DEVELOPMENT OF THE HAND GRENADE (EMZ-NR-20) FOR THE DUTCH ARMY



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THE DEVELOPMENT OF THE HAND GRENADE (EMZ-NR-20) FOR THE DUTCH ARMY.

Authors:

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• START OF THE DEVELOPMENT.

The development of the EMZ-Nr.20 hand grenade started in 1974

Participants in the development were:

- The Royal Dutch Army (Koninklijke Landmacht), who wanted to replace the existing hand grenades (the hand grenade N. 1C1 for defensive purposes and the offensive hand grenade Nr. 13 and Nr13C1 for assault operations), by a single type of hand grenade, which should be developed.
- The institute RVO-TNO (Rijksverdedigings Organisatie –Technisch-Natuurkundig Onderzoek), an institute owned by the government, comparable with RARDE (Research for Armement and Development Establishment) in the UK or BRL (Ballistic Research Laboratories) in the US. This institute RVO-TNO should translate the effectiveness for the hand grenade for assault and safety for the thrower during defense into a technical requirement, regarding the fragmentation characteristics.
- The company Eurometaal Zaandam, which was formed after a reorganization in 1973 of the government owned company "Het Staatsbedrijf Artillerie Inrichtingen", abbreviated AI. In the past AI had the mission to assist Dutch Forces (Army, Navy and to a lesser degree the Air Force), with technical knowledge, production, supply, testing of ammunition, small arms, etc.
- Al had produced a.o. the Dutch service rifle M95 (license from Steyr), the Lewis machine Gun, the Service revolver 9,4 mm M1873, small arms ammunition, middle caliber ammunition, artillery ammunition, etc.
- During its zenith, just prior to the Second World War, AI had around 10.000 people employed.

 Eurometaal was asked to design the hand grenade according to requirements set by the Army and TNO and later to produce the grenade for the Army.

• The existing hand grenades (which should be replaced):

• Defensive handgranaat nr. 1C1. (see picture 1)

This hand grenade consists of the following parts:

- 1. Fuze body with firing mechanism (ontsteker 19C1/20).
- 2. Pyrotechnical assembly with primer, pyrotechnical delay of 3-4 seconds, detonator, all contained within a cylindrical aluminum body (vertragingsslagpijpje nr 20).
- 3. Fragmentation body of cast iron.
- 4. Explosive charge of approx. 60 grams trotyl powder.
- -The weight of the total hand grenade is approx. 670 grams.
- Max throwing distance approx. 30 meters.
- Safety distance: At a distance of 30 m from the detonation point there could still be lethal fragments.

Blast hand grenade (Aanvals handgranaat nr. 13):

(See picture 2).

The blast hand grenade consists of the following parts:

- 1. Body made of cardboard with a top lid made of Bakelite, constructed with a threaded centerpiece to accept the fuze mechanism.
- 2. Striker Mechanism Nr. 23, including the detonator group; a copper tube containing a primer, pyrotechnical delay of 3-4 seconds and detonator.
- 3. Explosive charge of pressed trotyl, total weight approx. 226 grams).





Picture 2

- The weight of the complete hand grenade is approx. 340 grams.
- Max. throwing distance approx. 40 m.

Blast hand grenade (Aanvals handgranaat nr. 13C1):

(See picture 3).

The blast hand grenade Nr13C1 is a modification of the Nr.13. The construction is very similar to the Nr.13.

To simplify the construction process the top lid and bottom are constructed from tin plated sheet, fold-seamed to the cardboard container. The Nr.23 fuze is replaced by the modern Nr19C2 striker mechanism, fitted with delay and detonator group Nr.20 (vertragingsslagpijpje Nr.20) consisting of a cylindrical aluminum body containing a pyrotechnical delay and detonator.



Picture 3

Parts of the new hand grenade to be developed:

1. Hand grenade Fuze:

The existing hand grenade fuze (mechanical part and pyrotechnical part) for the existing hand grenade 1C1, should be used, but instead of the ring and split pin, the army wanted a system, which required a rotation and pulling action to release the safety handle.



Picture 4

This was easily done by using a device made of spring wire as seen in (picture 4). The position of the hole for the safety pin in the fuze body was moved towards the side of the mechanism body. The denotation for this modified fuze mechanism is nr19C3.

So the development of the new hand grenade EMZ-Nr. 20 was limited to the development of the fragmentation body with the explosive filling.

2. Technical requirements for the new hand grenade EMZ-Nr.20

2.1. Lethality against the target:

- a. Target:
 - i. The hand grenade should be used against unprotected enemy personnel.
- b. Hit probability:
 - The probability that the target (enemy soldier in the standing position) is hit by a fragment(s) depends on:
 - Number of fragments. This parameter is dependent on the permissible total weight of the fragments, which is limited by the total weight of the hand grenade (optimal for throwing).
 - Fragment distribution, depending a/o on the form of the hand grenade body (if the body is a sphere, then the fragment distribution is homogeneous.
- c. Kill probability (lethality):
 - i. The definition of a kill of an enemy target (enemy soldier) is to injure the target in such a way, that the target is unable to fulfill its task. Sometimes it is even more damaging to the enemy to cause wounds, so he needs to be rescued, treated, etc. then to kill him. It is also more demoralizing if the wounded enemy soldier screams, cries, etc.

The kill probability within Nato (Finabel) for unprotected personnel is defined by:

- The hit probability and ability to suppress enemy personnel from carrying out an assault for five minutes or a defense for 30 seconds.
- The clothing of the enemy soldier, e.g. is he wearing an armored vest, is he in summer or winter uniform, etc.
- The mass of the fragment, which hit him.
- The velocity of the fragment at impact.
- The number of fragments, which hit the target.
- The fighting mentality of the soldier, e.g. a Japanese soldier in WWII, or a fanatic SS soldier can take more damage than an Italian soldier, who was not motivated to fight.
- ii. A method to test the lethality against personnel, which is used especially for rifle or pistol bullets, is to fire the bullets or fragments (embedded in a carrier) into gelatin. The maximum volume of the cavity in the gelatin (comparable with human tissue) is a measure for the lethality.

2. Safety for the thrower:

- iii. The values for the parameters, which make the hand grenade safe for the thrower, are opposite to the values for the lethality against the target.
- iv. The fragments of the hand grenade should lose their lethality above the safety distance from the thrower, which means that the velocity of the fragments should be diminished to a value at which the fragments are not lethal any more.
- v. When a delay (3,0 s) is used in the pyrotechnical/explosive chain (vertragingsslagpijpje Nr. 20), it is not allowed that the delay is less than 3,0 s (critical failure), otherwise the distance between the exploding hand grenade and the thrower could be less than the safety distance.

3. Technical Requirements

It was the task of RVO-TNO (see point participants) to determine the complex requirements concerning effectiveness (lethal to a distance of 10m and safe at a distance greater than 20 m) in specifications that could be used by the manufacturer of the hand grenade.

<u>Test for lethality against an enemy soldier/ safety for the thrower</u>

- Lethality: This test is carried out by an arena test, where the hand grenade is placed on a wooden stake (1 m above the ground) in the center of an arena, consisting of half a circle of 1,5 mm plates (1x2 m) set 5 m from the center. (see picture 5)
- Safety for the thrower: This test is carried out in the same arena test, where the lethality is tested, namely opposite to the half circle set at 5 m from the center another half circle of 3 mm steel plates (1x2 m) are set at also 5 m from the center (see picture 5). The height of the arena is 2 m.



picture 5: set up for arena test

After the hand grenade is detonated there should be at least 5 perforations per square meter on the 1,5 mm steel plates and no perforations at all at the 3 mm plates independent on the orientation of the grenade.

Form and dimensions of the hand grenade

• Form:

The hand grenade should have an egg shaped form and should have the possibility to use the existing fuze body with its safety lever. The egg shape form is optimal for throwing according to tests done by the army.

• Weight:

The weight of the hand grenade should be between 350 and 450 grams, which is optimal for throwing according to tests done by the army.

• General requirements, which are applicable for ammunition

• Temperature range

The hand grenade must be fully functional in a temperature range between -40 to +60 degrees Celsius (see drop test at 10 m).

• Storage life:

The hand grenade should be fully functional for 10 years storage under normal conditions.

1. Environmental testing

The hand grenade in its packing must be able to withstand the conditions of transportation (shock, vibrations, etc.)

2. Drop tests:

When dropped from 10 m height at temperatures between -40 and +40 degrees Celsius the hand grenade must fulfill the lethality requirements. The situation of throwing the hand grenade against a stone wall is simulated by this test. That means that after this 10 m drop test the hand grenade must have no cracks, which would affect the lethality.

3. <u>Packing:</u>

The new hand grenade should be packed the same way as the existing hand grenades (only small modifications are allowed).

4. Marking:

The markings on the hand grenade should be according the requirements of the army.

• Price of the hand grenade;

The price of the complete hand grenade (including the fuze) should not exceed (NFI. 20, which is equivalent to around US\$ 15), so the filled hand grenade excluding the fuze should be less than NFI. 10.

Possible solutions:

Because the requirement that there should no perforations at all on a steel plate of 3 mm set at 20 m from the point of detonation of the hand grenade (see arena test), the design of a pre-fragmented steel body (like the mini hand grenade of the Kruithoorn, or the US M67 hand grenade), or notched steel wire wound inside a plastic body (like the PRB hand grenade M423), could not be used. It cannot be guaranteed that the pre-fragmented body or pre-notched steel wire will break in all the notches, so there are always a few larger pieces which will perforate the 3 mm steel plate.

The only solution to fulfill this requirement is a solution, where the fragments are preformed and are separated from their plastic matrix in which they are embedded by the detonation.

Prototype:

1. Prototype 1:

This prototype (see picture 6), consisted of:

a. An aluminum body of approx. 2 mm thickness, which was made by a free flow- turning operation from an aluminum pipe. Fragments from this body are not able to perforate the 3 mm safety plate, because they are aluminum and its thickness of 2 mm.



- b. The fragments were steel balls (used for ball bearings) of 2 mm diameter. We took this size of 2 mm, because of the following considerations:
 - 5. Permissible total maximum weight for all the fragments including the liner- was approx. 125-150 grams, because of the total weight for the hand grenade , including fuze, detonator and explosive was approximately 360 grams. It was calculated, that with an initial velocity of approximately 1500 m/s for a fragment of 2 mm the impact velocity at 5m would be enough to perforate the 1 mm steel plate, but not enough to perforate the steel of 3 mm at 20 m.

- Only one layer of steel balls was chosen because with several layer of steel balls, the steel balls would not have a uniform velocity after detonation.
- 7. With 2 mm steel balls we could have approximately 2000 fragments, to fulfill the requirement of a minimum of 5 perforations per square meter. With a larger diameter the total number of steel balls should be less and therefore the hit probability would also diminish.
- 8. We assumed that 2 mm was the lower limit for the dimension of the steel balls.
- c. A glue to adhere the steel balls to the aluminum body. At a later stage a plastic matrix could be molded to form the exterior surface of the hand grenade.
- d. Later an aluminum part with interior thread could be fixed to the aluminum body in which the fuze body could be screwed.
- e. A high explosive filling. To have the maximum initial velocity for the fragments we choosed RDX (a high explosive, which EMZ also used for the filling of HE artillery shells, like the 155mm M107).

Prototype 1 was liked by the army. The hand grenade gripped well in the hand, the surface was not slippery and had a good feel.

1. Problems for mass production of prototype 1:

- The greatest problem was to mass produce the aluminum body. Flow turning is a slow process and not well suited for mass production.
- Another problem was to coat the exterior surface of the aluminum body with one layer of steel balls. In principle, you can put the aluminum body in a mold with space for the steel balls, then fill the space with the steel balls and inject the plastic matrix around the steel balls, then put the body with the fragments imbedded in its plastic matrix into a second mold and make the complete hand grenade body by ejection molding of plastic to form the exterior surface.
- A problem of a plastic part (e.g. poly ethylene) by injection molding, is that plastic material, when it does not have an interlinked molecule structure, at temperatures of -40 degrees Celcius the material

becomes very brittle and will break apart when the hand grenade is thrown with full force against a stone wall, which impairs its effectiveness (not fulfilling the requirement of the 10 m drop test).

2. The chosen solution (EMZ nr. 20)

<u>Rotational Molding</u>

From our partner at that time, the German Company Dynamit Nobel in Nurnberg (a well-known company) we got a tip to use the process of rotational molding and to make contact with a company in Norway, named Bakelittfabriken, who made plastic ammunition (for training at short range, blank ammunition etc). for DNAG. Bakelittfabriken was owned by the family Ringdahl.

With rotational molding, which is used to make hollow bodies you can make the product relatively accurately in exterior shape, but the inside of the body is not well defined.

<u>Short description of the rotational molding process</u>:

You use a mold, which is split, to take the finished hollow body out.

You put a certain amount of granulated plastic (poly-ethylene) in the mold, bring it into an oven and rotate the mold in several directions. After a while, the inside of the mold will be covered with the fluid plastic, forming a hollow body with accurate dimensions on the outside of the body. The plastic material has molecular cross links in contrast with injected molding and is very strong, even at low temperatures. The thickness of the body depends on the amount of the plastic powder you put into the mold.

With this process, we make the outer upper part of the hand grenade body as well as the bottom part of the hand grenade body. (see drawings underneath).

• <u>Production of the upper fragmentation part and the bottom</u> <u>fragmentation part.</u>

Fragments:

Because of the price we did not use ball bearings, but used steel grit, which is used by shot blasting of steel. The grit is made of steel and is heat treated (hardness approx.HV400).

The fragmentation parts (upper fragmentation part and the bottom fragmentation part) are made by injection molding.

In a split mold at first the steel balls are filled, and then the mold is filled with polyethylene by injection molding. The end product is a upper half and lower half both containing fragments constructed by the same method.

The polyethylene is transparent in order to allow visual inspection of the homogeneity of distribution of the fragments.



embedded fragments in inner sups



Joining outer and inner cups

Welding the upper body with the bottom body part

These two parts are welded by a process which is known as mirror welding.

The upper body part is put in a fixture as well as the bottom body part, then a heated plate (the mirror plate) is put between the two parts, the parts are pressed against the heated plate, so the surface of the body parts will melt at its surfaces, the bottom and upper parts are retracted from the mirror plate, after which the body parts with its molten surfaces are pressed together, forming a strong bond between the upper and lower hand grenade bodies.



• Filling the hand grenade / Loading, Assembly and Packing.

The hand grenade body is filled with molten Comp B (hexogen type of explosive) and then a dummy detonator is screwed in to form the cavity for the real detonator.

There are no strict requirements regarding the filling in contrast to HE shells which are fired from a cannon, because the hand-grenade is not subjected to high acceleration forces, which can result in premature detonation of the artillery shell.

The quality of the filling should be as such that defects in the filling (air spaces) should not influence the requirements for the effectiveness.



After the explosive has solidified the filled grenade will go to the assembly line for completion.

The hand grenade can then be finished, marked, packed and delivered to the army for inspection.

This hand grenade in the factory denoted as hand grenade F.5.0. was adopted by the Dutch Army as "scherfhandgranaat Nr.20". Unfortunately, the exact date of introduction of the Nr.20 grenade couldn't be retrieved. Many files were lost or formal destroyed. The oldest known lot number is produced in 1976.

The Nr.20 served, together with the newer version Nr.20C1, until 1997-1998. By then the new grenade Nr.331 was already introduced. This Nr.331 grenade is equal to the Swiss HG-85 grenade. The last Nr.20 and Nr20C1 grenades on stock were destroyed.



Variants:

A production modification (Nr.20C1) was introduced in a later stage. The first guidelines for purchasing are dated November 1985. The plastic body of the Nr20C1 was formed as a whole where the steel fragmentation balls were positioned at the inside surface after molding. See pictures.



Solid aluminum cast drill grenades were developed and officially introduced in white color (old denotation for drill), gold and later gold plus hole (newer denotation methods for drill). See pictures.



A blue training grenade (nr.21) with a pyrotechnic charge was developed in a few variants. Due to the higher costs this was never adopted by the Army. See pictures underneath.



Trials for an adapter to convert the Nr.20 grenade into a rifle grenade were carried out but didn't succeed in a final production model. See picture.



Conclusion from the authors

We hope that we made it clear, that even with a relative simple product, like a hand grenade, because it is a type of ammunition, the requirements and testing are not as simple, as an outsider would expect. We hope we have made a contribution to enlarge the knowledge about ammunition to a wider public.