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CMAT Control # 712
1999279-0000010

AD E 425 033

TANK AMMO SECTION REPORT NO. 107

#35

A COMPARISON OF THE ADVANTAGES AND DISADVANTAGES OF DEPLETED URANIUM AND TUNGSTEN ALLOY AS PENETRATOR MATERIALS

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CLEARED
FOR OPEN PUBLICATION

MAR 8 2000 12

DIRECTORATE FOR FREEDOM OF INFORMATION
AND SECURITY REVIEW
DEPARTMENT OF DEFENSE

JUNE 1980

RETURNED ON:

1/18/85

DAVIES

U.S. ARMY ARMAMENT RESEARCH
AND DEVELOPMENT COMMAND
SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

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[redacted] Classified by: CDR, ARRADCOM
Declassify on: July 1986

UNCLASSIFIED

U 1/167/142 (3)

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00-S-0570

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A COMPARISON OF THE ADVANTAGES AND DISADVANTAGES OF DEPLETED URANIUM AND TUNGSTEN ALLOY AS PENETRATOR MATERIALS (U)

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DECLASSIFY ON: 31 JULY 1986

[redacted]

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(U) SUMMARY (U)

(U) Recent development and production experience have shown that DU and WA are excellent materials for application in anti-tank projectiles. Each material can be processed to yield unique combinations of mechanical properties that can be established to satisfy the environment that each individual cartridge will experience.

(U) From a producibility standpoint, each material has its advantages and disadvantages. If a review were conducted at this point in time, the reviewer would tend to conclude that the producibility of the materials is essentially equal. However, since one of the major disadvantages of DU is the lack of production experience, it is likely that DU may eventually be considered more producible than WA once that experience is acquired.

(U) A cost comparison of equivalent DU and WA cartridges (the XM774 was used for estimating purposes) was conducted. If the life cycle of a large quantity is considered, the unit cost of each version was found to be approximately equal (the DU cartridge cost was one percent cheaper).

(U) Considering the dramatic difference in raw material costs - DU being approximately ten to thirty times cheaper - this result warrants further explanation. A main contributer to the cost parity is the fact that the comparison was conducted on a full loaded and lot accepted cartridge where the cost of the penetrator represents a maximum of one-third of the overall cost. Secondly, a life-cycle analysis considers demiliterization cost or value. The WA core will have a significant scrap value while the DU core will require a nominal cost for disposal. If the acquisition cost is considered, the DU cartridge is found to be 7% cheaper, due entirely to the 44% cheaper DU penetrator cost.

(U) It is likely that the decision maker would be influenced more by a multi-million dollar present cost difference than by a theoretical reimbursement in 20 - 30 years. The reality of a significant acquisition cost difference gives the DU a favorable balance.

(U) When the inherent penetration performance of the two materials are compared, the DU is not only a superior armor penetrator, but in fact is required in order to penetrate modern targets with modern ammunition.

(U) Finally, if the safety, environmental and deployment implications of the two materials are considered, it becomes readily apparent that WA can be treated similar to any other metal, while DU requires

a host of special considerations.

(U) Little, if any, special controls are required during manufacture and testing of WA, while each step in the deployment chain must be analyzed from a worst case safety and environmental standpoint for the DU. The 105mm XM774, the Army's first anti-tank projectile utilizing DU, served as the standard bearer. It is becoming apparent that the precedents in terms of special studies and tests set by the XM774 will apply to the DU projectiles that follow, and that the material acquisition system will be more adaptable to cartridges utilizing DU in the future.

(U) If an arbitrary tabulation of the advantages and disadvantages of DU and WA were formulated, it might take the form of Table 1. The inherent superior performance of DU over WA, combined with the minor cost advantage more that compensates for the safety and environment requirements and gives the DU an overall advantage. As a result of production experience with both materials, the margin of that advantage is not as wide as previously expected.

Table 1 - (U) Summary of Advantages and Disadvantages of DU and WA as Penetrator Materials

	DU	WA
Producibility	Even	Even
Cost	+	-
Safety, Environmental and Deployment	-	+
Performance	++	-
Overall	+	-

II. (C) Background (U)

A. [redacted] Tungsten (U)

(U) During the late 1950's the primary material utilized for kinetic energy, armor piercing projectiles was tungsten carbide. Its extreme hardness (Rc 55+), although difficult to machine or form, combined with its relatively high density (approximately 13 gm/cc) allowed it to be efficiently packaged in a small volume and provide a quantum jump in penetration performance against single plate targets over its nearest competitor, high carbon steel. The M392 (developed by the United Kingdom) was a prime example.

[redacted] With the advent of spaced armor targets, such as NATO medium double and heavy triple (Circa 1960) it was quickly discovered that a tungsten carbide penetrator was susceptible to break-up against even a thin (e.g. 10mm) front plate and could be rendered ineffective against the remaining plates in a spaced array.

(U) The United Kingdom was one of the first to respond to this problem by developing the L52 (M728) which replaced the tungsten carbide core and cap with a 93 percent tungsten/7percent binder tungsten alloy (WA) of similar geometry but heavier due to the higher density of the WA (17 gm/cc). A parallel effort in the US was conducted during the same 1965 - 1972 time frame, the 152mm XM578 Cartridge Development Program to support the MBT-70 tank.[1-5] The XM578 Program selected a 97.5% tungsten/2.5% binder tungsten alloy (density of 18.5 gm/cc). The core was encased in a tapered maraging steel jacket to provide the necessary inbore support due to the high acceleration environment of the 152mm Gun.

(U) With the termination of the MBT-70 Program and the initiation of the XM-1 Tank Program, a need was expressed for a modern 105mm Anti-tank, Kinetic Energy Projectile. Picatinny Arsenal responded to this tasking by utilizing the technology gained in the 152mm Program - specifically the subprojectile - and adapting it to the 105mm Gun by means of a saddle sabot.[6] The 97.5% tungsten alloy was again selected from all available candidate materials. However, a new process of swaging, or radial cold working was developed by Picatinny that resulted in improved core mechanical properties and substantially improved penetration performance.[7]

(U) The direct adaption of the XM578 sheath/core assembly was known to be less efficient than a monolithic tungsten alloy core of the same weight (and smaller diameter). The first steps in this evolutionary process were taken with the XM735E1 and E2 where the volume of tungsten was increased at the expense of the maraging steel. The final research and development design of the XM735, that was type classified M735, contained approximately one pound more WA penetrator than did the original XM735 design.[7]

(U) A parametric study was conducted in FY73-74 to characterize the performance capability of a family of constant weight (eight pound) penetrators manufactured from both 97.5% tungsten alloy and depleted uranium alloyed with 3/4 weight percent titanium.[8] The following design features were considered:

Core Dia (mm)	Core Weight (lb)	Core L/D
32	8.0	10.7
28	8.0	13.3
24	8.0	15.5

[redacted] These penetrators were evaluated against single and triple targets. The 28mm was chosen as the most attractive candidate for further development, and it eventually became the XM774 - originally with both tungsten alloy (WA) and depleted uranium (DU). The 24mm diameter proved the most efficient against spaced armor arrays and only marginally superior versus monolithic targets. Given the preponderance of monolithic targets in that pre-special armor era, coupled with the difficulty envisioned to adapt the early generation sabot designs to support a very long, thin core, 28mm was an appropriate choice. A second exploratory development program was conducted during FY76 wherein a 26mm midpoint was evaluated and determined to be superior (in both WA and DU) to the parent 28mm. The configuration of the XM774 was formally changed to 26mm, as it remains today.[9]

[redacted] When the final series of Tripartite Trials - Growth Potential firings were scheduled for December 1977, the Ballistic Research Laboratories embarked on a program to further exploit the capabilities of the 105mm M68 Gun.[10] Their review of the Picatinny Arsenal study convinced them that the original 24mm geometry, modified to increase the L/D from 15.5 to 18.0, could be a functional, superior item. This basic design later evolved into the penetrator for the 105mm XM833 and the 120mm XM829.

(U) Testing of the tungsten version of the XM829, in this case the 90% alloy, fired in the July 1979 Germany trials, demonstrated that despite occasional core failure at high temperature, impressive penetration performance was obtainable.[11]

B. [redacted] Depleted Uranium (U)

(U) The availability of depleted uranium (DU) increased during the 1950's to the point where its application could be considered for non-Atomic Energy Commission - now Department of Energy (DOE) - programs.[12]

(U) Early reactor designs required DU rods as fuel sources. Several manufacturing facilities were constructed to satisfy the high tonnage requirements of DU rods necessary for the production of weapons material and the fledgling commercial electrical generation industry. As the second generation of reactors were installed in the late 1950 - early 1960's, reactors that did not use DU as a fuel, both material and facilities became available for alternate uses.[12]

(U) All three armed services began to experiment with the material for various applications. The initial Army work was centered at the US Army Material and Mechanics Research Center, Watertown, MA. Considerable research was conducted on alloy development as well as mechanical and chemical properties of various candidate compositions for military use.

(U) One of the Army's first applications of DU was as a ballistic weight in the spotting round for the Davy Crockett missile warhead. A four alloy "U'Quad" was used for experimental tests on the 105 and 120mm Delta APFSDS Program in the early 1960's. The Delta Program (which evenutally evolved into the 152mm XM578) chose tungsten alloy as a penetrator material.[13]

[redacted] The DU candidates at that time had two generic problems: the newness and complexity of the various alloys led to lot-to-lot inconsistency, and a direct comparison of DU and WA showed the WA to be at least equal in penetration performance. Given the target requirement of that time frame (six inches of armor at 60^{o}), the equal performance of DU and WA is understandable.

(U) The Army's lack of continuing interest in end item DU development during the 1960's was not typical of other services. The development of the Navy's PHALANX ship fired, anti-missile projectile initially considered a wide spectrum of candidate materials and eventually selected the U-2Mo alloy. The Air Force (AF) GAU-8A Program, a small, rapid fire projectile designed to attack the top of a tank when fired from the A-10 aircraft, selected U-3/4Ti.

(U) The AF GAU-8A completed development in the mid-1970's and was deployed to NATO forces in Europe in 1978. The PHALANX Program experienced a series of administration and funding problems and production was delayed until 1979.

[redacted] The Army's interest in DU was reactivated in 1973. In an effort to fully exploit the capabilities of the 105mm M68 Tank Gun, all design options were reconsidered. Several factors had changed since the Army's earlier experiments with DU. The requirement to defeat a heavy, monolithic target at nominal ranges had evolved into a requirement to defeat a wide spectrum of NATO standard targets including a heavy triple spaced array, and hints of the development of much

failed
152

more complex and difficult target descriptions loomed on the horizon. The development of DU alloying and manufacturing techniques had also advanced, particularly in the Department of Energy (DOE) laboratories.

early
XM1 Tank
in early

(U) The 105mm "Growth Potential" Program, the Exploratory Development Program that produced the XM774[9], considered all the options and requirements and selected U-3/4 Ti as the penetrator material. It was determined, based on field testing, that the use of DU was necessary to satisfy the performance requirements.

(U) The XM774 established a precedent for tank ammunition such that all major development items that have followed (e.g. 105mm XM833 and 120mm, XM829) have selected DU.

(U) A summary of the historical evolution of these materials for use in munitions is shown in Table 2.

Table 2 - (U) Historical Evolution of Tungsten Alloy and Depleted Uranium in Conventional Munitions

HISTORICAL EVOLUTION [redacted]

TUNGSTEN

TIME FRAME	MATERIAL	TYPE
1940 - 1950	Steel	AP Shot
1950 - 1960	WC	APDS
1960 - 1975	WA	APDS
1975 - 1980	WA - Swaged	APFSDS

DEPLETED URANIUM

TIME FRAME	MATERIAL	TYPE
1950 - 1965	U	Experimental
1965 - 1975	U-TI, QUINT QUAD, MO	Small Cal
1965 - 1975	U-TI, QUINT QUAD, MO	KE Experimental
1975 - 1980	U-3/4 TI	APFSDS

WC = Tungsten Carbide [redacted]
WA = Tungsten Alloy
U = Uranium (general)
TI = Titanium Alloy
QUINT = five alloying elements
QUAD = four alloying elements
AP = Armor piercing
APDS = Armor piercing, discarding sabot
APFSDS = Armor piercing, fin stabilized, discarding sabot

III. (U) Manufacture and Producibility (U)

(U) Both DU and WA offer the penetrator designer and the metallurgist a wide range of physical and mechanical properties from which to choose. Unlike more conventional metals, these alloys can be processed to yield high strength as well as high toughness and high ductility that are not simultaneously achievable in other alloys. While both alloy systems require tight process controls,[14] each has distinct differences in terms of sensitivity to variation during high volume production of penetrators. To date, tungsten alloys have been produced in large quantities; experience with DU, manufactured to the stringent XM774 requirements, has yet to be demonstrated. The outline of each manufacturing process that follows will serve to highlight some of these differences.

(U) Manufacture of the tungsten alloy penetrator starts with ammonia paratungstate (APT) and elemental powders of iron and nickel. The APT is oxidized and then reduced to elemental powdered tungsten. The powders are then blended with the proper proportions of each powder and subsequently hydrostatically pressed to cylindrical preform. Each pre-form is then sintered in a hydrogen atmosphere at a temperature near the melting point of the alloy. The sintered rod, in some applications, undergoes optional heat treatment. The sintered bar is then reduced mechanically to a smaller diameter by a radial swaging machine. Reductions in area between 12% and 25% may be appropriate depending on the alloy and the penetrator design. The swaged blank is then final machined. The critical process steps, once given a fully developed process, are sintering, heat treatment and swaging. The penetrator performance appears to be most sensitive to the swaging conditions.

Table 3 - (U) Physical Properties of DU & WA

	TUNGSTEN ALLOY		DEPLETED URANIUM	
	LOW	HIGH	LOW	HIGH
Tensile Strength (kpsi)	130	215	165	220
Yield Strength (kpsi)	75	200	65	200
Elongation (%)	1.0	35.0	5.0	32.0
Fracture toughness @ -50°F (K_{1c})	-	60,000	27,000	43,000
Modulus	40	55	16	24
Hardness (R_c)	26	48	36	58

(U) Depleted Uranium, typically begins in the core suppliers plants as UF_4 (green salt). The UF_4 is blended together with magnesium and heated until a spontaneous exotheric reaction begins which yields a uranium derby and a by-product of magnesium floride. The derby is charged into a vacuum furnace with titanium (0.75%), melted and cast into cylindrical ingots. The ingots are then extruded or rolled into a rod. A rod is cut into penetrator lengths and heated in a vacuum furnace to a solutioning temperature. The bars are then water quenched and aged before final machining.

(U) Some observations on the important differences between WA and DU include the factor of approximately two greater in the elastic modulus of WA over DU. This extra stiffness is an advantage in the gun tube where bending or column failure of the forward, unsupported length of the penetrator could present a problem. However, it is generally believed that the low modulus of DU with its associated low velocity of stress wave propagation is a primary reason for its superior penetration performance.

(U) Another notable difference is the strain rate sensitivity of the DU as compared to WA. While DU strength changes very little as the rate of tensile test changes from 10^{-4}/sec to 10/sec; WA can exhibit a 30% increase in strength. Although both materials undergo a temperature transition, the ductility and toughness of WA does not appear to degrade as drastically as that of DU when tested at temperatures as low as -50^{o}F.

(U) Over the last five years improvements have been made in the mechanical properties of both WA and DU alloys. Typical ranges of mechanical properties are shown in Table 3. Because the WA is a metal matrix composite, it probably offers more areas for advancement or refinement in mechanical properties.

(U) Mass production of a penetrator item from either of these alloy systems has built-in advantages and disadvantages (Table 4). The primary advantages of WA are its ability to combine high dynamic strength with good low temperature toughness. This is further enhanced by a proven ability to achieve these conditions in a high volume production line environment. These advantages are somewhat tempered by the high initial cost of tungsten and the "myth" about the limit availability. While the cost to mine and refine tungsten ore is high because of low concentrations, there is an abundance of free world sources more than sufficient to meet all known or projected requirements, including penetrators.[15] Many of these significant tungsten reserves are located in the Northwest Territory of Canada. However, the US production capability to reduce the low grade ore is minimal.

(U) Each material has its own critical manufacturing areas (Table 5). Those associated with WA are the very narrow temperature range that must be maintained during the sintering process, the design of the cold work die, and the capacity of US industry to reduce tungsten ore into ammonia paratungstate. These critical areas have been successfully mastered in the production of the M735 WA Core; however, they require constant, careful attention.

Table 4 - (U) Some Advantages and Disadvantages in Production of DU and WA Penetrators

TUNGSTEN ALLOY		DEPLETED URANIUM	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
High Toughness (50% Higher) with High Strength	High Cost Raw Mat'l	Better Penetration Against Complex Targets	Handling Restrictions
Proven High Volume Production Facility	Myth of Limited Availability	Low Initial Costs of Mat'l	Restricted R&D, Production, Training Firings
More Potential on Technical Limits for Component	Never Quite Equals DU Penetration	Std Metallurgy of Quench & Age Alloy	No Proven High Volume Production, H20 Quench, Straightening
	Limited US Reduction Capability	Higher Ductility w/High Strength	More Reactive Metal
		Conventional Extrusion/Roll Process	Experience with High Quality, Ductile, Tough, Coated) Only in DOE
			Goes thru Temp Transition

Table 5 - (U) Critical Manufacturing Areas

Tungsten Alloy

Narrow Temp Range for Sintering
Cold Work Die Design
APT - US Capacity

Depleted Uranium

Plant Flow Dependent on One Critical Press or Roll Mill
Trace Element Sensitivity
Water Quench/Hardenability
Cold Straightening/Lot Variability

(U) Likewise, the manufacture of U-3/4 Ti has several critical process sets. The production flow of material is dependent on a single extrusion press or rolling mill. This heavy equipment represents a large initial capital investment which renders a back-up system unfeasible. A major mechanical breakdown of this machinery could shut down the production facility for an unacceptable length of time.

(U) The Army's demand for very high quality, high ductility DU penetrators has required the large volume producers to abandon their previous procedures and concentrate on the exacting specifications that tightly control chemical impurities, mechanical properties and imply the necessity for a vacuum solutionize and slow water quench. These specifications have been found to be workable as experience is acquired, but care and attention will be necessary throughout the manufacturing program.

IV. (U) Cost

(U) The cost of a pound of uranium hexafluoride (UF_4) can range from $.0125 to $2.50 depending on the quantity, vendor, type of procurement facility, means of transportation, and condition of delivery. Tungsten powder, in the somewhat equivalent state (ammonia paratungstate - APT) costs approximately $10 to $16 per pound. This tremendous difference in cost for raw material has fostered the notion that a concomitant cost differential would be evident in the production of penetrators. Recent production experience has shown this notion to be erroneous.

(U) A direct cost comparison of two items of ammunition is ofter difficult due to numerous changes in the time, quantity and ground rules associated with the hypothetical or actual procurement. For the purpose of this discussion, a procurement of 500,000 cartridges over a three year period was postulated. The 105mm XM774 was used as an example, with the latest (May 1980) cost figures used as a basis for projections. Three years of production experience with the M735 Tungsten Alloy Core and initial FY80 contracts for the XM774 Depleted Uranium Core influenced the estimates.

(U) In order to illustrate the effect that a WA vs DU penetrator has on unit price, the three costs are highlighted: the unit cost of a penetrator, the unit cost of a cartridge delivered to the field and the unit cost of a cartridge that has completed its lifecycle and has undergone demilitarization (has been scrapped).

(U) Using the above ground rules, an itemized cost comparison was formulated (Table 6). The procurement cost for the DU version is substantially lower than its WA counterpart. The $137 WA core cost is approximately 77% higher than the $77 DU core cost. When the balance of the costs necessary to assemble and ship a cartridge to the field are considered, the cost difference is tempered by the larger unit cost and the WA cost is 15% higher. The dollar difference would still be $30 million for this hypothetical procurement.

(U) When the full life cycle of the cartridge is considered, one must evaluate the demilitarization costs of each item. For the DU cartridge, the disassembly and disposal of the components represents a one to three dollar expense, the higher value resulting if the DU core contaminates the aluminum sabot assembly which would require contaminated disposal. Demilitarizaiton of the WA version would result in a profit due to the high scrap value of the WA. This large scrap differential has a major influence on the overall life cycle cost, bringing the WA version within one percent of the DU version.

(U) It is likely that the decision maker would be influenced more by a multi-million dollar present cost difference than by a theoretical reimbursement in 20 - 30 years. The reality of a large acquisition cost difference should give the DU a favorable balance.

Table 6 - (U) Itemized Cost Comparison for Procurement of XM774 DU and WA Cartridges

	CARTRIDGE WITH DU CORE LOW	CARTRIDGE WITH DU CORE HIGH	CARTRIDGE WITH WA CORE	HIGHER WA COST (%)
MPTS & ASSY	94.84	94.84	94.84	-
CORE	77.28	77.28	136.99	77%
LAP	144.48	144.48	144.48	-
EDSP	24.55	24.55	24.55	-
P&A	45.23	45.23	45.23	-
REF HDW	2.87	2.87	2.87	-
QA	1.08	1.08	1.08	-
ACQUISITION COST	390.33	390.33	450.04	15%
DISP. COST (SCRAP CREDIT)	1.10	2.98	(53.24)	-
LIFE CYCLE COST	391.43	393.31	396.80	1%

<u>ASSUMPTIONS</u>:
1. Constant FY80 $'s
2. Total quantity of 500,000 procured over three years.
3. High and low DU cost based on maximum and minimum disposal costs.

V. [redacted] Performance (U)

(U) For the purpose of this discussion, performance is considered analagous with ability to withstand gun launch and to penetrate armor targets. Both materials have very high densities and, when properly designed into high length-to-diameter cores, provide efficient penetration of thick, complex armors.

(U) The behavior and resulting performance of the two materials is distinctly different and is often dependent on the combination of mechanical properties chosen. Due to its lower ductility and higher modulus, the tungsten penetration tends to break into pieces in the nose area or along its length. If this phenomenon is countered by increasing the ductility of the rod, the result would be an inefficient penetrator due to mushrooming of the nose and/or severe bending. If improved performance against a specific target is desired, two basic options are available to the tungsten designer. The mechanical properties of the rod can be manipulated, or the front of the rod can be designed to include precurser penetrators, attenuators, preferential notches, etc. all in an attempt to mimimize breaking of the rod.

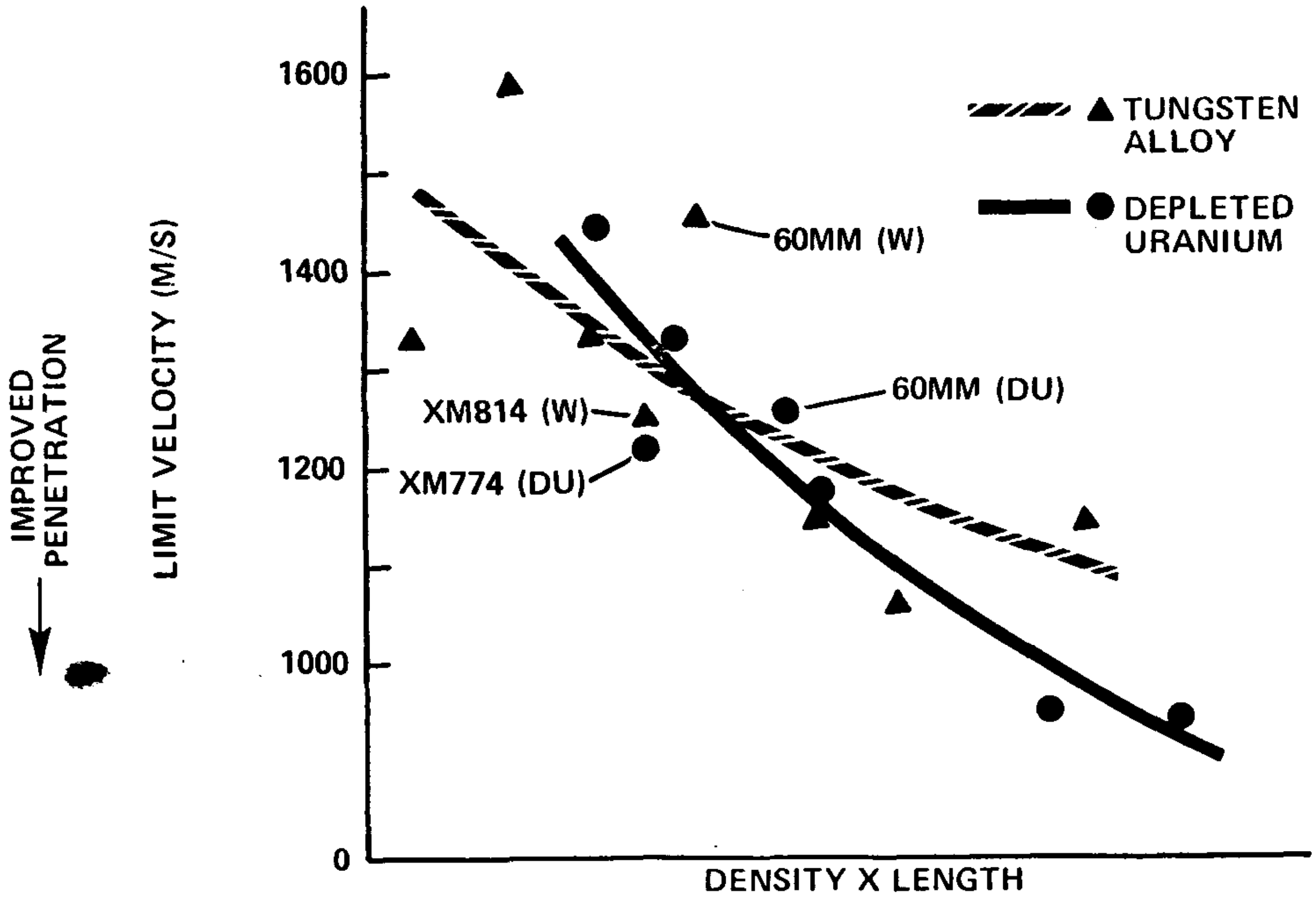
(U) The problems associated with the latter approach are that changes made to optimize performance versus a specific target tend to compromise performance versus other targets. Given the multitude of target arrays currently required, this task has become exceedingly difficult.

(U) The behavior of a DU penetrator attacking an armor array is noticeably different from that of its WA counterpart. The DU rod tends to "ablate" as it passes through armor. Its nose is worn away in relatively fine pieces while a reasonably efficient front cross section is constantly presented to the remainder of the target. Although minor bending of the rod may be observed, longitudinal breaking is not likely. This behavior is primarily attributed to the high duntility, high strength and low elastic modulus (e.g. sound speed) inherent in DU penetration.

[redacted] The performance differences between DU and WA penetrators is shown in Figures 1, 2 and 3. Figure 1 compares performance of the two materials when tested against the NATO Heavy Single Target. The lower limit velocity represents increased penetration. The graph shows that the advantages of DU are not manifested when attacking this target if the penetrator is low density, light and short. In fact, if the graphic representation of the rather scattered data is current, WA can outperform DU under those conditions. As the penetrator increases in density and length-to-diameter ratio, the DU version becomes increasingly more effective. With geometrics and materials typical of the 105mm XM833 and 120mm XM829 the superiority of DU becomes significant.

[redacted]

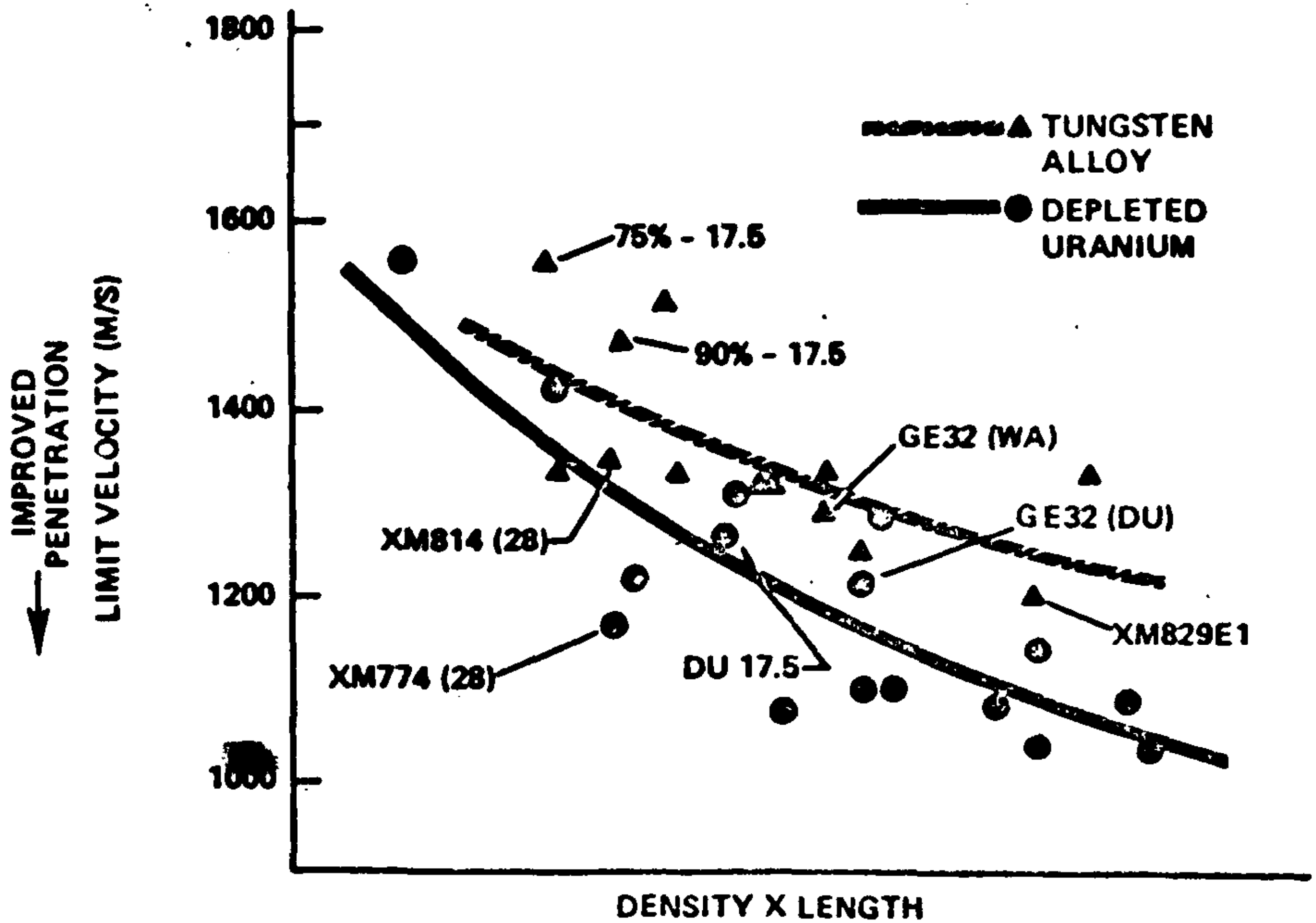
FIGURE 1. [redacted] PERFORMANCE OF VARIOUS DU AND WA PENETRATORS VERSUS THE NATO HEAVY SINGLE TARGET (U)



[redacted]

[redacted]

FIGURE 2. [redacted] PERFORMANCE OF VARIOUS DU AND WA PENETRATORS VERSUS THE NATO HEAVY TRIPLE TARGET (U)



[redacted]

[redacted] This trend is magnified as the target arrays become more complex. Figure 2 representing NATO Heavy Triple, shows that the DU outperforms the WA regardless of material or geometry of the penetrator. This trend is equally profound when these types of projectiles are evaluated against modern, special armor targets.

[redacted] The significance of this difference can be seen in Table 7 where the effective range of the XM833 and XM829 are shown for DU and WA for several postulated targets representative of current and future Soviet tanks. Though the difference in effective range between the materials is evident with the conventional targets, the WA still provides a reasonable effectiveness. However, as the targets become more difficult the WA core effectiveness drops off to zero. Although it is recognized that a zero effective range versus a simulated target is an overdramatization of ineffectiveness, the inability of the WA versions to penetrate critical areas of a future tank would seriously degrade the overall kill probability.

(U) This discrimination in penetration performance is probably the single-most important factor justifying the choice of DU over WA.

[redacted]

Table 7 - [redacted] Effective Range (KM) of KE Rounds vs. Modern Targets[19] (U)

		TARGET [redacted]					
PROJECTILE	PENETRATOR MATERIAL	HS*	HT*	INCREASED DIFFICULTY TARGETS			
XM833	DU	11.0	9.1	5.5	6.6	6.5	3.3
XM833	WA	4.5	4.0	4.8	4.1	3.9	-
XM829	DU	12.7	10.8	12.6	8.3	8.2	5.0
XM829E1	WA	8.6	7.3	9.8	5.9	5.8	-

* HS = NATO Heavy Single
HT = NATO Heavy Triple

VI. (U) Safety, Environmental & Development (U)

(U) The life cycle management of tungsten alloy kinetic energy cartridge is similar to that of any other inert material used in munitions and as such required no special handling or unique precautions.

(U) Having been sensitized to adverse air quality emissions resulting from repetitive armor penetration testing of DU munitions, DARCOM Safety formally required TECOM to sample and document the air quality from WA testing. This situation is viewed as temporary as it is unlikely that a requirement for enclosed or constantly monitored tungsten testing will endure.

(U) On the other hand, the utilization of DU as a penetrator material mandates a host of special requirements. DU is currently considered a Source Material and as such must be controlled by licensed installations only. Each licensee must satisfy all conditions specified in his license application. The Nuclear Regulatory Commission (NRC) is responsible for license approval and compliance.[20]

(U) The extent of special handling and precautions necessary depend on the operations being performed under the license. During the manufacture, armor penetration testing and operations where the DU is manipulated or processed requires rather extensive regulation. With other operations where the DU is simply handled, such as assembly into a projectile, load-assemble-pack or depot transportation, special requirements are minimal.

(U) The XM774, being the US Army's first production item utilizing DU, was the candidate for a wealth of special studies involving lab and field experiments.[21-31] Each step in the life cycle of the XM774 was critiqued to determine special procedures required. A conservative approach was adapted wherein data from testing and calculations was assumed to be required. The burden of proof was placed on the program.

(U) To date, the XM833 and XM829 have not been required to shoulder these same burdens. Two factors might be responsible for this low key atmosphere: The personnel normally involved in the safety and environmental issues have been preoccupied with the XM774, and the majority of the studies and tests conducted on the XM774 apply directly to the other two rounds. As can be seen from Table 8, the estimated funding and number of tasks deemed necessary for the XM833 and XM829 are considerably reduced from that required of the XM774. Some repetitive testing will be required on the 120mm XM829 due to the utilization of a new propellant ignition system.

(U) A similar situation exists with the special capital equipment necessary to support the production and fielding of a DU anti-tank cartridge. A considerable investment was made in manufacturing facilities and in test range equipment (e.g. armor plate target enclosure). Once established and proven, these facilities will be adaptable to the follow-on programs. The investments associated with the XM833 and XM829 will be required primarily due to the unique design features of each round, and not necessarily to support DU deployment.

(U) A less tangible yet very disturbing possibility is that the XM774 (and by association the XM833 and XM829) will not be deployed to NATO forces in Europe due to internal or external political considerations. The obvious solution to this potential problem is to jointly develop a tungsten alloy sister round. This ofter considered "insurance policy" option has been presented on several occasions but never funded. As an example, a proposal submitted in FY79 for a tungsten companion round for the XM833 would have required an additional five million dollars of RDT&E funds and could have been type classified concurrently. Despite its inferior penetration ability as compared to the parent DU version, it could have exceeded the performance of the DU XM774.

(U) An attractive offshot of a potential WA XM833 development would be foreign military sales (FMS). A very volital market exists with our allies to develop or procure the most effective tank ammunition candidates. A high performance XM833 WA would be an extremely attractive option. The current US policy (law) that a weapon cannot be developed exclusively for potential FMS negates what otherwise would serve as a major justification for development of the sister rounds.

Table 8 - (U) Special Studies & Tests Required to Support Fielding of a DU Cartridge (Approximate)

TASK	XM774/ M735E1	XM833	XM829
Hazard Burn Test	$ 60K	NR	$ 80K
External Radiation	20K	$30K	30K
Tank Radiation	30K	20K	50K
DA Personnel Training	40K	NR	NR
Air Quality Calculations	74K	30K	NR
Armor Test Air Sampling	160K	NR	50K
APG Environmental Monitoring	120K	NR	NR
Tank Burn Test	70K	NR	NR
Igloo Hazards Calcualtions	80K	NR	NR
	$655K	$80K	$210K

(NR - Not Required)

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