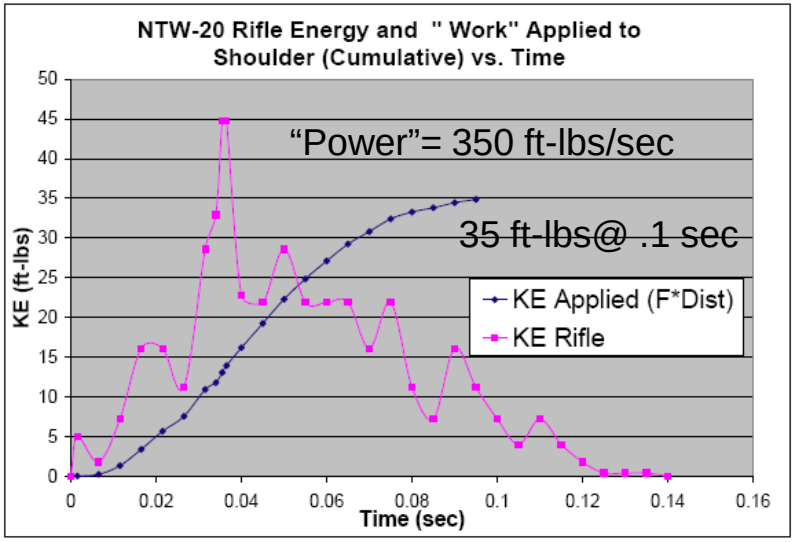
Both apply @ 100 lb-sec/sec max rate





Energy – << MK 15 NTW-20 >>

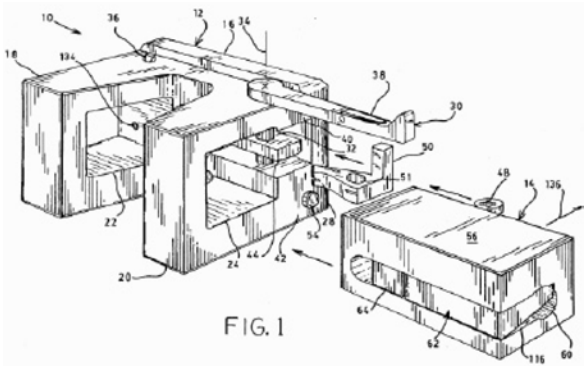
Rifle & Shooter (F*D)

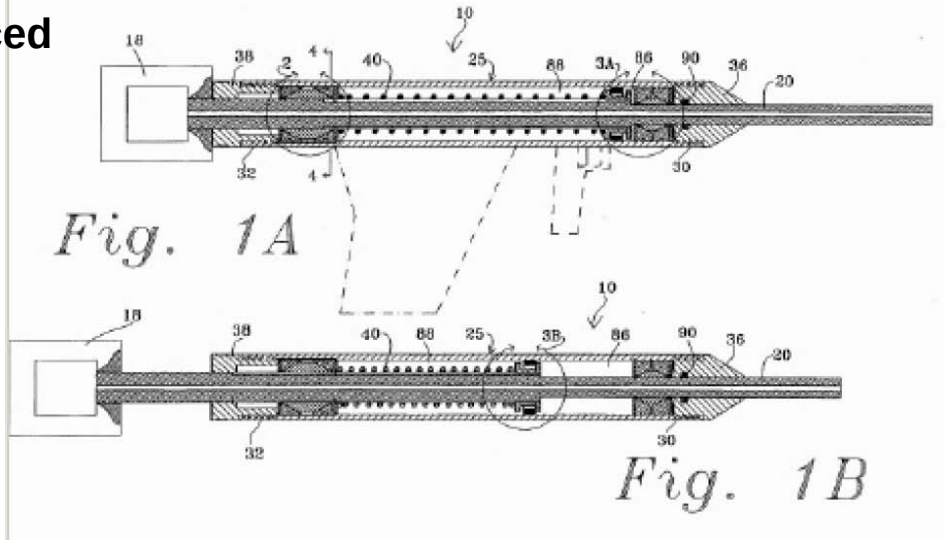


Sugg Breech & Recoil Mechanisms

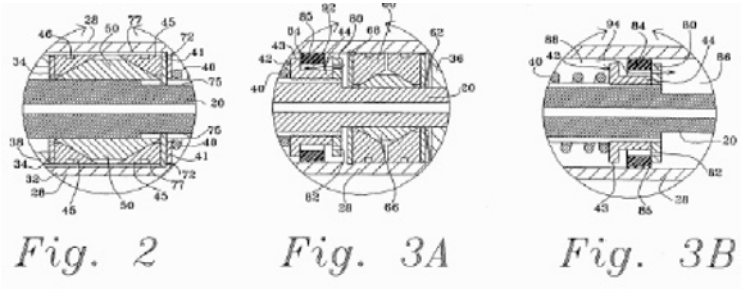
Compact Side Open – Auto Extract / Eject Design

Sugg .50 Action – Several Rifles Produced



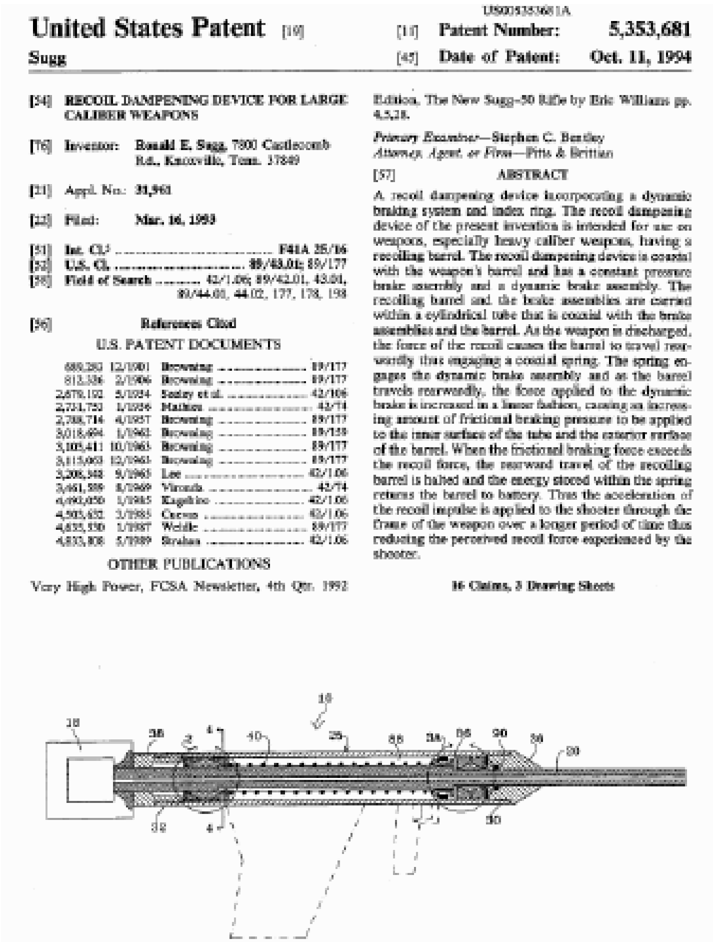


Combines Spring / Friction and Pneumatic Damping to Extend Recoil Pulse - a "Constant Recoil" System



Sugg Recoil Mechanism Patent

Combines Spring / Friction and Pneumatic Damping



US005353681A

United States Patent [19]
Sugg

[11] **Patent Number:** **5,353,681**
[45] **Date of Patent:** **Oct. 11, 1994**

[54] **RECOIL DAMPENING DEVICE FOR LARGE CALIBER WEAPONS**

[76] Inventor: **Ronald E. Sugg**, 7800 Castlecomb Rd., Knoxville, Tenn. 37849

[21] Appl. No.: **31,961**

[22] Filed: **Mar. 16, 1993**

[51] **Int. Cl.**[5] **F41A 25/16**
[52] **U.S. Cl.** **89/43.01**; 89/177
[58] **Field of Search** 42/1.06; 89/42.01, 43.01, 89/44.01, 44.02, 177, 178, 198

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Primary Examiner—Stephen C. Bentley
Attorney, Agent, or Firm—Pitts & Brittian

[57] **ABSTRACT**

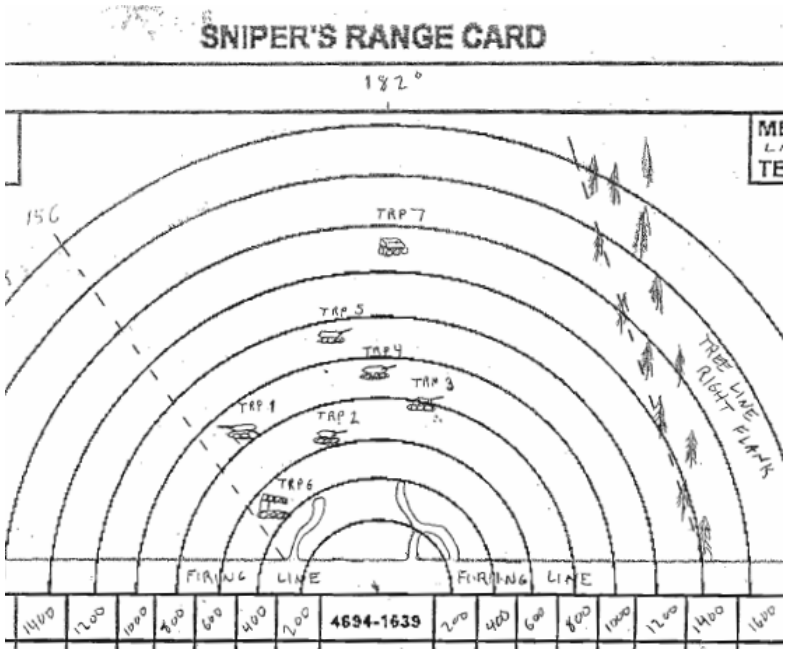
A recoil dampening device incorporating a dynamic braking system and index ring. The recoil dampening device of the present invention is intended for use on weapons, especially heavy caliber weapons, having a recoiling barrel. The recoil dampening device is coaxial with the weapon's barrel and has a constant pressure brake assembly and a dynamic brake assembly. The recoiling barrel and the brake assemblies are carried within a cylindrical tube that is coaxial with the brake assemblies and the barrel. As the weapon is discharged, the force of the recoil causes the barrel to travel rearwardly thus engaging a coaxial spring. The spring engages the dynamic brake assembly and as the barrel travels rearwardly, the force applied to the dynamic brake is increased in a linear fashion, causing an increasing amount of frictional braking pressure to be applied to the inner surface of the tube and the exterior surface of the barrel. When the frictional braking force exceeds the recoil force, the rearward travel of the recoiling barrel is halted and the energy stored within the spring returns the barrel to battery. Thus the acceleration of the recoil impulse is applied to the shooter through the frame of the weapon over a longer period of time thus reducing the perceived recoil force experienced by the shooter.

16 Claims, 3 Drawing Sheets

Photo Above - Sugg Rifle Action in "Recoiling" Status

Friction Braking Increases with Spring Compression while Pneumatic Braking is Greatest Initially at Highest Action Velocity.

20mm AMR – New Use for Unused Ammo



- **20mm Shoulder Fired Target Engagement – NTW-20X110HS**
  - **Fixed power optic on NTW-20 has range dial built into QD mount.**
  - **Mount for SAGEM Thermal Sight is available.**
  - **Able to consistently hit M113 APC at 1500 yards (APT & HEI).**
  - **Time of Flight to 1400m (1531 yds) is 2.9 sec @1033 fps Rem. Velocity.**
  - **DENEL advertised Operational Range at 1750 meters (1914 yds).**

20mm AMR – New Use for Unused Ammo

- **Conclusions**
  - **Available 20X110mm Ammunition is Effective Against Material Targets – More Damage and at Longer Range than for .50 Caliber BMG.**
  - **20mm AMR Accuracy can equal .50 Caliber with existing "free" ammo.**
  - **Currently available 20mm Rifles could be used for Area Denial & Over-Watch / Defense from Fixed Positions and Vehicles.**
  - **A 20X110mm chambered rifle could be converted to 20X102mm electric primed in the future to allow for a wider selection of ammunition.**
  - **While a .338 chambering can achieve 1500m+ anti-personnel capabilities, these lack the payload to be effective against material targets. Thus, a rifle focused on the Material Target Set is highly desirable.**
  - **The combination of standoff (1500m+), Accuracy, and Destructive Performance of a 20mm AMR could allow for decisive neutralization of many High Value Material Targets.**
  - **The increased proliferation of Advanced Mobile Missiles - to include Medium Range Theatre Ballistic Missiles, Long Range Surface to Air Missiles, and Anti Ship Cruise Missiles - is of great concern. (all prime 20mm AMR targets).**
  - **The challenge of developing a system light enough for full SOF mobility and suitable felt recoil can be overcome through efficient design with use of modern materials and recoil handling technologies.**

20mm AMR – New Use for Unused Ammo

20mm AMR – New Use for Unused Ammo

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