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ARMORED VEHICLE SHIELDING AGAINST RADIATION

NUMBER EIGHT IN A SERIES OF INFORMATION PAPERS ON TOPICS ASSOCIATED WITH NUCLEAR WEAPONS, PRINCIPALLY DESIGNED FOR USE BY TRADOC SCHOOL INSTRUCTORS AND MAJOR COMMAND STAFF OFFICERS

U.S. ARMY NUCLEAR AND CHEMICAL AGENCY
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FOREWORD

The series of papers, "Nuclear Notes," prepared by the US Army Nuclear and Chemical Agency is intended to clarify and explain various aspects of nuclear weapons phenomenology and usage. These papers are prepared in as nontechnical a fashion as the subject matter permits. They are oriented toward an audience that is involved with teaching, learning or applying the tactics and techniques of employing nuclear weapons in a conflict situation. Sufficient illustrations are provided to allow instructors or briefers to develop suitable vu-graphs. The dissemination of these nuclear notes will hopefully provide to the US Army accurate, up-to-date information of importance in understanding the use of nuclear weapons on the battlefield.

The principal author of this paper is Dr. Charles N. Davidson of the US Army Nuclear and Chemical Agency. Comments and views of readers are desired and should be forwarded to Commander, US Army Nuclear and Chemical Agency, 7500 Backlick Road, Bldg. 2073, Springfield, VA 22150.

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ARMORED VEHICLE SHIELDING AGAINST RADIATION

INTRODUCTION

Nuclear weapons may be used at any time on the tactical battlefield. The ability to operate effectively in such an environment and to employ nuclear weapons with confidence requires a knowledge of the protection provided crew members by representative US and Soviet armor. An understanding of the operational advantages to be gained from shielding improvements is also important. This note will summarize the shielding which armored vehicles provide against residual nuclear radiation, initial nuclear radiation, and neutron induced radioactivity in the tank armor itself; and will highlight the payoffs associated with improving this shielding.

WHAT APPROACH IS TAKEN?

In summarizing existing protection, the radiation shielding provided by the Soviet and US medium tanks, light tanks or assault vehicles, and armored personnel carriers listed in Figure 1 will be compared. The listed vehicles are the most recent for which unclassified data are available. Although interest in the radiation protection provided by vehicles of these two nations derives from different considerations -- defensive (friendly troop vulnerability) for US vehicles and offensive (weapon employment effectiveness) for Soviet vehicles -- making direct comparisons is an effective way to appreciate the relative advantages possessed by either nation.

HOW IS RADIATION PROTECTION EXPRESSED?

The shielding provided by a vehicle against radiation is expressed in terms of a "transmission factor" or "TF". This transmission factor can be defined simply as the dose received by crew members inside the vehicle, divided by the dose which would be received outside the vehicle. Or, in other words, the TF represents the fraction of the outside dose transmitted into the vehicle (Figure 2). (Some documents refer instead to a "protection factor" or "PF". The PF is the reciprocal of the TF.)

WHAT PROTECTION DO ARMORED VEHICLES PROVIDE AGAINST RESIDUAL RADIATION?

Residual radiation includes both fallout and neutron induced radiation in the soil. Fallout consists principally of gamma rays emitted from fission products which have been deposited on the ground following a surface or near-surface nuclear burst. Neutron induced radiation consists of gamma rays emitted from soil particles in the ground made radioactive by neutrons from air or surface bursts. As indicated in Figure 3, the radiation from either arrives from all directions. Although there is some variation in the protection provided to different crew members in the same vehicle, these variations are generally small enough to be ignored.

The residual radiation protection provided by Soviet and US vehicles is shown in Figures 4, 5 and 6. There is very high confidence in the validity of these residual radiation transmission factors.

Figure 4 compares the protection provided by medium tanks. The number on each vehicle is the transmission factor. For example, a TF of .04 means that, for every 100 rads of residual gamma radiation incident on the outside of the tank, only 4 rads are received by crew members inside. Two conclusions are immediately evident: first -- both Soviet and US medium tanks provide comparable residual radiation shielding; and second -- this shielding is excellent since, in crossing a residual radiation field, tank crews would receive only 3 to 4% of the radiation dose received by unprotected troops crossing at the same speed. Of course, this assumes that little radioactive dust gets inside the tank to remain there after the field is crossed. Such an occurrence could be avoided only by some type of air filtration or positive pressurization system for the vehicle. Tanks with such a system could possess a marked advantage in traversing contaminated areas, particularly if dry and dusty conditions exist.

The comparison of TFs for lighter tanks or assault vehicles is shown in Figure 5. Although these two vehicles do not perform identical functions and are thus not strictly

US	SOVIET
MEDIUM TANKS	
M60A1	T-55
M60A2	T-62
LIGHT TANKS/ASSAULT VEHICLES	
M551	PT-76
APCs	
M113A1	BTR-50

(*LATEST FOR WHICH DATA ARE AVAILABLE)

FIG. 1–ARMORED VEHICLES COMPARED *

$$TF = \frac{\text{INSIDE DOSE}}{\text{OUTSIDE DOSE}}$$

FIG. 2–TRANSMISSION FACTOR

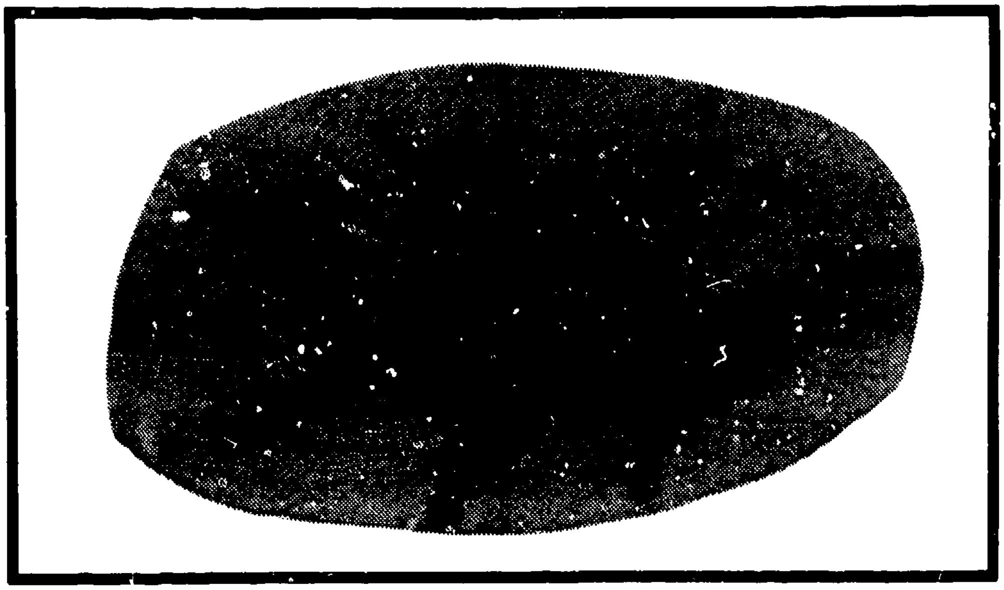

FIG. 3–RESIDUAL RADIATION

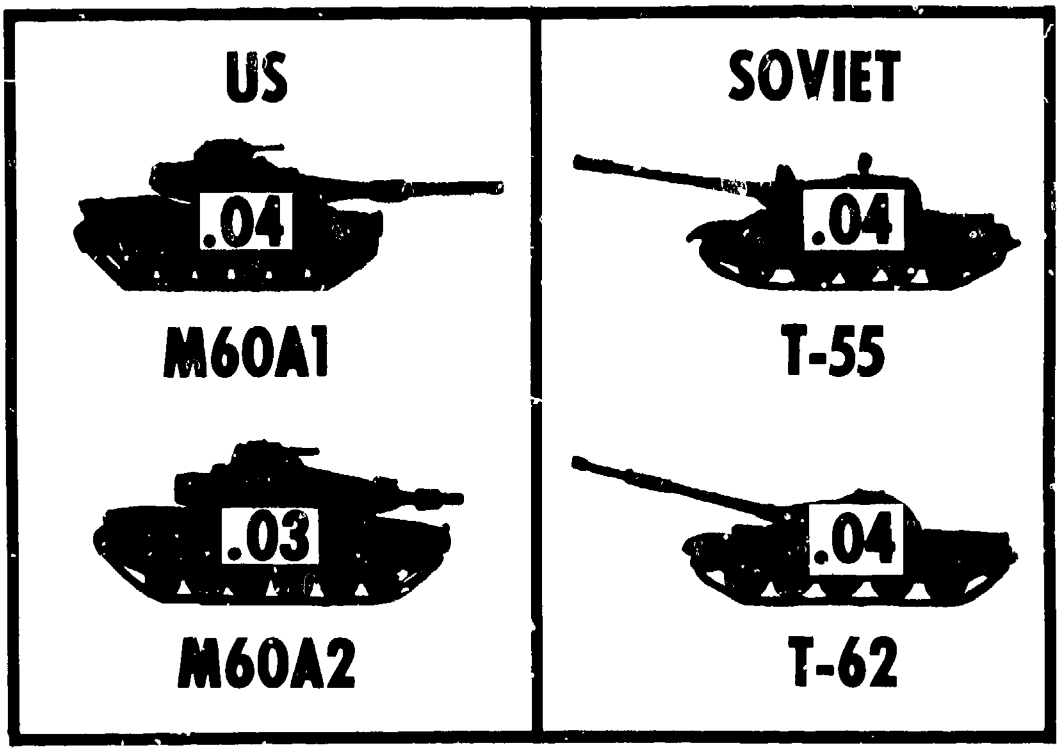

FIG. 4–RESIDUAL TFs (MEDIUM TANKS)

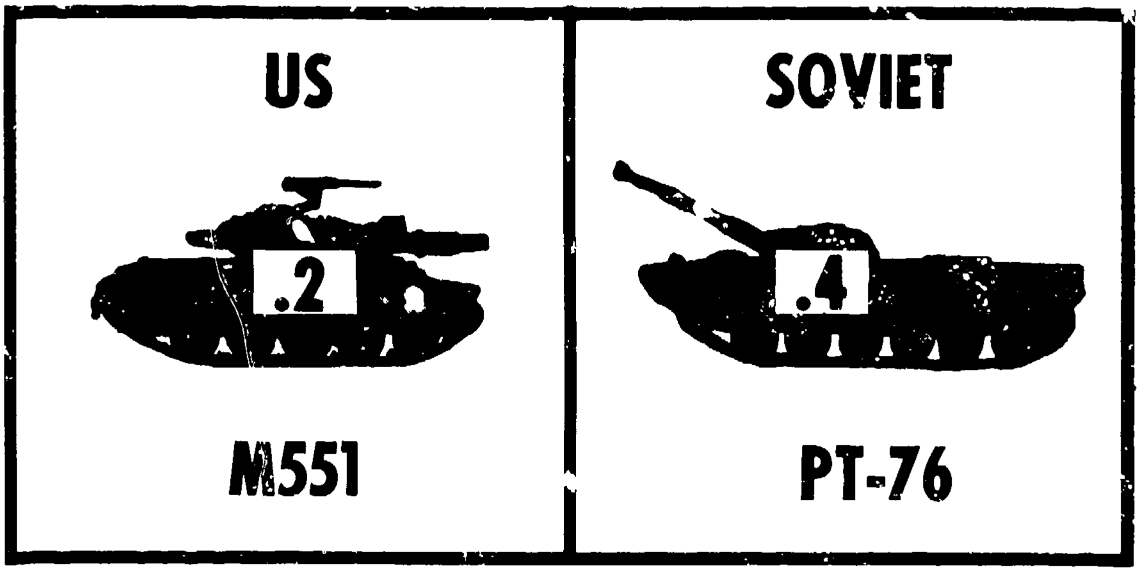

FIG. 5–RESIDUAL TFs (LT TANKS/ASSAULT VEHICLES)

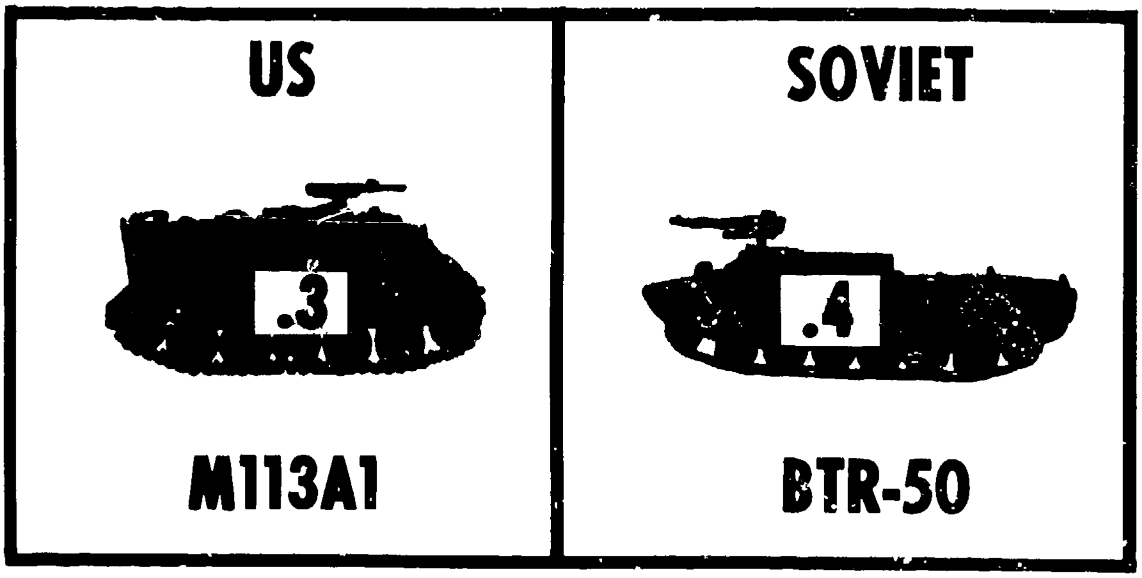

FIG. 6–RESIDUAL TFs (APCs)

comparable, they do illustrate the fact that crews of such vehicles are about 5 to 10 times more vulnerable than crews in medium tanks. As shown in Figure 6, the residual radiation shielding provided by these lighter vehicles does not differ significantly from that provided by APCs.

In summarizing the residual radiation situation, it can be seen that both Soviet and US armored vehicles, particularly medium tanks, afford substantial protection.

WHAT PROTECTION DO ARMORED VEHICLES PROVIDE AGAINST INITIAL RADIATION?

Initial radiation consists principally of neutrons and gamma rays that travel from the burst point to the vehicle (Figure 7). Because initial radiation is more directional in nature than residual radiation and because armor thickness is not uniform over the entire vehicle, initial radiation TFs vary somewhat with the orientation of the vehicle relative to the burst: in other words, they depend on whether the vehicle is head-on, rear-on, or side-on to the detonation. Since this orientation cannot be predicted in advance, an average of all orientations is generally used. Again, crew member positional variations are ignored.

Figures 8, 9, and 10 show initial radiation transmission factors for Soviet armored vehicles and compare this protection with similar US vehicles. These TFs are for fission weapon outputs; however, factors for enhanced radiation weapons do not differ significantly. Note that there are two initial radiation TFs for each vehicle -- one for neutrons and one for gamma rays. Keep in mind also that neutrons typically make up 50 to 75% of the radiation dose incident on the outside of the vehicle. Although there is high confidence in the validity of these initial radiation TFs, they are not quite so well established as are the residual radiation TFs.

Figure 8 compares the initial radiation protection provided by medium tanks. The number to the left of the slash is the neutron TF: the number to the right is the gamma TF. For example, the notation .5/.07 means that 50% of the dose caused by incident neutrons and 7% of the incident gamma dose are received by crew members. From this comparison, it can be seen that the T-55 and M60A1 have roughly equal protection against initial radiation; whereas the US M60A2 provides twice the protection of the Soviet T-62.

Initial radiation TFs for the Soviet PT-76 light amphibious tank are in Figure 9. This vehicle provides very little shielding against neutrons -- transmitting 90% of the radiation dose produced by incident neutrons. No calculations have been made of the M551 initial radiation TFs.

As in the residual radiation case, APC initial radiation TFs do not differ significantly from those for light tanks. Figure 10 illustrates that the BTR-50 and M113A1 provide initial gamma shielding which is roughly twice the initial neutron shielding provided.

In summary, these vehicles' initial radiation shielding characteristics indicate that their neutron protection is not nearly as good as their gamma protection. However, some US tanks have a marked advantage over Soviet models.

DO TANKS GET RADIOACTIVELY "HOT" WHEN IRRADIATED?

As the next topic on existing vehicle protection, consider whether or not initial neutron radiation will induce sufficient residual radiation in tank armor to result in a significant hazard -- either to the original tank crew or to a replacement crew, should one be available. In other words, will a tank become significantly "hot" as a result of being irradiated?

When vehicle armor is irradiated by neutrons, certain nuclei in the armor -- particularly manganese or aluminum -- can be "activated" by the neutrons and made radioactive (Figure 11). These radioactive nuclei will then emit gamma radiation over a period of time. This process is termed neutron-induced gamma activity, or more simply, induced activity. Some of this induced activity will result in a radiation dose to crew members.

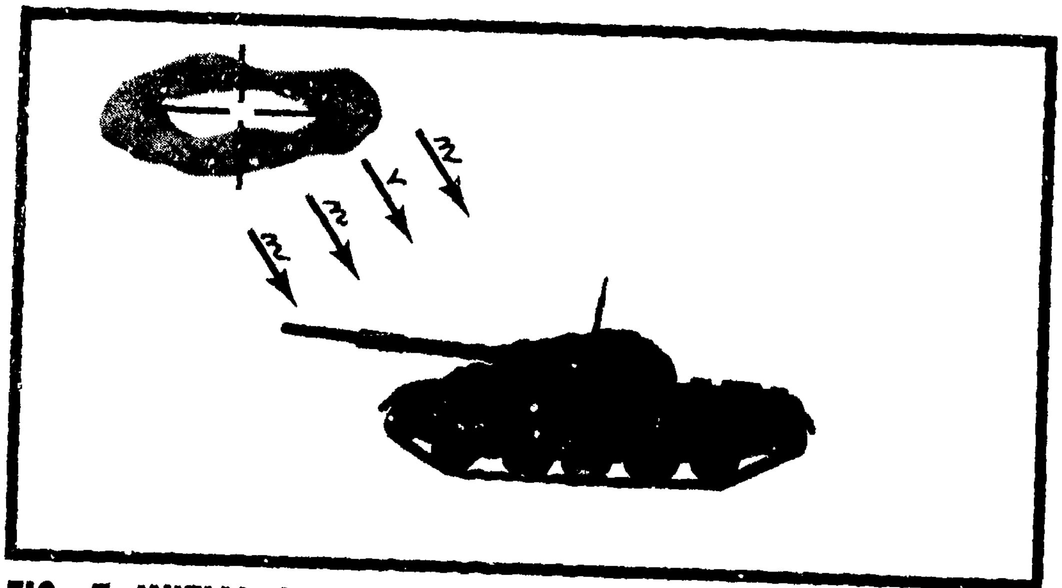

FIG. 7—INITIAL RADIATION

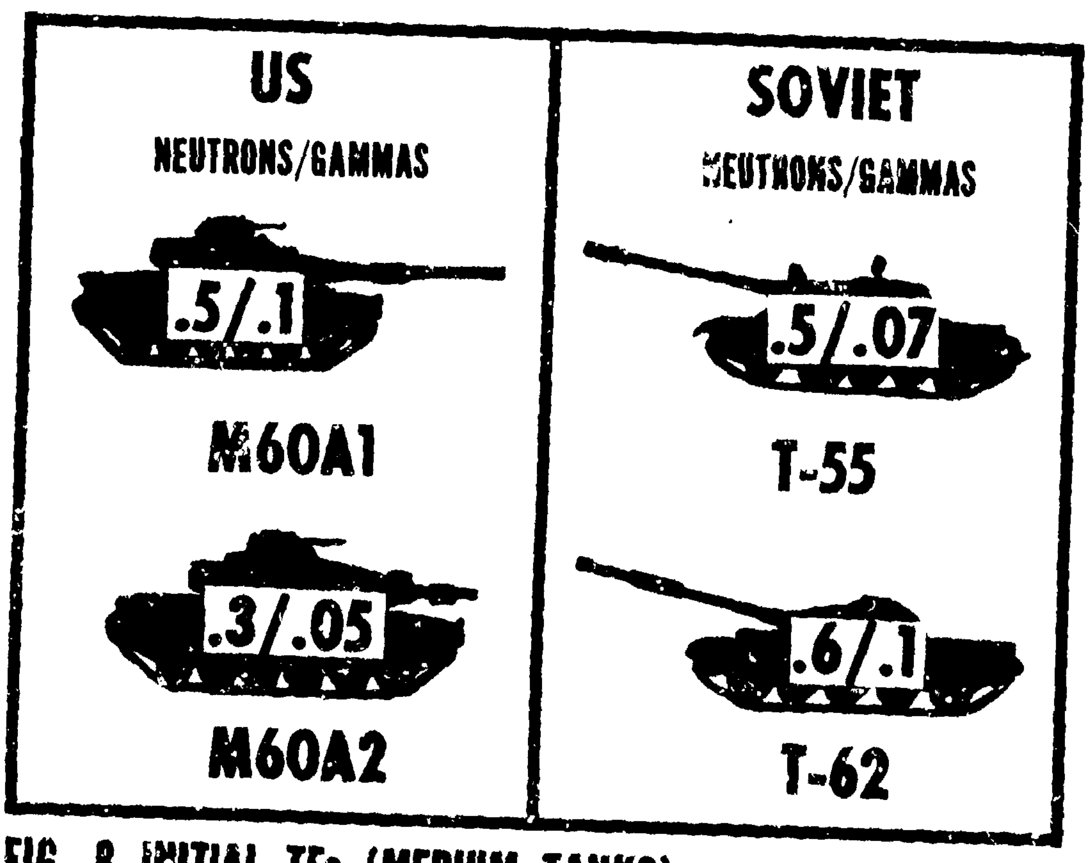

FIG. 8—INITIAL TFs (MEDIUM TANKS)

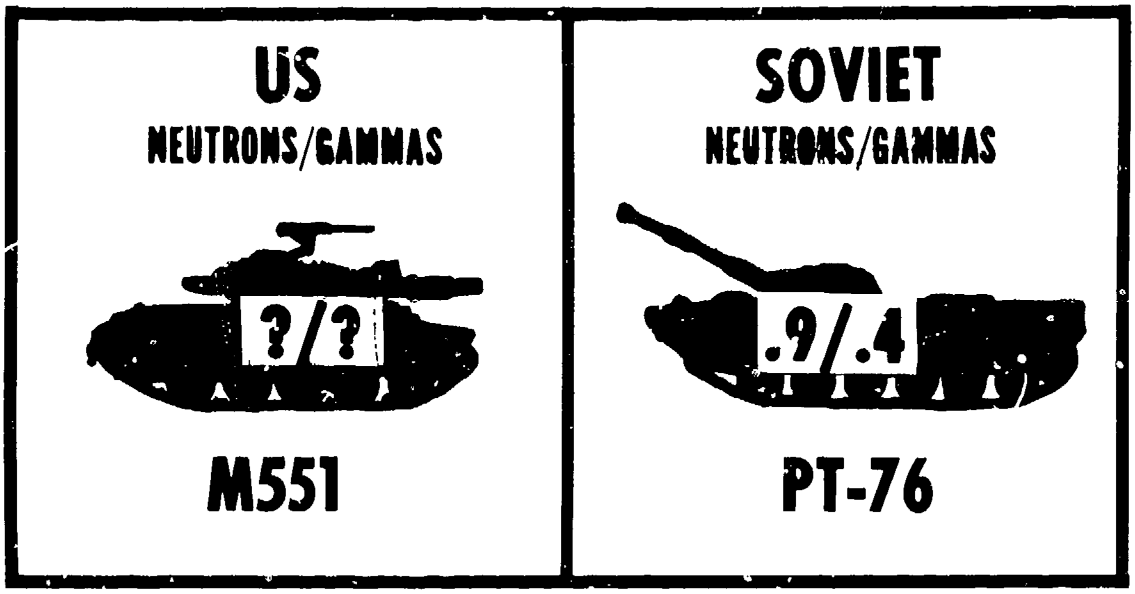

FIG. 9—INITIAL TFs (LT TANKS/ASSAULT VEHICLES)

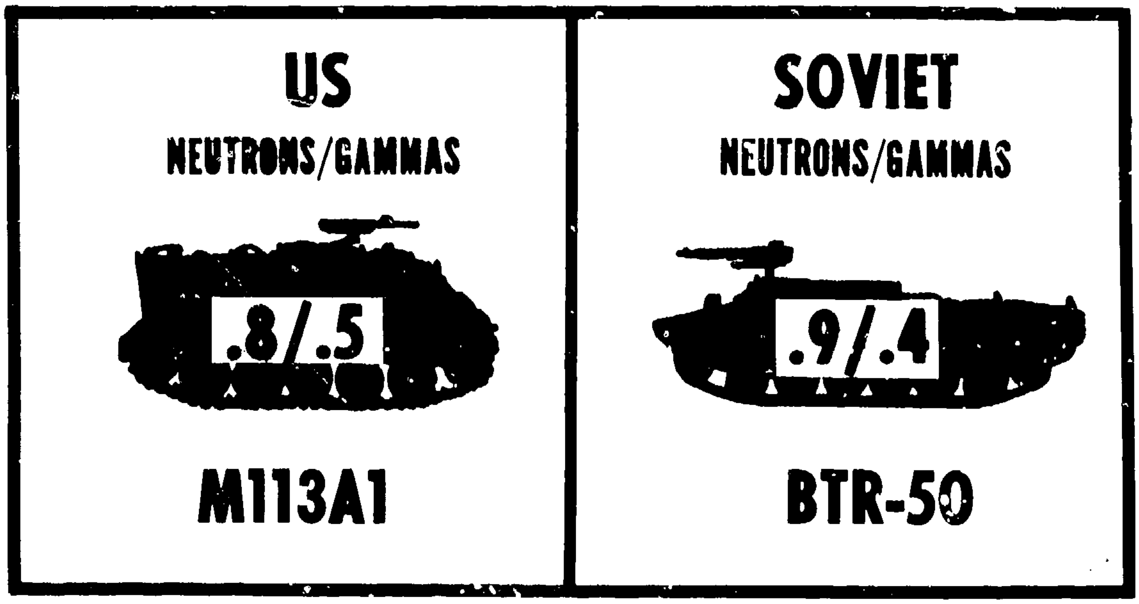

FIG. 10—INITIAL TFs (APCs)

There are few usable experimental data that provide an indication of the importance of this potential problem. The little data that do exist are for steel vehicles such as tanks and would not apply to aluminum APCs. These data indicate that levels of induced activity in steel armor depend on the incident neutron dose, the percentage of the element manganese in the armor, and the energy of the incident neutrons.

Calculations based on the limited data available give rise to the "700 to 1" and "1000 to 1" rules of thumb for approximating the induced activity dose for medium tanks (Figure 12). These rules assume that the steel tank armor contains about 1% manganese -- a typical value -- and (to worst case the hazard) assume that the original or replacement crew remains in the tank forever. (Over 95% of the dose will be delivered within 12 hours.)

The "700 to 1" rule applies to the original tank crew. This rule says that it takes at least 700 rad of neutron radiation on the outside of a tank to eventually result in the original crew receiving 1 rad of induced activity on the inside, assuming that they remain in the tank forever. As indicated in Figure 8, some medium tanks screen out about half of all incident neutron radiation. Thus, tank crews which receive about 1 rad of induced activity will already have received 350 rad resulting from initial neutron radiation. Clearly, then, induced activity is operationally insignificant to original tank crews.

But how about the possible hazard to crews which might replace an original crew that has been incapacitated? Since this is a replacement crew, they will receive only the dose resulting from the induced activity. Here, the "1000 to 1" rule applies, assuming that the replacement crew takes over operation of the tank approximately one hour after the nuclear burst. This rule says that at least 1000 rad of neutron radiation must have previously been incident on the outside of a tank to eventually result in the replacement crew receiving 1 rad of induced activity on the inside. So, for a replacement crew to receive what constitutes an emergency risk troop safety dose of 150 rad, the tank must previously have been irradiated by over 150,000 rad of neutron radiation. For this to occur, the tank would have had to be so close to ground zero at the time of a nuclear burst that, in almost every instance, it would have been destroyed by the blast wave. One concludes from this that induced activity in steel tank armor is operationally insignificant to replacement as well as original tank crews.

There are insufficient data to say exactly how well this conclusion applies to aluminum armor. However, crude approximations indicate that the hazard to original crews from aluminum activation would be somewhat worse than that for steel, but still operationally insignificant in view of the transmitted initial radiation dose. Because of the rapid decay of activated aluminum, the hazard to replacement crews in aluminum vehicles would be even more insignificant than to those in steel vehicles.

WHAT OPERATIONAL PAYOFFS ACCRUE FROM IMPROVING TANK SHIELDING?

The preceding portion of this note has concentrated on the existing radiation protection provided by US and Soviet armored combat vehicles. As a final topic, consider some of the operational merits associated with improving the existing shielding for the medium tank.

Using the US M60A1 tank as an example, Figures 4 and 8 indicate that its residual radiation protection is excellent (TF equals .04) and its initial radiation protection is fair for neutrons and good for gammas (TFs equal .5/.1). The previous discussion concluded that, operationally, induced activity is not a problem. From these data it follows that neutron shielding is the weak link in radiation protection provided by the M60A1, particularly since most of the incident initial nuclear radiation is comprised of neutrons.

Preliminary experiments and calculations have demonstrated that, by adding neutron shielding in a selective manner, the M60A1 or comparable medium tank can have its neutron protection improved fourfold with weight and bulk increases which may prove acceptable to the user. This is true because neutrons are best attenuated by lightweight materials, and because tank design is such that adding small amounts of shielding in selected locations can provide large improvements. The payoffs associated with such a fourfold increase in neutron protection are illustrated in Figures 13 and 14.

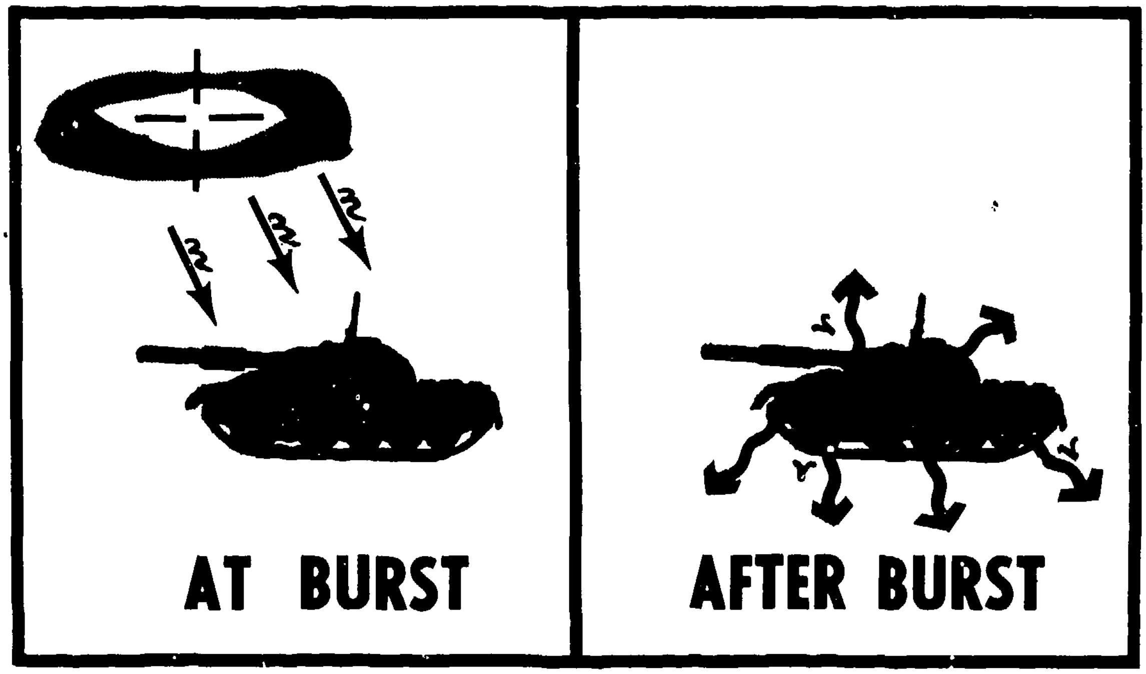

FIG. 11–INDUCED ACTIVITY

ORIGINAL CREW

700 TO 1

REPLACEMENT CREW

1000 TO 1

FIG. 12–INDUCED ACTIVITY RULES OF THUMB

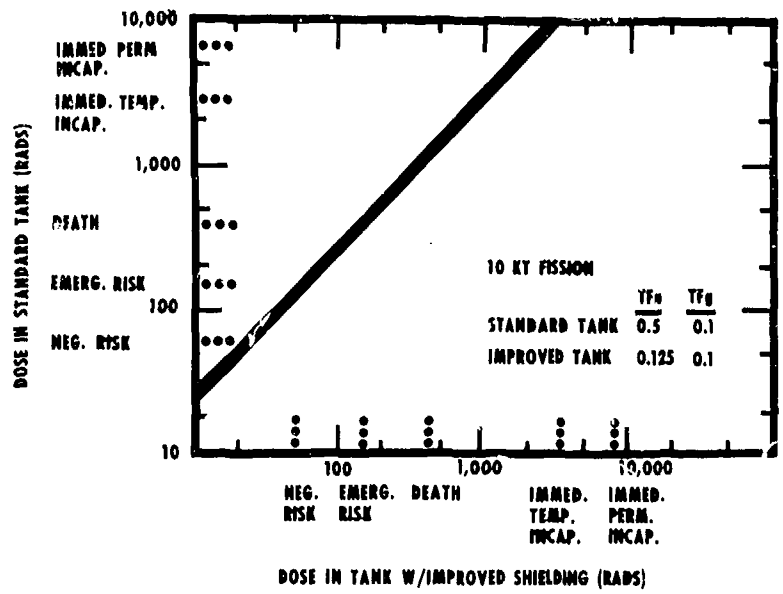

FIG. 13–MILITARY EFFECT PAYOFF FOR IMPROVED SHIELDING

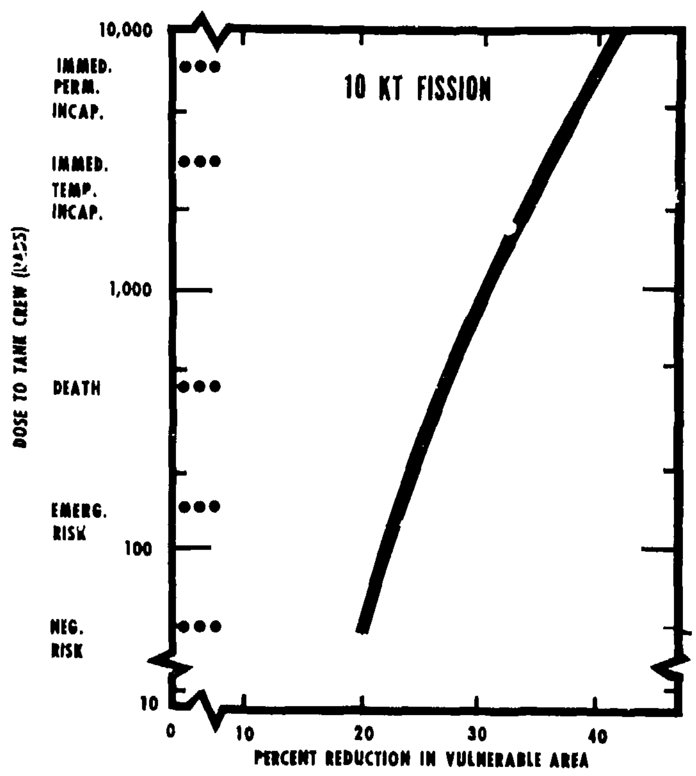

FIG. 14–VULNERABILITY AREA PAYOFF FOR IMPROVED SHIELDING

Figure 13 shows for a 10 KT weapon the relationship between total radiation dose received inside a standard M60A1 tank and that received by crew members inside an improved tank. For example, crew members receiving an eventually lethal dose (450 rads) inside a standard tank would receive only an emergency risk dose (150 rads) inside a tank with improved shielding. Similar payoffs accrue at other dose levels.

Figure 14 illustrates this payoff in terms of reduction in vulnerability area on the battlefield as a function of total dose to crew members. Depending on the radiation dose, the area of vulnerability is reduced by 20 to 40 percent for a 10 KT weapon. Even more significant are the reductions for a 1 KT threat yield: 30 to 55 percent.

The conclusion is that improved shielding can provide a significant increase in operational capability with weight penalties that may prove acceptable to the user.

SUMMARY

The main points of this note are summarized in Figures 15 through 18.

With respect to shielding against residual radiation -- for example, fallout -- US and Soviet armored vehicles generally provide comparable protection. Medium tanks, in particular, provide excellent protection, transmitting less than 5% of the fallout radiation dose. Lighter armored vehicles provide shielding only one tenth as effective as do medium tanks. These data strongly support existing doctrine in FM 3-12 which maintains that crossing radioactively contaminated areas in tanks or other armored vehicles can significantly lower radiation exposures and the resulting risk to combat troops.

The situation for initial radiation shielding is somewhat different. Armored vehicles are not nearly as effective in shielding against neutrons as they are against gamma rays. In fact, lightly armored vehicles provide comparatively little protection against neutrons -- on the order of 10 to 20%. Some US medium tanks do, however, provide about twice the initial radiation protection of some Soviet tanks. Of course, these comparisons could change when data become available for the Soviet T-72 and US XM1 tanks, and for the Soviet BMP armored fighting vehicle. The available data do indicate that tank-mounted troops present a harder target to opposing nuclear delivery means. Conversely, nuclear weapons can be employed closer to friendly tank units without exceeding a given degree of troop safety risk.

Although data are extremely limited, the amount of neutron induced gamma activity in steel tank armor can be approximated. These approximations clearly indicate that induced activity is operationally insignificant either to the original tank crew or to a replacement crew, should one be available.

Neutron shielding is the weakest link in radiation protection provided by medium tanks. Improvements in the neutron protection provided by these tanks appear feasible and practical. Operationally significant reductions in radiation dose to crews or in vulnerability area on the battlefield result from a fourfold increase in neutron protection.

- US AND SOVIET VEHICLES COMPARABLE
- TANKS OFFER EXCELLENT PROTECTION
- LIGHT VEHICLES LESS EFFECTIVE

FIG. 15–SUMMARY–RESIDUAL RADIATION SHIELDING

- GAMMA SHIELDING BETTER THAN NEUTRON SHIELDING
- MARKED ADVANTAGE FOR SOME US TANKS

FIG.16–SUMMARY–INITIAL RADIATION SHIELDING

- INDUCED ACTIVITY TACTICALLY INSIGNIFICANT

FIG. 17–SUMMARY–INDUCED ACTIVITY

- IMPROVED SHIELDING PAYS OFF OPERATIONALLY

FIG. 18–SUMMARY–IMPROVED SHIELDING