



Projectile or warhead

The invention relates to projectiles or warheads for combating targets, in particular armoured targets, with an inner arrangement for the dynamic formation of expanding zones and for achieving large lateral effects.

In a great many fields of application for projectiles and warheads it is also desirable, in addition to the demanded penetration power, to achieve the highest possible effect over area (lateral effect) for increasing the efficiency. This is required in particular in the case of projectiles against flying targets such as fixed-wing aircraft, unarmoured helicopters or missiles, which from a terminal-ballistic viewpoint belong to the easier target classes.

In this field, however, so-called "hardened" objects are appearing increasingly, so that in addition to the high lateral effects in some cases also high penetration powers are demanded. The same applies in a comparable way to other structures such as ships, for example. But also in respect of armour-piercing projectiles of high penetration power, which must be achieved with increasingly slender and long penetrators, ensuring a sufficient lateral effect during the target penetration or in the target interior is of increasing importance. These requirements apply both to cannon-launched kinetic energy projectiles (KE projectiles) and to warheads with KE effective bodies or so-called hybrid projectiles made of KE effective bodies and hollow charges.

Pursuant to DE 25 54 600 C1 a solution is proposed, by means of which an improvement of the lateral effect of kinetic energy projectiles is achieved in that by way of a forward core, which conically tapers in its rear end, the said conical end is delayed on impact and in the subsequent penetration process and is thus pushed in between the prefabricated subprojectiles which are located in the rear multi-part core and accelerates



the said subprojectiles radially either immediately or by way of a deformable transition piece. The function of this constructionally sophisticated solution was proved both in spin-stabilized and aerodynamically stabilized projectiles (arrow projectiles). However, the effectiveness is particularly limited owing to the constructional requirements. Particularly where thin target structures are concerned they are not effective. Such solutions are very complex and thus cost-intensive. All these factors severely limit the application.

For the purpose of achieving increased lateral effects tests with projectiles which on impacting a target disintegrate or fragment are also known. These concern effective bodies with brittle steels or hard metals or brittle heavy metals, for example. Such approaches to solutions, however, do not lead to very large fragmentation cone angles in comparison with the usual penetrators. The possibilities concerning construction and materials are severely limited in this case too. Moreover, such solutions are preferably suitable for spin-stabilized projectiles only. Furthermore, the penetration power of such projectiles decreases drastically, so that they are only useful for a limited range of applications. Such solutions are less effective particularly in the case of thinner targets, and also in the case of structured targets (multi-plate targets).

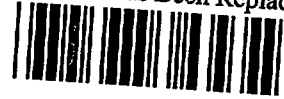
In EP 0 343 389 A1 the projectile core of a discarding sabot projectile is described which consists of a relatively brittle central portion of the projectile core in which a relatively ductile projectile-core rod is inserted which is anchored at its rear end in the tail portion of the projectile core and at its front end in a nose of the projectile core. For the brittle middle portion of the projectile core a frangible tungsten is preferably proposed, whereas the projectile-core rod consists of a ductile tungsten, hard metal or any other material with a terminal-ballistic effect. The relatively brittle middle portion of the projectile core already disintegrates during the penetration of the first target plate of a multi-layer armour-



plating, whereas the ductile projectile-core rod does not fragment during the penetration process, but instead successively penetrates the following target plates and thus decomposes continuously in its length and mass. The relatively thin and thus low-mass projectile element is, however, not suitable particularly for achieving a larger depth effect or for penetrating deeper targets with a continuous lateral effect. The densities of the brittle middle portion of the projectile core and the ductile projectile-core rod are nearly the same. A high lateral effect of the fragments in combination with a penetration of multi-layer target plates is thus not provided.

WO 92/15836 A1 discloses a spin-stabilized armour-piercing fragmentation projectile which is formed from a projectile case with a high-density material and a forward head element of the same material, in which the disintegration of the projectile case occurs mechanically with the help of a prestressed heavy material located in a pocket hole in the tail portion of the projectile case and of a pre-notch in the case structure. Tungsten powder is proposed as compressed filling material. This solution is as ineffective in relatively thin targets as in deep targets. It is also constructionally impossible to achieve a compression with a terminal-ballistic effect owing to the pulverulent filling material.

EP 0 238 818 A1 describes a spin-stabilized discarding sabot projectile which consists of a hollow fragmentation jacket which is closed at the rear and front and a projectile nose attached thereto. An inert powder with a density of not less than 10 g/cm^3 is proposed as filling material. The fragmentation jacket is provided with predetermined breaking points which determine the size of the individual fragments. The fragmentation jacket is to fragment after the penetration of the projectile and disintegrate into individual effective fragments. The pulverulent filling made of tungsten is expelled after the penetration owing to the rotation of the projectile.



A high lateral and, simultaneously, high depth effect cannot be achieved with such a concept, as the invention is based primarily on the centrifugal forces of a spin projectile and despite prefragmentation the tungsten powder will not sufficiently disintegrate the surrounding thick jacket in the radial direction, not least owing to the natural hollow spaces. Moreover, the powder filling is intended as a replacement for an explosive and incendiary charge, with the high density being intended to directly produce terminal-ballistic effects.

A further disintegration principle for achieving a lateral effect is proposed in the printed publication (JP 08061898 A) in which a reactive metal is arranged in a metal cylinder which reacts thermochemically with air and water when the armour-piercing munition collides with an object. It is obviously intended in this case to produce a "quasi" explosive and incendiary effect by the special reaction of the metal so as to achieve a strong radial destructive force.

A non-armour-piercing method to achieve an increased lateral effect with a projectile after impacting or penetration of a target is known from DE 28 39 372 A1 in which a projectile is proposed for hunting purposes which consists of a massive projectile jacket which is provided with a central pocket hole extending from the front to the rear in which a filling, preferably made of lead, with hollow spaces, is introduced. In this design the heavier material is located in the interior of the surrounding case and causes a mushrooming of the forward projectile part during the penetration of the soft target body. In this way the projectile is able to transmit its energy to the body of the hunted game in an intended and increased manner and achieve a higher spreading effect. A lateral disintegration of the projectile body or a lateral fragmentation effect is not intended, and indeed is even undesirable. A similar effect is achieved with the prohibited dum-dum principle against persons.

With respect to solutions provided for armour-piercing



projectiles with high penetration power which must be achieved with increasingly slender and long penetrators, few inventions are known whose subject matter is the achievement of a sufficient lateral effect. Usually, the objective of such projectile designs is solely the achievement of a large depth power.

DE 40 07 196 A1 describes a hyperspeed kinetic energy projectile with a carrying outer jacket which encloses a mass body of heavy bulk material, preferably tungsten powder and depleted uranium powder. In this invention the case is merely used for the stability of the insert consisting of the heavy-metal powder during the launch acceleration and the flying phase. The projectile, which impacts the target at a very high velocity, achieves its high depth effect because in the hyperspeed range the strength of the material of the penetrator no longer or only insignificantly influences the penetration power. At lower velocities the depth power thus greatly decreases. The lateral effect is imperceptibly low. These projectiles are known as so-called segmented penetrators.

In US 5,440,995 a heavy-metal penetrator is presented which is composed of tungsten whiskers. In the case of common penetrators made of polycrystalline tungsten heavy metal, a plastic or hydrodynamic head (mushroom) forms during the penetration of an armoured target, which head influences or reduces the penetration depth power. The proposed penetrator concept is intended to prevent this head formation and thus to increase the depth power. The principle is therefore solely aimed at the achievement of the highest possible depth power. A lateral effect is not provided.

A subcalibre kinetic energy projectile with a high length/diameter ratio and a hybrid construction is disclosed in EP 0 111 712 A1 which essentially consists of a main, intermediate and nose body. The intermediate body, consisting of a brittle high-density sintered material such as tungsten or

depleted uranium, is connected in a plane abutting joint area on the rear side with the main body and on the front side with the nose body also in a plane abutting joint area, with both the main body and the nose body being formed from a tenacious high-density sintered material such as the same aforementioned metallic materials. On impacting an armoured target the particles which form from the brittle material of the intermediate body are to expand the penetration channel and cause a strong blasting effect after the first target plate. Such free buffer layers in principle act both in a pressure- and power-reducing way. The fragmentation effect remains substantially limited both locally and laterally owing to the design and the low differences in density between the brittle and tenacious sintered materials, as the brittle intermediate body is compressed on impact in the axial direction by the nose body and main body and, together with these two ballistically highly effective masses, is driven purely axially through the penetration channel.

A further development of the invention as discussed above according to EP 0 111 712 A1 is described in DE 33 39 078 A1 in which the connection between the brittle high-density intermediate body and the ductile main body also of high density, or the same density, or the brittle intermediate body per se, is stabilized by a high-strength thin case. Although this causes an improvement of the stability of the KE projectile during the launching and the flying phase, it does not, however, change anything with respect to the terminal-ballistic mode of action as compared with the invention pursuant to EP 0 111 712 A1.

From the state of the art as discussed above one can derive that to date practically no solutions, and particularly no simple ones, are known for an armour-piercing projectile where a high lateral affect is achieved in different targets in conjunction with an adequate depth power.

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It is further known that by using glass bodies which are enclosed under high pressure during the impact and penetration of projectiles it is possible to achieve increased lateral effects. These effects are caused by the special dynamic behaviour of glass, which has been used for decades in the area of the protection of armour against hollow charges. Accordingly, the use of glass leads by way of a so-called "crater collapse" to an influence on the stream during the penetration and thus to a considerable reduction of the penetration depth.

Any application of brittle materials such as glass or ceramics as a dynamically acting medium is, however, naturally subject to considerable limitations concerning the production techniques for the projectiles and, optionally, warheads and concerning the transmission of forces, such as during the acceleration phase of the projectiles or missiles. The technical problems with the introduction of glass into the corresponding hollow spaces of a projectile body are an example. In prefabricated glass bodies the constructional possibilities for use are severely limited. Moreover, the configuration of the contact surfaces with the surrounding (enveloping) bodies requires considerable technical efforts. Furthermore, glass and ceramics are limited to a certain density range.

In the case of the introduction of glass by way of casting, which means that ceramics can in principle be omitted owing to the extremely high sintering temperatures required, stresses in the glass body per se would have to be expected as a result of the cooling process even if a perfect casting-in could be achieved. These stresses may in some cases also have a negative effect on the surrounding bodies. Moreover, as was already mentioned above, contact problems arise at the transition surfaces between the medium and the parts surrounding this medium. But even during the casting-in of glass, temperatures occur which in many cases would lead to impermissible changes



in the surrounding materials. Furthermore, in the use of these fragile and impact-sensitive substances as a dynamically active medium it is not possible in principle, with the exception of pure pressure forces (primarily in the sense of a polydirectional or hydrostatic pressure), to transmit any technical stresses, and thus forces (tension and shearing forces), worth mentioning.

Furthermore, in the Franco-German Institute (hereinafter referred to as ISL) experiments with provided GRP materials have been performed. It was intended in these experiments to test primarily whether glass could be replaced as the effect-carrying medium and whether in the case of a positive answer to this question it could be assumed, analogously to the protective technology, that the glass content (resin content) or the hardness of the GRP material, for example, are relevant for the operativeness and that consequently with special highly filled varieties it is possible to achieve a disintegration factor comparable to pure glass. It was also proposed to verify in principle the previously presumed "glass effect" by varying the resin content.

The experiments confirmed that with glass fibre-reinforced materials with a high proportion of glass (a proportion of approx. 80% by weight) terminal-ballistic effects can be achieved which correspond to those of pure glass as working medium. These first experiments also led to the result, however, that with materials which possess a considerably lower proportion of glass it is possible to achieve in a surprising manner corresponding or even considerably higher lateral effects. The further considerations arising from this and the experiments additionally proposed to the ISL and performed there led to the finding that the effects originally described in connection with glass are obviously not so crucial for the increased lateral effects observed in this connection.

According to the latest findings it is, rather, important to



introduce into a body with a terminal-ballistic effect or into a case made of a material which has a terminal-ballistic capability an "expanding medium" (hereinafter referred to as EM) which shows little compressibility and possesses a comparatively low density or terminal-ballistic power in relation to the actual effective bodies. The same naturally also applies in the case where the EM is located between an outer body with terminal-ballistic effectiveness and a central penetrator.

The terminal-ballistic power of an effective body is determined in the range of lower impact velocities (below 1000 m/s) by its mechanical properties and its density, and in the upper velocity range (above 1000 m/s) increasingly by its density.

In the thesis "Das Verhalten von Kupferstiften beim Auftreffen auf verschiedene Werkstoffe mit Geschwindigkeiten zwischen 50 m/s und 1650 m/s [The behaviour of copper pins on impacting various materials at velocities between 50 m/s and 1650 m/s]" by Dipl.-Ing. Günter Weihrauch of February 12, 1971 of the University (TH) Karlsruhe and in the ISL report with the same name, a number of things are said about this behaviour on pages 98 to 101. The following pressure balance arises in a co-ordinate system which is moved along with the stagnation point:

$$\frac{1}{2}\rho_p * (v - u)^2 = \frac{1}{2}\rho_z * u^2 + F$$

with v = projectile velocity, u = penetration velocity, ρ_p = density of the projectile material, ρ_z = density of the target material, F = factor which is variable with the flattening velocity of the expanding zone and depends both on the dynamic strength of the target and of the projectile material and thus also of the EM.

Accordingly, the influences arising from the compressibility of the material and the propagation velocities of the elastic and



plastic faults are also included by way of term F. At higher projectile velocities v the proportion of F decreases and the known Bernoulli's equation applies with sufficient accuracy:

$$\frac{1}{2}\rho_p * (v - u)^2 = \frac{1}{2}\rho_z * u^2.$$

From this equation one obtains for the penetration velocity u , which is also known as the crater base velocity, a term where the velocity u only depends on the projectile velocity v and the material densities ρ_z and ρ_p :

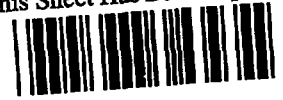
$$u = v / (1 + \sqrt{(\rho_z / \rho_p)}).$$

If the projectile does not consist of a uniform material, this term applies under the prerequisite of high projectile velocities v for every single material in the projectile, with the respective material density such as ρ_{EM} or ρ_{case} then having to be inserted for ρ_p .

It can easily be derived therefrom that materials with lower density than the actual penetrator material with a high terminal- ballistic effect will achieve lower penetration velocities at high projectile velocities and thus will lag behind in the target as compared with the penetration material with a high terminal-ballistic effect.

At relatively low projectile velocities, F becomes a velocity term on an equal standing, i.e. the dynamic strengths of the materials involved are equally decisive. For the achievement of rapidly commencing and high lateral effects, low-strength materials should then be used as expanding medium, there still being a relatively large amount of leeway in the case of the density.

Accordingly, at high projectile velocities (above 1000 m/s) one can vary the density of the EM, because then the mechanical



properties do not play a major role any more.

At very high velocities (1500 m/s up to several km/s) one can usually entirely neglect the dimensional stability of projectile and target material, so that the strength of the materials involved does not play a role any more. In this case metallic and other materials can also be treated approximately as liquids.

The velocity from which the strength of the matter can be ignored depends, however, heavily on the respective properties of the material. Accordingly, these impact phenomena from the high-velocity range, for example, already occur at relatively low velocities when dense and at the same time dynamically soft materials such as lead, copper or tantalum are involved.

These considerations show that the effectiveness of the arrangements as proposed here is not limited to a specific velocity range, but is present both from relatively low impact velocities (several 100 m/s), as occur at large combating distances for example, right up to very high impact velocities in the order of several km/s, as occur for example in engagement situations with so-called tactical missiles (TBM defence).

In line with the above considerations it is necessary to influence the dynamics of the inner expanding zone in projectiles and warheads over wide limits and with very simple means.

It is therefore the object of the invention to design projectiles and warheads with simple means in such a way that the same can both achieve a strong lateral effect and simultaneously ensure high penetration depths if required, for the largest possible number of targets imaginable.

This object is achieved in accordance with the invention by the

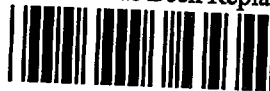


features specified in the characterizing part of claim 1.

Further features, details and advantages arise from the description below in conjunction with the claims and the individual figures.

The invention will be described below with reference to the drawing in which:

- Figure 1 shows in three different phases a basic representation of the penetration and expanding process in accordance with the invention;
- Figure 2 shows in three different phases a basic representation of the penetration and expanding process in accordance with the invention with an additional central penetrator;
- Figure 3 shows in three different phases a basic representation of the penetration process and the lateral fragmentation;
- Figure 4 shows a basic representation of the process in accordance with the invention for a two-plate target;
- Figure 5 shows a basic representation of the process in accordance with the invention for an arrangement with a central penetrator and the penetration through a two-plate target;
- Figure 6 shows a basic representation of the experimental model projectile;
- Figure 7 shows an X-ray flash photograph of an experiment with GRP as expanding medium (EM);



- Figure 8 shows an X-ray flash photograph of an experiment with a hollow model projectile without expanding medium;
- Figure 9 shows an X-ray flash photograph of a further experiment with GRP as expanding medium;
- Figure 10 shows an X-ray flash photograph of a further experiment with aluminium as expanding medium;
- Figure 11 shows an X-ray flash photograph of a further experiment with an expanding medium of particularly low density (PE);
- Figure 12 shows the crater, represented on a grid, of the reference experiment (Fig. 8) with a hollow penetrator without expanding medium;
- Figure 13 shows the fragmentation picture, represented on a grid, of the experiment with GRP in accordance with Fig. 9 as EM;
- Figure 14 shows the fragmentation picture, represented on a grid, of the experiment with aluminium in accordance with Fig. 10 as EM;
- Figure 15 shows the fragmentation picture, represented on a grid, of the experiment with PE in accordance with Fig. 11 as EM;
- Figure 16 shows an X-ray flash photograph of a further experiment with GRP as expanding medium and a thinner first target plate;
- Figure 17 shows an X-ray flash photograph of a further experiment with GRP as expanding medium in accordance with Fig. 9 and a low impact velocity



(< 1000 m/s);

Figure 17A shows the fragmentation picture, represented on a grid, of the experiment in accordance with Fig. 17;

Figure 18 shows a basic constructional proposal for the introduction of a prefabricated EM body and fixing by a thread and gluing/soldering;

Figure 19 shows a basic constructional proposal for the introduction of a prefabricated EM body and fixing by a connecting medium;

Figure 20 shows a basic constructional proposal for the introduction and fixing of a prefabricated EM body with random surface roughnesses;

Figure 21 shows a modified constructional proposal according to Fig. 20 for the introduction and fixing of a prefabricated EM body;

Figure 22 shows a section through a projectile with EM and central penetrator in accordance with Fig. 2;

Figure 23 shows a section through a projectile with EM and central penetrator and additional strips as subprojectiles;

Figure 24 shows a section through a projectile with EM and central penetrator and additional bodies which are rod-shaped or disposed behind one another and have a terminal-ballistic effect;

Figure 24A shows a section through a projectile with EM without a central penetrator and with additional bodies which are rod-shaped or disposed behind one



- Figure 25 another and have a terminal-ballistic effect; shows a section through a projectile with EM and central penetrator and additional notches on the inner side of the outer body with a terminal-ballistic effect;
- Figure 26 shows a section through a projectile with EM without a central penetrator and with additional notches on the outer side of the outer body with a terminal-ballistic effect;
- Figure 27 shows a section through a projectile with EM and central penetrator and random bodies embedded in the EM and having a terminal-ballistic or any other effect;
- Figure 28 shows a section through a projectile with EM without a central penetrator and with random bodies embedded in the EM and having a terminal-ballistic or any other effect;
- Figure 29 shows a section through a projectile with EM and four centrally arranged penetrators;
- Figure 30 shows a section through a projectile with EM and a centrally arranged penetrator with a square (random) cross section;
- Figure 30A shows a section through a projectile with EM and a centrally arranged cylindrical penetrator with a hollow space;
- Figure 31 shows a partial section through a projectile with a stepped arrangement of the EM;
- Figure 32 shows a partial section through a projectile with a partial arrangement of the EM for the



achievement of a high initial penetration power;

Figure 33 shows a further partial section through a projectile with three dynamic zones for the achievement of different lateral and depth effects;

Figure 34 shows a section through a projectile with a central penetrator and two radially arranged dynamic zones for the achievement of different lateral and depth effects;

Figure 35A shows a section through a projectile with EM without a central penetrator and with an outer case made of a ring of longitudinal structures;

Figure 35B shows a section through a projectile with EM without a central penetrator and with two different outer cases;

Figure 35C shows a section through a projectile with EM without a central penetrator and with an outer case in which random bodies are embedded;

Figure 35D shows a section through a projectile with EM without a central penetrator and with a ring of subpenetrators on the inner side of the outer case;

Figure 36 shows a projectile with EM and a hollow nose;

Figure 37 shows a projectile with EM and a nose filled with EM;

Figure 38 shows a projectile with EM and a massive nose;

Figure 39A shows a special shape of the nose in which the EM



reaches into the nose;

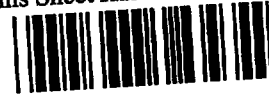
Figure 39B shows a special shape of the nose which in partial regions contains the EM;

The sequence of the penetration and expanding process in accordance with the invention is shown in a basic and schematic manner in Figure 1.

Owing to its specific properties, the inner or enclosed expanding medium (EM) 1 lags behind relative to the surrounding terminal-ballistic effective body 2 during the penetration. Owing to its compressibility, which is also limited under the high pressures occurring, a lateral flattening and thus also a dynamic expanding of the surrounding material 2 occurs as a result of the material of the expanding medium 1 which continues to flow from behind.

This process is determined by the physical and mechanical properties of the involved materials 1 and 2. The dynamic expanding usually leads to a tearing-open or the disintegration of the outer body (case) 2. In conjunction with its mechanical properties, dimensions, its density and velocity (sliding-by velocity), an angular range arises in which the resulting subpenetrators or fragments move.

Figure 1 shows the three penetration states 1A, 1B and 1C, with 1A showing a first phase, 1B a second phase and 1C a third phase of the process. In Subfigure 1A the projectile consisting of the expanding medium 1 and a case 2 with a terminal-ballistic effect is currently impacting the target plate 3. In Subfigure 1B a pressure zone 4 has built up as a result of the reduced penetration of the EM 1 into the target material 3. This leads to an expansion or deflection region 5 of the case which is sliding by. This process has progressed further in Subfigure 1C. The pressure and expansion zone 4a has widened and lags behind the case which is sliding by, in an



increasingly marked way. The deflected or expanded region 5a increases accordingly.

Figure 2 shows this process according to Fig. 1 with a projectile in which a central penetrator 6 is additionally located. Here too three different penetration states 2A, 2B and 2C are shown at different penetration times. At the time 2B the pressure and expanding zone 4 has formed between the case 2, which is sliding by and is expanded or deflected in the deformation zone 5, and the central penetrator 6 which also penetrates more rapidly and usually possesses at higher impact velocities a plastic or hydrodynamic head 6a. Subfigure 2C shows this process in an even later state. The pressure and expanding zone 4a is enlarged and the case 2 is further deformed via the deflection zone 5a. Owing to its new direction of movement, the deflected zone 5b penetrates into the target plate 3 with a considerably increased radial component.

Figure 3 depicts in Subfigures 3A, 3B and 3C the effects caused by the projectile according to Fig. 1 in the region of the ejection crater in the target plate 3. Subfigure 3A corresponds to the Subfigure 1C of Fig. 1. At the time or position 3B, following the formation of shear fractures, a breakout region 7 begins to form which, owing to the described high lateral effect during the penetration, is considerably larger than is the case with common KE projectiles. As a result of the simultaneously occurring relief from the rear side of the plate, the pressure zone 4a of the EM is relieved. The relieved material 1a exits from the crater behind the breakout region 7 (Subfigure 3C), followed by the residual projectile 5c. As a result of the detaching ejection crater region 7a which exits with increasing acceleration and a further relief, there is usually also a separation of the expanded penetrator region (case region) 5b from the residual projectile 5c, so that case fragments 5d form. Owing to their higher velocity, the latter slide off from the target region 7a which is still exiting at a relatively low velocity. In this process they are deflected



still further radially. This causes an additional enlargement of the exit angle 8 of the fragments 5d.

Figure 4 depicts the process according to Figs. 1 and 3 in an exemplary manner in a two-plate target.

Once a crater has been formed in the first plate 3 (Subfigure 4a), whose size arises substantially from the projectile parameters (construction, materials, dimensions, impact velocity) and the target plate data (material, thickness, mechanical properties), the residual projectile 9 which still remains after the formation of the case fragments 5d, the broken-out crater region 7a and the fragments 5d of the expanded partial region of the case impact the second plate 3a. Subfigure 4B shows a view of the impinged second plate 3a. Different crater zones arise: the impact region 10 which is formed by the residual projectile 9 and the central part of the breakout region 7a, crater 10a which is caused by the outer part of the breakout region 7a, and the region of the fragments 11 which is produced by the case fragments 5d. Still further outside is the region 11a of the fragments 7b torn out from the target material 3.

Usually, the outer crater regions in particular will overlap to a greater or lesser extent depending on the physical and technical conditions.

When adding further target plates the descriptions set out above apply analogously. Figure 5 shows the case where a projectile with a central penetrator 6 according to Fig. 2 penetrates a two-plate target according to Fig. 4. On penetration of the first plate 3 the descriptions as given in connection with Figure 4A apply, with the addition of the central penetrator 6 or penetrating penetrator head 6a. Thereafter the residual penetrator 6b penetrates the broken-out crater region 7a and forms a further breakout 7c therein. The thickness of the second plate 3a was chosen here in such a way



that it is still penetrated by the central residual penetrator 6b. Only the correspondingly shortened residual penetrator 6c exits after the second plate, surrounded by a fragmentation cone made of penetrator parts 13 and target fragments 13a which have formed from the breakout 7c or were detached from the second target plate 3a. This target zone thus corresponds to the usual penetration picture of a KE projectile without EM.

A section through the second plate 3a shows the different crater zones. Firstly, the inner crater zone 12, formed by the residual penetrator 6b and the breakout 7c, followed by the region 10 which is formed by the residual projectile without a central penetrator 9a. A crater region 10a follows which is produced by the broken-out crater region 7a. This is followed by a crater region 11 produced by the fragments 5d of the disintegrated partial region of the case. Still further outside there is located a crater region 11a which is formed by the broken-out target fragments 7b of the first plate 3.

These considerations lead to the conclusion that in the projectile design as described herein an introduced central penetrator 6 is virtually not impaired in its terminal-ballistic capability. Accordingly, its penetration depth corresponds to the performance as achieved by such massive penetrators alone. This applies analogously with corresponding dimensionings also to penetrators which are introduced at other positions in the expanding medium (preferably in the vicinity of the axis). At the same time this finding explains how in the case of armour-piercing munition a required high basic penetration power is to be combined with the large lateral effects as described herein.

As was already mentioned, experiments with model projectiles according to Figure 6 were performed in accordance with the considerations as set out above. The projectiles consisted in accordance with Fig. 1 of a case made of tungsten heavy metal (WH; length 40 mm, outer diameter 6 mm, inner diameter 3.5 mm,

density 17.6 g/cm^3) which enclosed the introduced expanding medium of the same length (diameter 3.5 mm). The tail was formed by a resistance plate for aerodynamic stabilization.

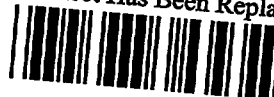
Figs. 7 to 11 and Figs. 16 to 17 show X-ray flash pictures of the experiments. All images concern two X-ray flash photographs each taken at two different times. The left image in each case shows the impacting projectile (in all graphics and images the projectile flies from left to right), the right one shows the respective deformation condition at the time of the photograph. Both relatively thick one-plate targets (Fig. 7) and two-plate targets (Figs. 8 to 11 and Figs. 16 to 17) were shot at.

Figure 7 shows the X-ray flash pictures of an experiment with a homogeneous target plate 3 made of armour steel (strength approx. 1000 N/mm^2) of a thickness of 25 mm. The EM 1 consisted here of a GRP with a density of 1.85 g/m^3 . The crater contours are entered as dashed lines, and the crater which is produced in corresponding comparison experiments of massive heavy-metal penetrators of the same outer diameter is entered in dotted lines. The crater diameters of the case 2 consisting of WH without EM 1 are comparable to this.

The right frame shows a previously unknown, enormous enlargement of the produced crater, and thus also an enlargement of the exiting fragmentation cone, formed from projectile and target fragments.

This allowed experimental evidence to be provided that in the case of massive target plates there is a perfect function of the expanding medium within the terms as described herein (corresponding to Fig. 1). The lateral effect was a multiple of all previously known results. In these experiments, for example, a crater volume of approximately 5 times more was achieved as compared with being fired at with a massive penetrator made of WH of the same outer diameter or a WH casing of the same mass without EM.

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Corresponding results were also achieved with other expanding media such as copper, aluminium and polyethylene in the velocity range between 1000 m/s and 1800 m/s.

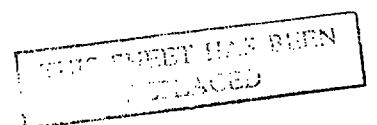
The experiments in connection with Figs. 8 to 11 were intended to provide evidence that both a relatively weak first plate 3 with simultaneous low density and thus low mass per unit area causes the full lateral effect and that in this case different materials other than the EM 1 can be used in accordance with the above statements.

A two-plate construction according to Fig. 4 was used as a target, with a first plate 3 made of duraluminium with a strength of 400 N/mm^2 and a thickness of 12 mm and a second plate 3a made of armour steel and erected at a distance of 80 mm. The impact velocity in these experiments was between 1400 and 1800 m/s. The projectile construction corresponded to the structure in accordance with Fig. 6. The expanding medium 1 was varied, with the density being assumed as main parameter in accordance with the high impact velocities.

Figure 8 shows first of all the comparison experiment with a hollow penetrator (i.e. without EM) made of WH with the same outer diameter. As a result of the relatively light target plate, virtually no plastic head has formed. With the exception of a small breakout on the right X-ray flash picture, one cannot recognize any lateral deformation.

The GRP that was already used in the experiment in accordance with Fig. 7 was used as EM in the experiment in connection with Figure 9. The lateral disintegration occurs to the full extent here.

Figure 10 shows an experiment with aluminium as EM. The lateral disintegration occurs in accordance with the above descriptions, but surprisingly more markedly.





In Figure 11 polyethylene (PE) was used as EM. In this material with a very low density, but with a sufficiently low dynamic compressibility or relatively large shock hardness, there is a very marked lateral disintegration as well.

These X-ray flash pictures show clearly that even in the case of perfect lateral acceleration there are considerable differences in the behaviour of the various expanding media.

Accordingly, in the case of PE as EM with a particularly low density (Fig. 11) for example, the entire heavy-metal case is in many cases slit open over the entire length of the projectile by the first plate, with the lateral acceleration of the formed segments (subpenetrators) occurring continuously from the nose to the tail (cf. Fig. 11, on the right). In the case of aluminium as EM (Fig. 10) there is an even more marked lateral effect at least under the prerequisites which apply to this experiment. However, in this case only about half of the projectile length is greatly expanded.

This influence will presumably show even more clearly when using copper or lead as EM. Owing to their relatively high density they should lead to correspondingly lower lateral accelerations at even shorter expanded projectile lengths.

In addition to the aforementioned projectile and target parameters, the velocity with which the plastic deformation propagates in a material, but which should not be confused with the speed of sound which usually propagates with a velocity of several km/s, certainly also plays an important role in the axial progression of the disintegration. This velocity range extends from a few 100 m/s up to the order of 1 km/s and thus lies considerably below the speed of sound of the respective materials.

The processes in unrestrained cylindrical bodies during the



dynamic flattening are discussed in detail and described analytically in the aforementioned thesis by G. Weihrauch on page 25 ff. on the basis of copper as an example. The contexts outlined there only apply to freely flattening bodies, i.e. without lateral restraining. They can therefore also only be used to a limited extent for fundamental considerations in connection with the arrangements as proposed herein. In particular, the lateral restraining of the EM by the surrounding material has a decisive influence both on the lateral and the axial deformation velocity of the EM.

Accordingly, any lateral restraining can help to achieve, and this is also confirmed by the present experimental results, that even at relatively low projectile velocities in the order of 1000 m/s for example, the plastic deformation in the EM propagates in aluminium, GRP and in particular polyethylene or nylon with relatively high axial velocity, which means that it no longer primarily remains limited to the forward projectile region (cf. Fig. 11 and Fig. 17 in particular).

A comparison of the exemplary materials chosen for the formation of an expanding zone even in lighter target structures makes clear that there are a multiplicity of materials which meet the stated requirements not only in respect of the aforementioned considerations, but that the properties of the EM can be changed within wide limits. Moreover, the comparatively few materials that have been examined to date show that the lateral effects are adjustable or controllable by way of the behaviour of the EM under dynamic compression.

The experiments also prove that not the special property of pure glass under dynamic load, but the considerations on which this invention is based are decisive for the formation of an expanding zone.

Ductile materials with higher density (such as soft iron, armco

iron, lead, copper, tantalum, or even also heavy-metal admixtures) open up the possibility to use such expanding media in cases when, for example, higher mean densities of the projectiles are demanded or when certain constructional requirements, such as exterior-ballistic requirements, with respect to the centre-of-mass position for example have to be fulfilled.

Figs. 12 to 15 show the corresponding fragment distributions of the experiments in accordance with Figs. 8 to 11 on the second target plate 3a. The small craters in the outermost region 11a (Fig. 5) which were formed by the detached target plate fragments 7b were not taken into consideration.

Figure 12 shows the crater of the reference experiment (Fig. 8) with a hollow penetrator. It shows clearly the effect of an introduced EM in comparison with Figs. 13 to 15. The crater diameter is approx. 11 mm, and is thus in the order of two projectile diameters.

Figure 13, as a fragmentation image of the experiment (Fig. 9) with GRP as EM 1, shows analogously to the description in accordance with Fig. 4 on the second plate 3a, which is located 80 mm away, a relatively even outer distribution 11 of the fragments 5d (diameter approx. 90 mm corresponding to 15 projectile diameters) formed primarily from the case 2, in addition to a considerably enlarged central crater region 10,10a in the order of 4 projectile diameters.

Figure 14 shows the highly interesting crater image corresponding to Fig. 10 which is to be expected with aluminium as EM. The large central crater (diameter of approx. 5 projectile diameters) is surrounded by a ring of longitudinal subcraters (diameter of approx. 10 projectile diameters). The other fragments are distributed in a circle of approx. 13 projectile diameters.

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In Figure 15 (corresponding to Fig. 11), with PE as EM, the subprojectiles formed produced a relatively large inner crater diameter (approx. 6 projectile diameters) which is surrounded by a mixed fragment ring with a diameter of approx. 13 projectile diameters.

In principle, the penetration depth decreases in line with the lateral expansion of the fragments. For here too the known laws of terminal ballistics naturally also apply, so that the total crater volume formed corresponds in a first approximation to the projectile energy introduced into the target.

In order to prove the high lateral effects with arrangements in accordance with this invention two further experimental studies as proposed and performed by the ISL are mentioned by way of example. It was intended to test first whether in the case of a considerably thinner first plate (6 mm as compared with the previous 12 mm of duraluminium) the lateral effect would still occur with the same projectile dimensions in accordance with Fig. 6 (expanding medium: GRP). This is confirmed by the X-ray flash photographs in Figure 16. According to the prerequisites as chosen herein, the projectile still opens very favourably during the passage through the first plate, but only over a comparatively (Fig. 9) small projectile length. Notice should be taken, however, that a more extensive disintegration could be influenced over wide limits both by way of the expanding medium and by way of the geometries.

As the dynamic properties of the expanding material which is enclosed by a body with a terminal-ballistic effect such as tungsten heavy metal (WH), tungsten hard metal (WC), depleted uranium (DU) or high-strength steel can evidently be changed within wide limits owing to the above statements on the density and mechanical properties, the possibilities of application concerning the technical configuration allow the highest range of possible applications both with respect to construction and specific materials, which differ to a correspondingly marked





extent in their width and performance from those when using materials such as glass or ceramics.

As was already mentioned above, combating fixed-wing aircraft and helicopters forms an important field of application for the projectile constructions as described herein. A selective and, optionally, load-dependent disintegration of a munition can, however, also prove to be very advantageous for the design of different warheads or special-purpose munitions, right up to combating tactical missiles. Corresponding arrangements can be used both for types of munitions with large effects in the interior of light targets right up to heavily armoured vehicles as well as ships (Exocet principle). The target scenario to be combated determines the expanding medium to be introduced and the dimensionings.

The arrangements as proposed herein are in principle highly effective in the fields of application as defined so far. In order to ensure the high lateral effects, however, it is necessary to have a pressure and expanding zone. For this purpose it is necessary that certain physical prerequisites are fulfilled in the EM. Thus, among other things, the impact shock or load must be sufficiently high to initiate the process. Moreover, the dimensions of the EM and of the penetration material surrounding the same must be matched to one another.

Within the widest of margins these prerequisites are fulfilled at the relatively high impact velocities as are required in armour-piercing (both rotation-stabilized and aerodynamically stabilized) projectiles or in antiaircraft projectiles, for reasons of exterior- or terminal-ballistics alone. The velocity range is here approximately between 800 m/s and 2000 m/s. The type and dimensioning of the EM and the surrounding case or the construction of the subpenetrators primarily determine the desired effects here.

At even higher velocities the formation of expanding zones will



certainly be even more marked, which means that the proportion of the EM can become smaller with increasing impact velocity.

In a further experiment it was intended to prove the efficiency of arrangements in accordance with Fig. 1 at considerably lower impact velocities. A target construction according to Fig. 4 in conjunction with a projectile according to Fig. 6 was again used as reference. GRP in accordance with Fig. 9 was used as EM.

In the experiment in accordance with Figure 17 the impact velocity v in the target was only 962 m/s. The right X-ray flash photograph shows that here obviously the velocity range was reached from which the lateral disintegration is only just ensured with the predetermined geometrical dimensions and the materials used.

Owing to the nose pressure occurring during the impact a full lateral disintegration was still achieved in the forward part of the projectile. The nose pressure $\rho_p \cdot c_p \cdot v$ (with c_p = speed of sound in the projectile material (or in the EM, respectively), v = impact velocity and ρ_p = density of the projectile material (or of the EM, respectively) is reduced relatively rapidly in the course of the penetration to the quasi-stationary dynamic pressure (Bernoulli pressure: $\rho_p/2 \cdot u^2$ with u = penetration velocity). This pressure is determinative for the formation of the following pressure and expansion zone. The pressure and expansion zone extends here over the entire remaining projectile length as a result of the lateral restraining (cf. the statements in connection with Fig. 11). The case is thus disintegrated into several longitudinal fragments.

Figure 17A shows the corresponding crater image on the second plate (distance 80 mm). The central crater produced corresponds to approx. 5 projectile diameters. The fragmentation cone is

still very considerable with a circle of approx. 11 projectile diameters.

Evidence was thus provided that the high lateral effects are still ensured at impact velocities below 1000 m/s. Moreover, the considerations presented in conjunction with the confirming experiments prove that the desired lateral effects can be ensured and varied within wide limits by way of the geometrical configuration and the choice of the appropriate materials.

According to the considerations presented so far and the findings already made up to this point, it may be assumed, however, that by choosing appropriate parameters it is possible to achieve a high lateral disintegration even at much lower impact velocities. In projectiles or warheads with relatively low impact velocities such as merely a few 100 m/s the margin is certainly limited accordingly and the dimensionings and materials must be matched carefully to one another. The disintegration will be assisted by thin-walled cases, for example.

Similarly, in the case of light armourings, it will be advantageous to use correspondingly thin-walled surrounding envelopes with a terminal-ballistic effect and particularly suitable expanding media such as PE, GRP or light metals such as aluminium.

It is also possible to greatly reduce the penetration depth by means of corresponding dimensionings and pairings of materials such as by very thin cases in conjunction with "sensitive" expanding media and thus to design projectiles with no effect or a very low effect. The use of biodegradable fibre composites as EM is also a particularly viable possibility in this regard. With this novel kind of very light composites, which were mostly developed by DLR Braunschweig, strength values can be achieved which nearly correspond to those of glass fibre-reinforced plastics.

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Such a special case of a cylindrical body with very low penetration power has already been described in the aforementioned thesis of G. Weihrauch on page 100. From the equation $\frac{1}{2} * \rho_p * (v - u)^2 = \frac{1}{2} * \rho_z * u^2 + F$, for $u = 0$ the values $F_x = \frac{1}{2} * \rho_p * v_x^2$ are derived at which no plastic penetration occurs any more. By an appropriate setting of the densities and strengths of the expanding medium and of the penetration material which surrounds the same it is thus possible to prevent a penetration into the target structure nearly entirely.

A technically highly interesting application exists for this borderline case also when a disintegration of the case by way of a suitable EM is to occur in such a way that in the case of special-purpose munition, for example, a target is damaged as little as possible or the projectile slides off from a target without causing any destruction there. For this purpose, however, the target plate must be sufficiently thickly dimensioned in order to avoid any punching through. This is presumably ensured even with thicknesses in the order of 0.5 to 1 projectile diameters.

The range of materials as shown herein allows a very wide range of applications, particularly also utilizing possibilities for the transmission of forces in the axial and radial direction in conjunction with a controllable disintegration mechanism, via the selection or the setting of the material for the expanding zone per se (e.g. by using plastics, light metals, fibre composites or other mixtures).

Materials such as GRP or other plastics play a special role from a technical point of view. As this type of material is only to be used in an exemplary manner to describe the technical advantages in the realization of the present invention, the possibilities for the design of the GRP materials by different production methods shall not be

discussed in detail herein.

Only the following shall be stated as keywords. "proportion of glass can be altered, type of resin, filling materials, load-oriented composites, production methods, cross-linkage techniques, gluing techniques, mixing varieties, variable densities, etc.".

The temperature behaviour of GRP is also very favourable within the terms of the requirements. Moreover, it is known from various fields of technology that a composite of metallic materials (plates, pipes) with glass fibre-reinforced components (technical GRP structures) leads to an overall improved stability under load, particularly in complex load situations. These occur frequently in applications in the area of ballistics.

According to the considerations given above in connection with the example of GRP or plastics, or even metallic components, there are considerable advantages in the application of such materials as dynamic expanding media in projectiles or warheads. In addition to the extremely favourable mechanical values, especially the particularly advantageous technical arrangements and connections shall be briefly outlined below.

Apart from the fact that a very extensive range of materials is available as effect-carrying media, the possibility also arises to use prefabricated inserts, for example. Potential materials are metals with favourable plastic deformation properties such as lead or copper, materials which can be favourably worked such as light metals, materials of low density such as plastics (PE, nylon, etc.) and, naturally, primarily materials which are introduced or glued in in a mechanically favourable manner. Moreover, the EM can be introduced into corresponding hollow spaces if provided with liquid, plastic or kneadable properties. In this respect mixtures or mechanical mixtures are of particular interest.

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In principle, two directions are thus possible for the introduction and connection of metallic materials, plastics or special-purpose materials, and in particular GRP, into the structural bodies which are adjacent or have a restraining action during the impact or penetration of kinetic energy projectiles and projectile parts:

A The introduction as prefabricated technical structure.

B. The introduction as a loose (mush-like or dry) mechanical mixture

Concerning A:

1. Metallic materials. Other materials with different densities and sufficient mechanical strength and low compressibility. Construction of a technical structure.
2. The materials mentioned are introduced as prefabricated bodies and are glued or encased by injection moulding.
3. Combinations of 1. and 2.

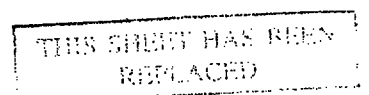
Concerning B:

Injection moulding of thermoplastic and fibre-reinforced materials; castable and pressable mixtures of different materials such as elastomeric materials.

DP-RTM methods (duroplastics) for dry inserted mixtures and mechanical mixtures.

The processes according to B can naturally also be combined with the technical structures according to A.

Concerning the technical configuration and the possibilities





for the introduction of dynamically acting expanding media in projectiles and warheads, particularly interesting variants are possible with regard to the effect such as by:

- * different materials as EM with different specific properties;
- * in the case of GRP: different glass contents and resin types;
- * different radial and/or axial construction of the technical structures;
- * mixtures of differently acting materials (such as differences in density and strength);
- * sliding of prefabricated components into one another (hollow cylinders; telescope; cone);
- * placing in some cases differently dimensioned bodies in a row next to one another;
- * introduction of special materials with specific effects (e.g. incendiary);
- * introduction of explosive materials;
- * introduction of materials with different terminal-ballistic effects.

The advantages in respect of the production technique for the design of projectiles and warheads with such dynamically acting components would be, among other things:

- * the inner and outer bodies (penetrator, case, casing, inserts) can be provided with virtually any desired surfaces. The special-purpose materials bridge the surface

roughnesses for example (cheaper production; possibility of using components from other production);

- * introduction of duroplastic or thermoplastic resins or elastomers by injection, pressure or suction;
- * bridging of edges, shoulders and threads or the like;
- * form-locking by way of threads;
- * favourable temperature behaviour;
- * shock resistance (during launching or in special target structures such as bulkhead arrangements, composite armourings, etc.);
- * controllable disintegration efficiency;
- * embedding of metallic and nonmetallic bodies such as fragments, rods, cylinders and balls right up to prefabricated subprojectiles and small bodies of different shapes and materials.

The aforementioned listing shall in no way be regarded as complete.

In addition to the above statements, reference shall hereby be made to materials other than EM whose application can be of additional benefit in the development of new types of munitions with high lateral effect. This relates in particular to the field of the elastomers. Rubber acts, for example, like polyethylene, in a dynamically incompressible manner when enclosed and can produce very high forces on the walls surrounding it (hydraulic module). In the case of certain types of rubber the modulus of elasticity changes abruptly by a few powers of ten under high dynamic load.

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The injection method is particularly suitable when using elastomers, which method creates a plane and highly durable connection to the surrounding projectile bodies. Even complex types of configurations and connections can be realized in this way in a simple manner.

It is also possible to fill expanding media with metal powders of high density (tungsten, etc.) in order to considerably increase the mean density (e.g. GRP with $> 3 \text{ g/cm}^3$) if desired.

The use of powdery materials (metal or other powders) is also of interest as EM, which are introduced either as unsintered pressed powder parts into the projectile or are pressed directly into the cases in order, for example, to increase the density in the projectile or keep the penetration power low.

Members of the family of synthetic-resin-compressed wood can also be used as EM. They possess a low density and are at the same time relatively incompressible and react in a corresponding dynamic manner (such as Lignostone^(R) with a density range of 0.75 g/cm^3 to 1.35 g/cm^3).

Additional pyrophoric effects in the target after the penetration of the outer skin can be achieved by adding appropriate materials (cerium or cerium composition metal, zirconium, etc.) which can be incorporated easily in the GRP or elastomer materials. But the concentrated introduction or embedding of such materials is also possible in principle.

The introduction of explosive materials, either as admixtures to plastics or as explosives per se, can optionally lead to a controllable detonating disintegration of the projectile body via the function as expanding medium.

The aforementioned extremely wide spectrum of possibilities for combination opens up a completely new field of design for projectiles and warheads in conjunction with the technical

applications, production aspects and special terminal-ballistic effect-carrying media. This wide field of innovations will lead to very interesting concepts for the most varied types of munitions.

The following figures are used to explain the possibilities as discussed in principle above. In this respect, Figs. 18 to 21 relate more to the technical advantages of the introduction of an expanding medium, whereas Figs. 22 to 30A relate more to the technical implementation of such projectiles.

Accordingly, Figure 18 shows the case where a prefabricated body is introduced as EM 1 by means of a thread 15,15a between the surrounding terminal-ballistic effective material 2 and a central penetrator 6. For the purpose of a stronger connection it is possible to additionally introduce a connecting layer as a gluing or soldering layer.

In Figure 19 a prefabricated body is introduced as EM 1 between the surrounding terminal-ballistic effective material 2 and the central penetrator 6. A connecting medium 16 is introduced in the gaps between the case 2 and the central penetrator 6, which medium is preferably used for the transmission of forces.

Figure 20 shows the case where both the inner surface 17 of the projectile case 2 and the surface 18 of the central penetrator 6 have a random surface roughness or surface shape. An EM 1 that is injected for example will bridge any such unevenness and ensures in addition to a lateral effect also a perfect transmission of forces between the case 2 and the central penetrator 6.

In Figure 21 the EM 1 is introduced as a prefabricated body with uneven surfaces. Here a layer 19 with the required properties, which is comparable to the connecting medium 16, ensures the technically perfect connection between the case 2 and the penetrator 6.

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Figure 22, as a reference figure for Figs. 23 to 30A, shows a section through a projectile in accordance with Fig. 2, which projectile is formed from the components of EM 1, case 2 and in some cases a central penetrator 6.

In Figure 23 strips 20 as subprojectiles have been introduced between the central penetrator 6 and the outer projectile element 2. These strips 20 of random length remain substantially excluded from the lateral acceleration. The EM is used here additionally as a carrier for the subprojectiles (strips) 20. Appropriately thin strips 20 can be used for the mere fixing of the central penetrator 6.

In Figure 24 bodies 21 which are either rod-shaped or disposed behind one another and have a terminal-ballistic effect are introduced into the EM. They are radially associatively accelerated as a result of their arrangement on the outside. In this way prefabricated subpenetrators or other effective parts can be laterally accelerated simultaneously with the enclosing body. Figure 24A corresponds to Figure 24 without a central penetrator.

Figure 25 shows the case where notches 22 or embrittlements are provided on the inner side of the surrounding body 2 with a terminal-ballistic effect. They predetermine a desired disintegration of the body 2 or assist the same.

Figure 26 shows in an exemplary manner a projectile without a central penetrator, with notches 23 or other measures benefitting the disintegration being situated on the outer side of the body 2, in contrast to Fig. 25.

In Figure 27 random bodies 24 with a terminal-ballistic or any other effect are embedded in the EM. They are deflected in a greater radial manner by the formation of the expanding zone only in the case of a positioning in the outer region.



Figure 28 shows the corresponding case without a central penetrator with a larger number of identical or different bodies 25.

A further case which is particularly interesting for the configuration of such projectiles is shown in Figure 29. Here, four long penetrators 26, for example, are introduced into the EM in the axial region.

The above examples are intended to show that any desired central penetrators, penetrator parts or other effect-carrying media can be embedded and fixed by way of the EM. This also applies analogously to the case where, for example, the bodies 24 and 25 in Figs. 27 and 28 represent fragments or penetrators.

In Figure 30, a penetrator 27 provided with a square cross section is introduced as an example that the EM allows embedding any desired penetrator shapes and also penetrator materials (they only have to survive the launching acceleration).

In addition to Fig. 30, in Figure 30A the central penetrator 28, which in this case has a cylindrical shape, is provided with a hollow space 29. In this way the mass of the penetrator can be reduced, for example. Such a hollow space can also be filled with foam or can be used for receiving materials with special properties (pyrophoric or explosive).

Furthermore, the positioning of bodies in the EM opens up the possibility to influence the type and the extent of the lateral disintegration or acceleration.

Figs. 31 to 34 show a number of examples with the principle as proposed herein from the large number of possible projectile designs and effective zones of projectiles.



Figure 31 shows the case where the EM is located in a stepped arrangement 30. Such a design, for example, reacts very "sensitively" on impacting a thin structure in the forward part, whereas the rear projectile parts form different subprojectiles or fragments owing to the geometrical configuration and also for instance by the use of different expanding media 1b, 1c and 1d.

Figure 32 shows a penetrator 31 for increasing the effect in the interior of the target after a penetration path corresponding to the forward massive projectile part. For this purpose the EM 1e is located in the tail region of the projectile. Such a projectile 31 is capable of combining high penetration powers with large craters and corresponding lateral effects in the interior of the target or on the following structures.

Figure 33 shows as a further example a projectile 32 with three separate dynamic zones and the EM 1f, 1g and 1h. A projectile 32 which is constructed in such a way is capable, for example, following a partial disintegration in the case of thin outer structures, of developing an increased lateral effect only after the penetration of a thicker, further plate. It is followed by a massive zone for achieving a further, larger penetration path and thereafter the zone with the EM 1h for increasing the residual effect (Fig. 32).

Figure 34 shows a cross section through a projectile 33 which includes, as an example, in the radial direction two of the effective combinations presented herein with EM 1 and 1i between the cases 2 and 2a or the case 2a and the central penetrator 6 respectively. Such combinations can naturally also be arranged more than once on the longitudinal axis of a projectile or be combined with the examples as described above.

Projectiles which contain constructionally predetermined,



enveloping bodies with a terminal-ballistic effect can also be equipped with the effective principle as described herein. Figs. 35A to 35D show four examples which also apply analogously to projectiles with an additional central penetrator.

In Figure 35A the outer case 34 which restrains the EM consists of a ring of longitudinal structures. They are either mechanically solidly connected with one another, e.g. also by thin sleeves, or glued or soldered together. It is also possible to treat the case by an appropriate treatment such as inductive hardening or laser embrittling in such a way that the same is fragmented into predetermined bodies under dynamic load.

Figure 35B shows the case where a case which restrains the EM, corresponding to the case 2 of Fig. 22, is surrounded by an outer case 34 corresponding to Fig. 35A. In Figure 35C random bodies 37 are embedded in the case 36. In Figure 35D a ring of subpenetrators or fragments 34 corresponding to Fig. 35B is located on the inner side of the outer case 35.

A further element which is important for the efficiency of a projectile is the projectile nose. Below, a number of basic examples are shown (hollow nose, massive nose and special shapes of noses), with the configuration of the noses in principle allowing for the full effectiveness of the principle as described herein, which means that it does not negatively influence the same or supplements it in a useful way.

Figure 36 shows an example of hollow noses 38. They are used primarily as exterior-ballistic hoods and are immediately destroyed on impacting even light structures, so that the lateral acceleration process can be initiated immediately by the impact shock, as already described. Figure 37 shows a nose 39 according to Fig. 36, filled with an EM 40. Figure 38 shows a massive nose 41. It can be of one or more than one part and



is suitable, for example, in cases where more massive preliminary armourings are to be penetrated without any immediate disintegration of the projectile.

Figs. 39A and 39B serve as examples of special shapes of noses. In Figure 39A the EM 42 reaches into the nose 43. In Figure 39B the nose 44 contains an EM 45 in partial regions. By way of the construction or design or the selection of material of the respective nose or the forward part it is also possible to start the initiation of a high lateral effect both in an accelerated manner (by a particular rapid transmission of the shock load and thus rapid build-up of pressure) and in a delayed manner. This is of interest, for example, when the lateral fragmentation effect is to occur at a specific target depth or in a specific target region.

It is also possible by means of a forward or lateral (outer) "protective device" to bring constructions with the described lateral effect to the desired location in a target structure, so that this effect will become effective only at such a location. Such a protective case can also form a hollow space between an outer case and the construction for the achievement of the lateral effect. Similarly, the protection can be formed by a buffering material which forms the outer case either by itself or is introduced in the aforementioned hollow space. Such a protective case can be of particular interest in warheads, because with its help it is possible to introduce individual or a plurality of devices for achieving high lateral effects into the interior of a hardened or unhardened warhead and thus allow the effect to develop only there.

By the equipment of a warhead with the devices as described herein it may also be useful to achieve different lateral effects and/or depth effects by mixing different bodies. This can occur for example in that appropriate cylinders with different geometries or wall thicknesses or case materials are provided with different EM fillings.



A further application of the lateral concept as described herein which may be very interesting technically is obtained when munition bodies or warheads are to be converted or disposed of. It may be of great economic interest, for example, to change from a concept which is too expensive or until now too ineffectual to this novel technology. Thus it is readily conceivable for parts of the munition to be removed and replaced by bodies with the high lateral effect as described herein. It is also possible to press a plastically deformable material or to introduce the same by way of casting into a predetermined projectile body (with or without inner parts) in such a way that the lateral effect as described herein can occur in the now modified projectile.

It is also conceivable to replace pyrotechnic devices in projectiles or warheads by inert materials (EM) or, to the extent as is permitted by the safety regulations, to embed the same partly or entirely in these in order to obtain inert effective bodies with high lateral effects. Such reconfigured munition bodies or warheads could then be used according to their altered mode of action for new purposes or be used as practice munition.

The lateral principle as described herein can also be used:

- * in combating missiles and warheads (TBM);
- * as effective or partial component in warheads and missiles.

In combating warheads, and TBMs in particular, one can assume very high impact velocities. This not only assists the build-up of a pressure field and thus the initiation of high lateral effects, but the proportion of the effective EM mass required for the effect is reduced accordingly. In all other respects the laws apply in combating hardened or unhardened warheads

which have already been discussed in the description of the lateral effect against different targets.

If the principle as described herein is used as effective component in missiles, expulsion bodies (submunitions) and warheads of guided or unguided missiles, either the body as a whole can be designed according to the concept as proposed herein or it is used as a container for one or more devices for producing high lateral effects.

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**Claims:**

1. A projectile or warhead for combating armoured targets, characterized in that a material with practically no terminal-ballistic effect as an expanding medium (1) is radially enveloped by an outer body (2) made of a penetration material with a distinctly higher terminal-ballistic effect.
2. A projectile or warhead according to claim 1, characterized in that the two materials have a distinct difference in respect of the density.
3. A projectile or warhead according to one of the preceding claims, characterized in that a massive penetrator (6) is arranged at the centre of the expanding medium (1).
4. A projectile or warhead according to claim 1 to 3, characterized in that the expanding medium (1) is made entirely or partly of a light metal or alloy thereof.
5. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of a fibre-reinforced plastic.
6. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of a duro- or thermoplastic material.
7. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of an elastomeric material.
8. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of a dense and dynamically soft metal or a metal compound.

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9. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of powdery substances.

10. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) contains substances additionally with a pyrophoric effect.

11. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) contains substances additionally with an explosive effect.

12. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made of a mixture of materials according to claims 4 to 11.

13. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is entirely or partly liquid.

14. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is pressed, injected, cast or introduced by negative pressure into the outer body (2).

15. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of prefabricated structures.

16. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is made entirely or partly of two or more components which are slid into one another.

17. A projectile or warhead according to one or more of the



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preceding claims, characterized in that the expanding medium (1) is made entirely or partly of two or more components which are arranged behind one another.

18. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) and the outer body (2) are connected by a thread (15).

19. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) and the outer body (2) and, optionally, the central penetrator (6) are connected by gluing or soldering (16,19).

20. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) and the outer body (2) and, optionally, the central penetrator (6) are connected by form-locking.

21. A projectile or warhead according to one or more of the preceding claims, characterized in that strips (20) are entirely or partly located in the expanding medium (1) between the central penetrator (6) and the case (2).

22. A projectile or warhead according to one or more of the preceding claims, characterized in that bodies (21,24,25) are entirely or partly embedded and arranged or randomly distributed in the expanding medium (1), which bodies are identical or different, are rod-shaped or are disposed behind one another and have a terminal-ballistic or any other effect.

23. A projectile or warhead according to one or more of the preceding claims, characterized in that the bodies (21,24,25) or strips (20) embedded in the expanding medium (1) possess pyrophoric properties.

24. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) is





made of a high-density sintered or pure metal.

25. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) is made of a brittle material.

26. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) is made of a very hard steel.

27. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) gives rise to subprojectiles or fragments in a randomly distributed manner.

28. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) is pre-notched on the inside (22) or outside (23), or is correspondingly embrittled there by heat treatment.

29. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2,34) is made of a ring of prefabricated individual longitudinal structures which are mechanically connected or glued or soldered together.

30. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) is surrounded entirely or partly by a case (34) which disintegrates into predetermined bodies.

31. A projectile or warhead according to one or more of the preceding claims, characterized in that the case (34) which disintegrates into predetermined bodies is arranged between the EM (1) and the outer body (2,35).

32. A projectile or warhead according to one or more of the





preceding claims, characterized in that the outer body (2,36) contains entirely or partly segments or prefabricated subprojectiles or fragments.

33. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) has an inner diameter which is variable over the length.

34. A projectile or warhead according to one or more of the preceding claims, characterized in that the outer body (2) has an outer diameter which is variable over the length.

35. A projectile or warhead according to claim 33 or 34, characterized in that the outer body (2) has wall thicknesses which are variable over the length.

36. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) is made entirely or partly of high-density sintered or pure metal.

37. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) is made entirely or partly of brittle metal.

38. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) is made entirely or partly of very hard steel.

39. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) has a random cross section (27) which is entirely or partly variable over the length.

40. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6,28) entirely or partly has a hollow space (29).





41. A projectile or warhead according to one or more of the preceding claims, characterized in that the hollow space (29) located in the penetrator (28) contains substances for achieving additionally desired effect properties.

42. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6,28) has a random surface shaping.

43. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6,28) is made entirely or partly of a pyrophoric material or contains such a material.

44. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) is made of a mixture or mechanical mixture of different materials.

45. A projectile or warhead according to one or more of the preceding claims, characterized in that the central penetrator (6) is made of two or more individual penetrators (26).

46. A projectile or warhead according to one or more of the preceding claims, characterized in that centrally there are arranged two or more individual penetrators (26) two or more times behind one another.

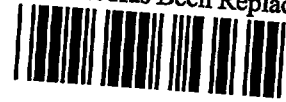
47. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1b,1c,1d) is arranged in a stepped structure (30) with a terminal-ballistic effect.

48. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) is arranged in the forward region of a structure (31) with



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a terminal-ballistic effect.

49. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1e) is arranged in the rear region of a structure (31) with a terminal-ballistic effect.

50. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1f,1g,1h) is arranged more than once one behind one another in a structure (32) with a terminal-ballistic effect.

51. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1,1i) is arranged more than once radially in a structure (33) with the cases (2,2a) which have a terminal-ballistic effect and each enclose the respective expanding medium.

52. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium is arranged once or more than once radially (1,1i) and once or more than once axially (1e,1f,1g,1h) in a structure (33,2,2a) with a terminal-ballistic effect.

53. A projectile or warhead according to claim 51 and 52, characterized in that a central penetrator (6,28) or a plurality of subpenetrators (26) are arranged once or more than once behind one another in the structure (33).

54. A projectile or warhead according to one or more of the preceding claims, characterized in that it has a hollow aerodynamic nose (38).

55. A projectile or warhead according to one or more of the preceding claims, characterized in that the expanding medium (1) has a pocket-like recess on its end face.





56. A projectile or warhead according to one or more of the preceding claims, characterized in that it has a massive one-part or multi-part nose (41).

57. A projectile or warhead according to claim 56, characterized in that the nose (41) reaches into the expanding medium (1) of the projectile or warhead.

58. A projectile or warhead according to one or more of the preceding claims, characterized in that it has a nose (39,43,44) which is filled entirely (40) or partly (42,45) with an expanding medium.

59. A projectile according to one or more of the preceding claims, characterized in that it is spin-stabilized as a full-calibre projectile.

60. A projectile according to one or more of the preceding claims, characterized in that it is aerodynamically stabilized as a full-calibre projectile.

61. A projectile according to one or more of the preceding claims, characterized in that it is spin-stabilized as a subcalibre discarding sabot projectile.

62. A projectile according to one or more of the preceding claims, characterized in that it is aerodynamically stabilized as a subcalibre discarding sabot projectile.

63. A projectile according to one or more of the preceding claims, characterized in that it is a hybrid projectile.

64. A projectile according to one or more of claims 59 to 62, characterized in that it is a projectile with combined stabilization.

65. An unguided missile, characterized in that it possesses



one or more warheads according to one or more of claims 1 to 58.

66. A guided missile, characterized in that it possesses one or more warheads according to one or more of claims 1 to 58.

67. A dispenser (a container under an aircraft), characterized in that it contains subprojectiles (e.g. effective bodies to be expelled) according to one or more of claims 1 to 58.

68. A distance dispenser (self-flying container under an aircraft), characterized in that it contains subprojectiles (e.g. effective bodies to be expelled) according to one or more of claims 1 to 58.

69. Guided or unguided missiles, characterized in that they are subprojectiles (e.g. expelled effective bodies of a larger unit) according to one or more of claims 1 to 58.



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