Polish Explosive reactive armor:

ERAWA-1 and ERAWA-2

·Origins of the ERAWA armor

·ERAWA -1 – the build and effectiveness

·ERAWA -2 – the build and effectiveness

·ERAWA armor on PT-91 and PT-91MZ

·ERAWA-2 unique features, and compare whit other ERA armors.

Origins of the ERAWA armor

The ERAWA armor is connected whit person of the Prof. Ph.D. D.Sc. Adam WISNIEWSKI from Military Institute of Armament Technology (WITU) in Poland . Name of this reactive armor is based on acronym: **E**xplosive **R**eactive **A**rmor **W**isniewski **A**dam 1 and 2 layered.

The origins of the ERAWA are hidden in half of the 1980s when polish Military Institute of Armament Technology had started (in person Prof. Ph.D Wisniewski) development process about new armor for deep modernization of the T-72M1. In fact WITU work had started about whole family of the armor whit two „tank" part: ceramic CAWA armor for main tank armor and explosive ERAWA armor as external layer.

Rumors about eastern (Soviet Union) origins of the ERAWA are false. Polish Army during negotiation about future production in Poland T-72s tank (planned at half of the 1990s) rejected Kontakt-1 armor as solution whit many flaws and not good enough against suspected RPG's and ATGMS warhead in breakthrough of the 1980/1990.

New armor ERAWA-1 was available in 1993 whit first PT-91 prototype.

ERAWA -1 – the build and efectivnes

ERAWA-1 - TX01 - 24-02 – WITU

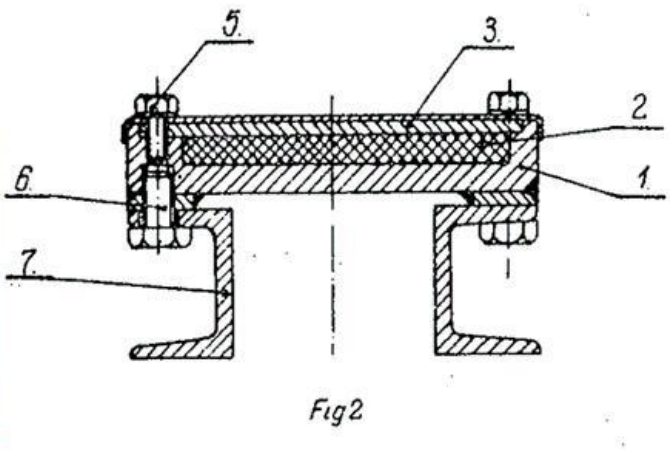


Fig 2

Basic parameters of the ERAWA-1 cassette:

(Photo description:

Left: ERAWA-1 TX cassette

Right: ERAWA-1 patent draw: 1-casette; 2-HE (trotyl or trotyl-heksogen); 3- external HHS (HB500) plate ~6mm thick; 5,6 – screws;

7 - brackets for ERAWA-1 cassette in distance 30-50mm form armor)

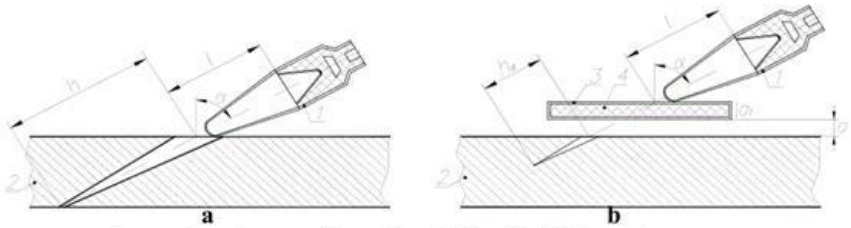
I. Parameters:

1. Size of the ERAWA-1 cassette - 150x150x26 mm

2. Mass of the ERAWA-1 cassette - 2.9 kg

ERAWA-1 is build form RHA cassette whit HE insert (TNT or TNT-hexogen) cover by circa 6mm HHS plate whit 500HB hardness. Whole cassette is mounted by two screws to the brackets. This build, seems to be primitive, but thanks to strong explosive and very good quality HHS plates provides very good capability of the protection:

Scheme of test of protection capacity of the ERAWA-1 cassette



a b

- warranted capacity of penetration of the RHA with thickness *h*
- depth of penetration *hw* in witness plate, protected with the ERAWA-1 cassette
- shaped charge before detonation
- the ERAWA-1 cassette before detonation
- the RHA
- casing of the ERAWA-1 cassette
- explosive
- warranted depth of the RHA penetration
- depth of penetration of the RHA protected with cassette
- angle of shaped charge jet penetration of the ERAWA-1 cassette and the RHA

Capability of the Protection is based on formula:

CP - capability of protection

CP=(H-Hw)/H

H- Guaranteed penetration RHA armor with thick "H"

Hw - real depth of perforation RHA armor (witness) after perforation ERAWA brick

In result ERAWA-1 (single layered) have sucht efectivnes valued in CP factor:

against hand held AT weapons sucht Komar (The Mosqito), PG-7 and PG-9 whit (circa 300-330mm RHA penetration):

CP = 92%

against 9M113 warhed (circa 460mm RHA penetration):

CP = 83%

against 125mm BK-14M round (circa 450mm RHA penetration):

CP = 94%

ERAWA-1 casettes are insensitive to react:

·during impact of

·AP small calibre amunition

·fragments from exploding projectiles

·during burning of by: petrol, napalm, thermite

Seafty tests ERAWA-1 photos:

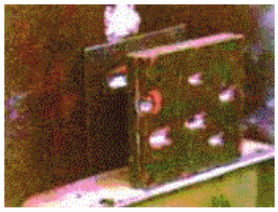


Fig. 9. ERAWA-1 cassette after firing with six 7.62 mm armour-piercing projectiles B-32 ($\infty = 60°$)

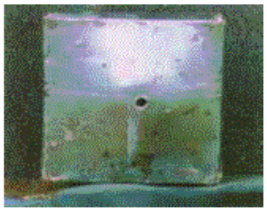


Fig. 10. ERAWA-1 cassette after firing with 12.7 mm armour-piercing projectiles B-32 ($\infty = 0$)

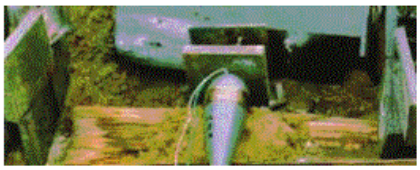


Fig. 11. Scheme of resistance test of ERAWA-1 cassettes to detonation and destruction with explosion of 82 mm mortar grenade

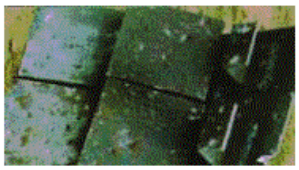


Fig. 12. ERAWA-1 cassettes after explosion of 82 mm mortar grenade

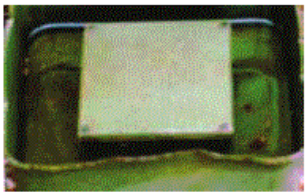


Fig. 13. Scheme of resistance test of ERAWA-1 cassette to detonation and destruction during burning of petrol around it

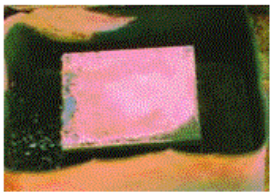


Fig. 14. ERAWA-1 cassette after combustion of petrol around it

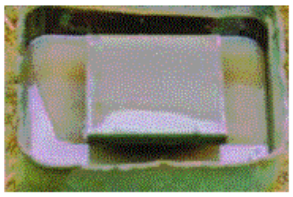


Fig. 15. Scheme of resistance test of ERAWA-1 cassette to detonation and destruction during burning of napalm on it and around it

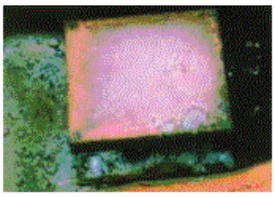


Fig. 16. ERAWA-1 cassette after combustion of napalm on it and around it

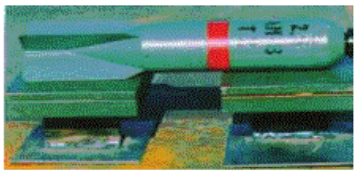


Fig. 17. Scheme of resistance test of ERAWA-1 cassette to detonation and destruction during burning of incendiary bomb ZAB-2,5 containing thermite (3000 °C) on it

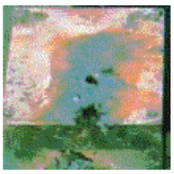


Fig. 18. ERAWA-1 cassette after combustion of incendiary bomb ZAB-2,5 on it

ERAWA -2 – the build and effectives

ERAWA-2 (two layered) was answer for modern thread: AT weapons whit precursor (PG-7VR, MBT LAW, Panzerfaust-3T etc), EFP projectiles formed from 100mm cone diameter, partially APFSDS penetrators, and challenge to reduce RCS tank signature. ERAWA-2 and ERAWA-1 cassettes are fully swichable.

Basic parameters of the ERAWA-2 cassette:

ERAWA-2 - TX02 - 24-02 - WITU

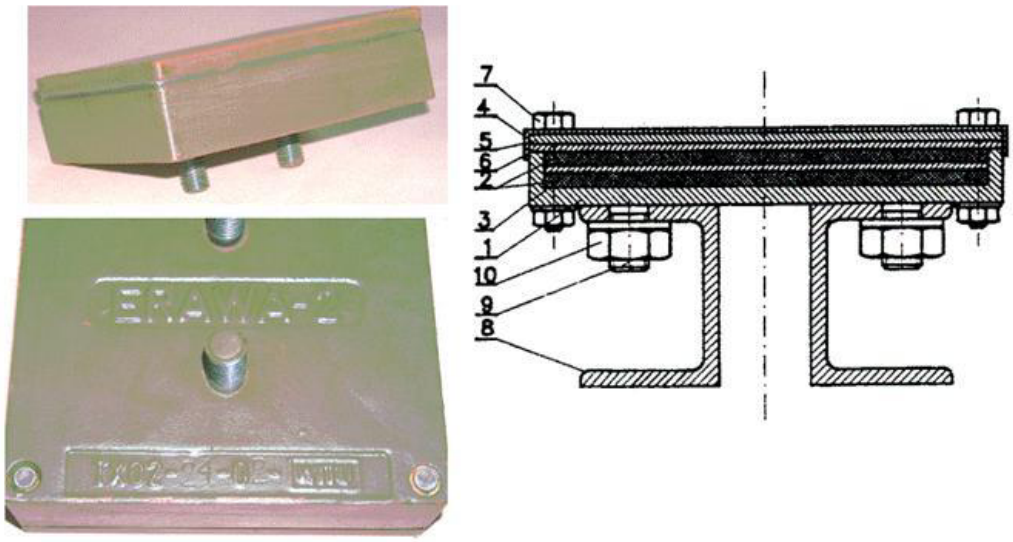


Photo description:

Left: ERAWA-2 TX02 cassette

Right: ERAWA-2 patent draw: 1-casette; 2 double HE layer (trotyl or trotyl-heksogen); 3- thin HHS plate separation two HE layers;

4- thin metal lid ; 5 – ceramics layer; 6 – thin HHS plate; 7- rivet/screw; 8 - brackets for ERAWA-2 casette in distance 30-50mm form armor; 9 – screw between cassette and brackets, 10 – mounted nut.)

Parameters:

1. Size of the ERAWA-2 cassette - 150x150x46 mm

2. Mass of the ERAWA-2 cassette - 4.7 kg

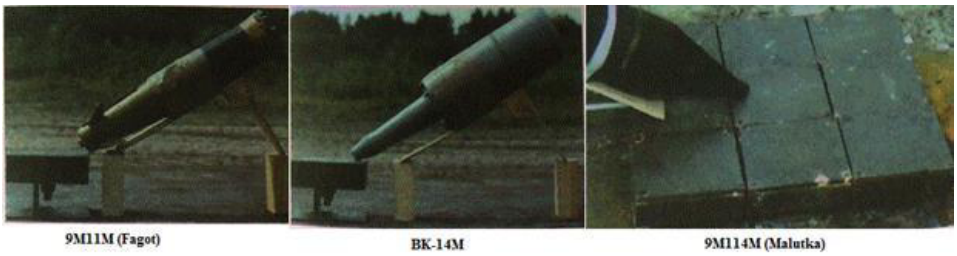
Internal build of the ERAWA-2 cassette is much more sophisticated then ERAWA-1 and it's very different then other known ERA cassettes.

Basic build is similar to the ERAWA-1 – metal cassette attached by mounted screws to brackets in distance 30-50mm from armor surface. But internal ERAWA-2 build is different. First they are two HE layers inside cassette separated by thin (circa 2-3mm) HHS plate whit hardness above 500HB. Probably both HE layers have slightly different HE material whit different reaction time and other parameters. Second – external ERAWA-2 plate is not thick HHS plate but multilayered layout made by: thin metal lid then circa 4-5mm thick **ceramic layer** and second thin (circa 2-3mm) HHS plate whit hardness above 500HB.

Such, unusual, layout make ERAWA-2 different then other known ERA. And give surprisingly good capabilities of the protection:

·**Agiainst single SC (HEAT) warheads** like 9M113 (Konkurs) or 9M111M (Fagot) or BK-14M

CP = 95%



9M11M (Fagot) BK-14M 9M114M (Malutka)

·**Against single EFP** formed form 100mm cone diameter and penetration circa 85mm RHA

CP= 94%

Fig. 7. Scheme of test of protective ability of ERAWA-2 cassette (2) by firing with the use of EFP warhead (1) (d = 100 mm, h = 85 mm), (∞ = 60°)

Fig. 8. Traces on RHA armour after penetration of ERAWA-2 cassette with warhead EFP; 1 - trace of detonation of ERAWA-2 cassette, 2 - trace of destroyed EFP projectile (EFP – h = 85 mm), h_w =5 mm, protective ability of cassette CP = 94 %, (∞ = 60°)

During test ERAWA-2 proof abiities to protect in PT-91 hull top and turret top against EFP formed from 50-155mm cone diameter (so up to 120mm RHA penetration) and to protect hull sides against EFP formed form 200mm cone (so up to 150mm RHA penetration).

·**Against APFSDS rounds** 3BM15 (125mm) and DM-33A1 (120mm)

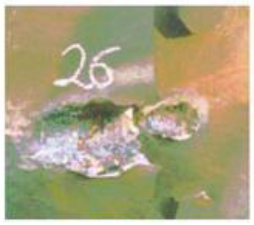


Fig. 6. Crater in plate of RHA armour after firing ERAWA-2 cassette from tank, with 125 mm projectile BM-15 (APFSDS-T, h = 300 mm, ∞ = 60°). Penetration of RHA armour h_w = 130 mm, protective ability of cassette CP = 57%

CP in first case (3BM15) was equal to 57%

CP in second case (DM33A1) was not given, but ERAWA-2 placed on PT-91 hull model (so T-72M1) was enought to stop APFSDS whit guaranted 470mm RHA penetration, from 600m distance:

In this case DM-33 penetartor was heavy damage during ERAWA-2 penetration, then perforate first plate and rebound from deeper (glas textolite) layers without reach second RHA plate (backplate)

PT-91 hull is consist by: (for 90 degree) 60 mm RHA + 105 mm STEF + 50 mm RHA, and glasstextolite thickness effectiveness is circa 0.4 against APFSDS, and ERAWA-2 cassette is 46mm thick

So layout for 68 degree is: ~120mm ERAWA-2 cassette + 160mm RHA + 280mm STEF + 146mm RHA

Hull base armor (without ERAWA) works as circa 420mm RHA against APFSDS.

Guaranteed DM-33A1 penetration is 470mm RHA on 2000m. DM-33A1 after passing ERAWA-2 perforate first RHA plate and circa half STEF layer then rebound.

In theory ERAWA-2 give CP=42% in this case (using formula: CP=(H-Hw)/H) but in author opinion such test is not relevant cause rather rebound mechanism then only ERAWA-2 working. Some sources (Kajetanowicz J., *POLIGON 2/2013, „Czolg podstawowy PT-91 Twardy"* page 7.) give ERWA-2 abilities to reduce APFSDS penetration up to 30-40%. What is consist whit above example. For the other hand - both used on test APFSDS rounds are not modern. 3BM15 is complete obsolete and antic and DM-33A1 is not really young (DOI 1987). Probably ERAWA-2 test against much modern rounds (DM53, M829A2, KEW-A2, OLF-F1, M332) will give much worse results. Anyway - ERAWA-2 ERA incares a lot protection of the PT-91 tank against non monoblock penetrator, so: 3BM15, 3BM22, 3BM26, 3BM42 and even help against first generation longer monoblock penetrator (DM33). So for typical angle +/- 30. degree from longitude tank axis and against APFSDS from half of the 1980s decade ERAWA-2 have capability of the protection – circa CP= 50-60% for penetrator whit tungsten or steel slug inside and achieve unknown (30%?) but rather significant protection against slightly younger APFSDS whit monoblock penetrator (DM33A1).

·**Against SC warhead (HEAT) whit precursor.**

Proliferation of the AT hand held weapons whit precursor able to destroy ERA cassette starts to be serious problem for armor developers in 1990s decade. Most of the precursors are working not as typical SC warhead able to perforate armor and are not working in idea „fast ERA detonation" before main warhead SC jet hit target. In modern hand held AT

weapons (PG-7VR, MBT-LAW, PzF-3T and IT600, probably in RPG-29) precursor is working in different way. As Panzerfaust-3IT developers wrote: „*The dual warhead has a small first charge and a main shaped charge.* ***The first charge penetrates the reactive add-on armor on the combat vehicle*** ***<u>without initiating the charge inside it</u>*** *to ensure it does not compromise or pre-vent the armor-piercing action of the main shaped charge."* Such mechanism was describe in some ballistic symposium thesis too:

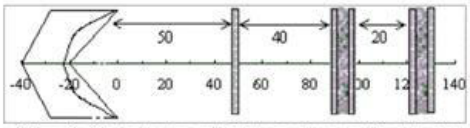


Figure 6: The test set-up, with distances between the plate stacks.

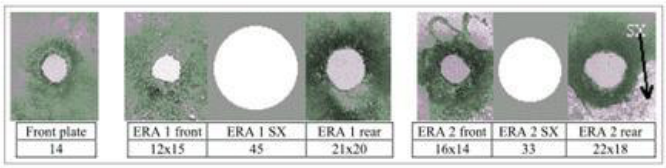
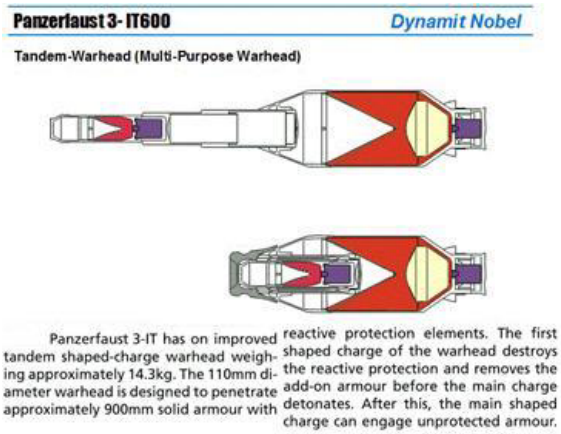


Figure 7: Photographs of the plates with a HDPE liner, to scale, with hole dimensions in mm, and with sketches of the holes in the ERA.

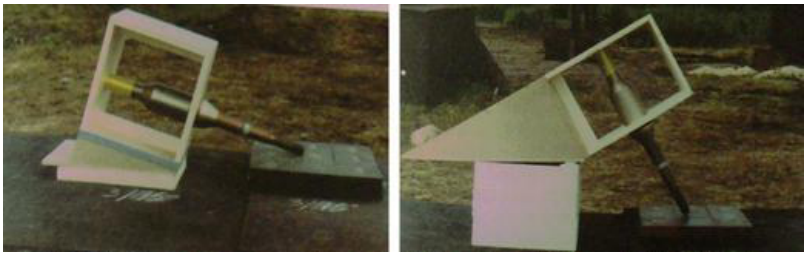
A prime advantage of the non-initiating approach is that the designer of the warhead system does not need to be constrained by the time taken for ERA plates to move out of the path of the main jet. The main charge may be initiated as soon as the hole in the ERA explosive is large enough.

ERAWA-2 was tested against several tandem warhead (main warhead + precursor) AT weapons, but probably the most difficult test was against Pzf-3T and PzF-3IT600:

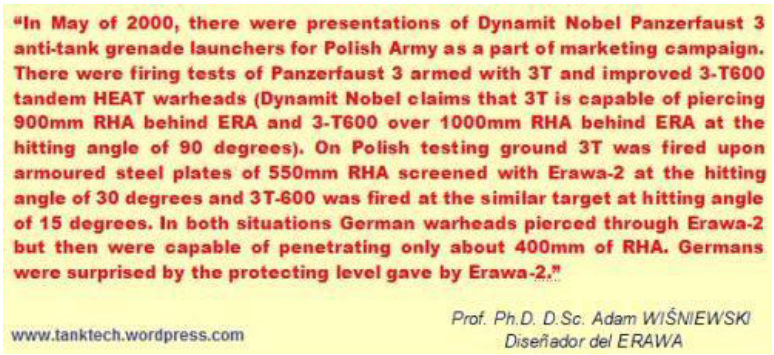


Pzf-3IT600 main warhead (110mm diameter) is able to perforate 900mm RHA plate, and PzF-3T warhead is able to perforate 800mm RHA plate.

Both of them where tested against ERAWA-2 cassettes placed on angle 30 and 15 degree (so 75 and 60 degree form the surface):



The result was more then good:



ERAWA-2 against PzF-3T placed at 30 degree (60) achieve **CP = 50%** what including sophisticated precursor in Pzf-3T and powerful 110mm warhead (800mm RHA penetration) was greater success.

·**Reduce tank RCS signature.**

ERAWA-2 casettes are covered by 4mm special absorber layer (1K2KS and 1KF2KS absorber) whit mass 6kg/m2 and able to protect against radar working in band X and Ku whit f=8-16GHz. On typical PT-91 such absorber cover circa 20m2 and achive reduce detecting range at 50 to 60% for typical conditions.

ERAWA armor on PT-91 and PT-91MZ

There was three generation of ERAWA armor on PT-91 tank.

First generation consisted 394 ERAWA-1 cassette. On hull front was placed 118 cassettes and on turret 108 cassettes.

On each hull side was placed 84 cassettes. Such cover weight circa 1144kg.

ERAWA-1 cassettes are mounted by screws and nuts to individual metal brackets on armor surface:

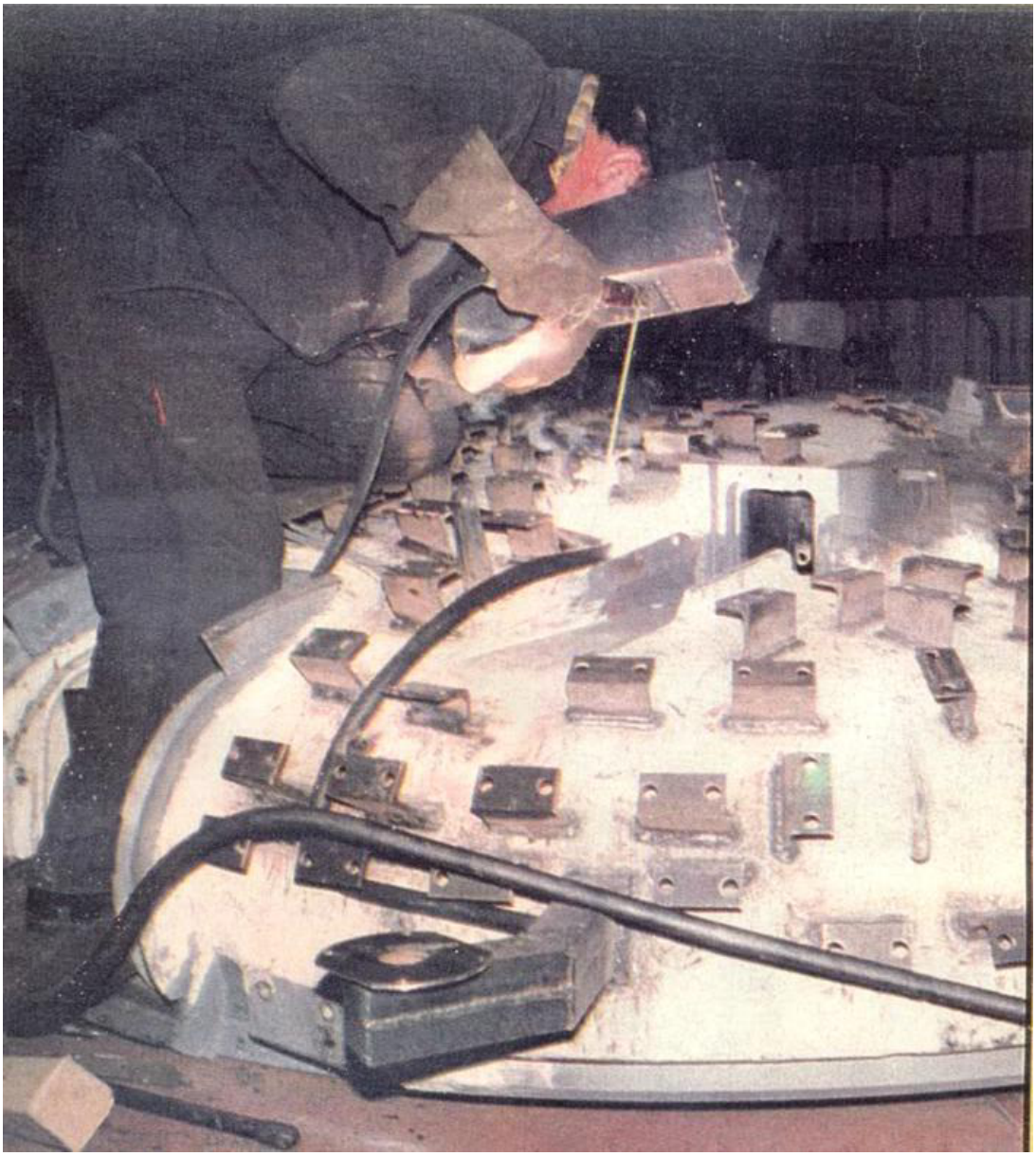


Photo:

First generation ERAWA mount on early PT-91 tank prototype:

Second generation ERAWA armor on serial PT-91 tank consist 296 ERAWA casettes:

·204 x ERAWA-1

·92 x ERAWA-2

With total weight 2014kg and mounted by screws to the special metal bar- brackets:

Photo:

second generation ERAWA mount on serial PT-91 tank :

Third generation ERAWA armor on PT-91 tank consist 259 cassettes:

·164 ERAWA-1

·92 ERAWA-2

Weight 907kg. The main change is modular designed to achieve faster replace damage cassettes on battelfield. On hull are placed 79 segments, on turret 90 segments and on each hull side 45 segments. This generation layout is used on PT-91M „Pendekar” (or „Malaj”) for Malaysia , PT-91Ex and PT-91P prototypes.

Photo:

Third generation ERAWA mount on serial PT-91M „Pendekar” tank :

It is importand to notice that typical ERAWA can't be use on light platforms like IFV or APCs. ERAWA armor will not be use on Polish Leopard-2A4 and 2A 5 tanks for law resons – agreement whit KMW and German Republic excludes non authorisated and non tested solution in Leopard-2 modernisation program. Cost of sucht certification and legalization problems propably will be to big to put ERAWA armor on polish Leopard-2.

ERAWA-2 unique features, and compare whit other ERA armors.

Polish ERAWA armor have some special features whit make ERAWA-1 and 2 very interesting example of different principles during ERA development process.

First – ERAWA cassette have small dimensions. While in other countries ERA cassettes are rather big, ERAWA developers had tried to make ERAWA cassettes as small as it possible, whit under cassette montage system. This solution give possibility to mounted ERA cassettes without heavy metal frame known from other ERA or without space between ERA cassettes. In some ERA gaps between cassettes are almost 50mm wide. ERAWA ERA haven't such problems, so it can better cove the tank. Any flat surface cover by ERAWA is protected in 95% of it's area.

Photo:

Lack of any gaps between ERA cassettes on PT-91A hull and present sucht gaps on T-72B hull.

T-72B with Kontakt-1 PT-91A whit ERAWA II.gen layout

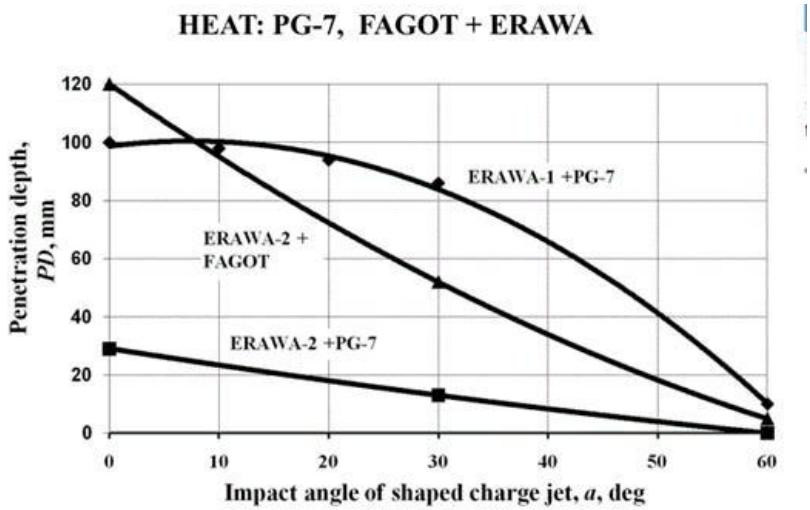
Photo: Compare turret cover by ERA:

Second special features of the ERAWA is its high effectiveness even on great angle. While most developers are trying to slopped ERA cassettes at 60 degree (30) form 0 to achieve some needed effectives level ERAWA-1 and ERAWA-2 can be slopped at smaller angle whit the same effectiveness.

Typical ERAWA-2 CP value (capability of the protection) against single SC warhead is CP = 95% at 60. Degree ERA slopped angle. But even for extremely difficult for ERA cassettes angle 70-90. ERAWA-2 is effective in impressive CP=67-80%

Photo:

ERAWA-1 and ERAWA-2 effectiveness at difficult angle grater then 60.



Penetration depth (*hw*) of the RHA protected with the ERAWA cassettes in the function of the impact angle (∝- in relation to normal to surface of cassette) of different jets of shaped charge projectiles

Third special feature of the ERAWA armor is confirmed abilities to significant reduce (CP=50% for 60. slopped angle) modern AT hand held SC (HEAT) warhead whit precursor. So Pzf-3T, PzF-3IT600, PG-7VR, RPG-29, MBT-LAW, etc

Some ERA manufacturer claimed that they ERA have counter double warhead abilities (Relikt, Knive -Duplet, ARAT-2, ERAWA-2, etc) But till now only in Poland (and Ukraine) are known and have confirm in open public sources evidences that ERA armor can withstand such thread. Despite that ERAWA-2 ERA can stop most EFP warhead what is rather unique feature too, and it's cover by microwave absorber to reduce tank RCS.

The last, maybe not unique, but really good ERAWA armor feature is it's insensitive for AP small caliber ammunition, fragments from exploding projectiles, and burning of by: petrol, napalm, termite., insensitive for 10m height drop, and chain reaction after ERA cassette explosion. What more – ERAWA have confirm abilities to work in -50 to + 80 C temperature, have more then 20 years guaranteed lifetime and is small and easy to fixed it on tank.

In compare to exist now ERA (BRENUS, Blazer, ARAT-1, ARAT-2, Kontakt-1, Kontakt-5, Relikt, Knive /Duplet,) etc. ERAWA have the smallest cassettes and it can cover the biggest tank area (except Ukrainian Knive ERA in Oplot-M modules). ERAWA-2 abilities to stop single HEAT warhead is rather no different then other ERA, this what is special in ERAWA is it's ability to work even on greater angle (90-70.) whit significant effectiveness (CP=67-80%) and abilities to stopped even big EFP warhead. Unknown is effectiveness of the ERAWA-2 againt big tandem ATGM warhed like in Kornet, Ataka, etc. Probably ERA will not achieve such good results in this scenario. But for the other hand – ERAWA-2 have confirm (not only in marketing ads) abilities to deal whit modern hand held SC (HEAT) warheds whit precursor. Reduce at 50% penetration for such warhead like PzF-3T (for 60 angle) and abilities to similar reduction in other modern AT weapons (like RPG-29) should be notice as extremely good.

This what modern ERA (Relikt, Knive, etc) have definitely better then ERAWA-2 is ability to stop APFSDS penetrator. Probably ERAWA can deal with only 1980s penetrators (3BM26, 3BM42, 3BM32, DM33A1 etc) whit fluent effectiveness between 30-56% and in case modern monoblock 1980s penetrator rather based on rebound mehanism (like in DM-33A1 case) then destroying penetrator. So effectiveness against modern APFSDS (even 1990s) is rather highly questionable. Good ERAWA feature is covered ERA cassette by microwave absorber to reduce RCS.

In summary: ERAWA-1 and ERAWA-2 are good example completely different way making ERA to achieve quite good results. Of course ERAWA seems not to be so good as the most modern IBD, FCCT Microtek, NII Stali solutions, but it's not bad anyway. For polish point of view ERAWA armor was necessary and relatively cheap way to increase a lot PT-91 (so originally T-72M1) armor protection.

Future of the ERAWA armor in Poland is unclear. Probably for pure German reasons ERAWA will not be used during polish Leopard-2A4 modernization, and then Leopard-2A5 ones program. Trilateral Polish Army – German Army - KMW agreement almost blocked using pure polish solution in modernization program, and few allowed (polish RCWS, driver camera, BMS, etc) where more important and cheaper then long an expensive ERA certification process – including fire tests.

Lighter platforms don't need such heavy ERA as ERAWA-1/2 and in polish Military Institute of Armament Technology was developed whole family armors for lighter then tanks platforms like:

- CERAWA-1 composite-reactive armor

- lightweight special bar armor (the cage)

- ceramic armor CAWA-4 and CAWA-3

- main multilayer passive armor CAWA-2 and CAWA-1NA armor

In other institutes in Poland where developed NERA armor and polonisated lightweight ceramic armor

for Rosomak (AMV) APC.

In fact ERAWA successor can be used only in future IFV.

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