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Brief Communication

High Velocity Projectiles for Killing Whales. Hunting Trials using 20 mm High Velocity Projectiles for Minke Whales in 1982

Norway was requested by the International Whaling Commission (IWC) to explore the use of high-velocity projectiles to replace cold harpoon as killing device for minke whales (*Anon* 1980). Tests of suitable high-velocity projectiles for minke whales were therefore initiated in 1982 as part of a wider project with the purpose of studying alternative killing methods to the traditional cold harpoon used in the Norwegian minke whale hunt until 1984 (*Øen* 1995). The results of the trials have previously been presented in unpublished reports to the IWC (*Øen* 1982, 1983, 1992).

For the trials, 3 hollow point projectiles (type A, B and C) weighing 115 g and measuring 20 mm×66 mm an estimated muzzle velocity (v_0) of 1,058 m/s and impact energy at 100 m (E_{100}) of about 60 kJ were built in co-operation with the Raufoss A/S in Norway (Fig. 1). A licensed whaling boat with a trained crew was equipped with a military 20 mm high-velocity weapon operated by a gunner trained in the use of this weapon, in addition to its 60 mm harpoon gun.

To investigate the terminal effect, the target ballistics and the effect of water, shots were fired both above and below the waterline at 2 dead whales. These were kept afloat with part of the back above the water by fastening air-filled buoys to the rostrum, flippers and body behind the dorsal fin. Projectile A was partly splintered by hits both on the water and in whales and was not utilized for live animals. Projectile B was also partly deformed when it hit the whale. Projectile C was neither deformed nor splintered to the same degree as A or B.

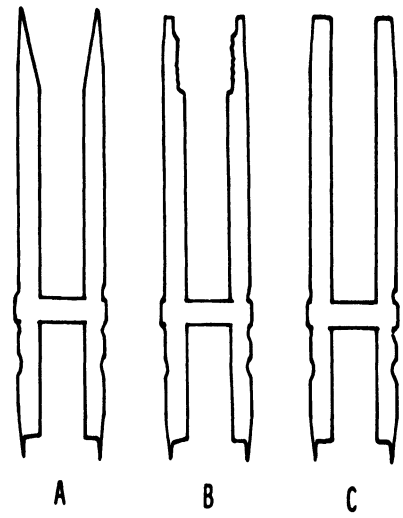

Figure 1. Longitudinal section of 20mm high-velocity projectiles used in hunting trials on minke whales in 1982.

The shooting trials on targets and dead whales revealed that the projectiles were liable to ricochet if they hit the water at ranges between 200 m and 400 m. Projectiles that first hit the water more than about 1 m from a whale were often stopped in the blubber either due to the braking effect of the water, or to fragmenting

or tumbling. Examination of the carcasses at the preliminary trials and post-mortem examination of whales killed in the hunting trials revealed that only direct hits caused wounds more than 30 cm deep. Some projectiles were retrieved at a depth of 80-90 cm inside the animal. The entry opening in the skin and blubber could vary from 3 cm in diameter to a large, crater-like wound with visible damage in tissue up to 25 cm from the impact point. The cavity made by the projectile in the musculature also varied in size from 3 cm to 12-15 cm in diameter and along the projectile path, injured muscles could be transformed into a granular mass. Bleeding and patches of light coloration in the normally deep red muscle could be seen with the naked eye up to 30 cm from the centre of the wound. Blubber and muscle tissue in proximity to the projectile path was often light-coloured and jelly-like in consistency because water was drawn inwards into the wound. Bones struck by the projectiles were splintered. A hit in the dorsal spines of the vertebra completely split the vertebral body, revealing the spinal cord.

During the hunting trials, the projectiles were used as a secondary killing device on whales which did not die instantly from the harpoon shot. Ten whales were killed during the trials, 2 with projectile B and 8 with projectile C. The whales were killed instantaneously or very rapidly (≤ 2-3 min) when they were hit in the skull, thoracic part of the spine or the thorax. With 1 exception, hits in the musculature were not immediately fatal. A hit could be registered as a strong jolt in the animal, which in the case of a fatal hit rolled sideways with the belly up before sinking.

The primary effects of a low-velocity projectile is damage of tissues by laceration and crushing. A high-velocity projectile also causes damage through shock and pressure waves and the formation of temporary and permanent cavities which form as energy is transferred from the projectile to the tissues adjacent to the projectile path *(Harvey et al.* 1962, *Amato et al.* 1974). The overall effect of a high-velocity projectile on an organism will therefore be greater than of a low-velocity projectile. Factors such as the point of impact, body size, the kind of organs that are affected, the size, weight and shape of the projectile, how deep it penetrates and how it behaves as it travels through the tissues will, however, determine whether a hit is fatal or not.

There does not seem to be a clear distinction between low- and high-velocity projectiles but several authors (e.g. *Berlin et al.* 1976) describe high-velocity projectiles as projectiles with a muzzle velocity of over 750 m/s or 2500 ft/s. Although speed is the most important factor, both the shape and braking capabilities of the projectile will also determine whether it causes the changes in the organs and tissues that are characteristic of high-velocity projectiles. According to *Berlin et al.* (1976), a sharp-nosed projectile, which is not much retarded by the tissue, needs a velocity of 1,300-1,350 m/s to cause such changes, whereas a blunt projectile that brakes rapidly in the tissues produces this effect at 600 m/s if it tumbles.

The shock and pressure waves of high-velocity projectiles are created by compression of the tissues at the impact site and projectile path. The region of compression ahead of the projectile moves away as a shock wave, whose velocity is slightly higher than the speed of sound in water (1,450-1,500 m/s). It generates complex pressure changes at a level of several hundred atmospheres and radiate outwards spherically from the projectile path *(Berlin et al.* 1976, *Charters & Charters* 1976), expanding the missile tract into a pulsating temporary cavity. When it collapses, it leaves behind a permanent cavity, the wound channel, which in the musculature is wider than the projectile

because the pulsation causes swelling and cellular disorganization of the muscle fibres *(Harvey et al.* 1962) which become dissociated from each other. Blood vessels along the path become compressed and occluded for a short moment before the blood flow to the traumatized region increases as vasodilatory substances are released *(Rybeck* 1974). Nerves are stretched resulting in serious conduction problems *(Harvey et al.* 1962). The damage caused by high-velocity projectiles in organs and tissues is very similar to and has therefore led various workers to compare high-velocity projectiles with explosives (*Øen* 1995).

Both the whales' reactions on being hit and the pathological findings in the introductory trials and hunting trials correspond well with descriptions of pathological changes caused by high-velocity projectiles. Used with a weapon that allowed more precise, rapid shooting projectile C used in the trials would probably have been very effective for killing minke whales. However, the trials also showed that high-velocity projectiles could only be used in conjunction with harpooning, not as an independent method. It also had other disadvantages. In 2 cases, the harpoon lines were shot away, resulting in 1 loss. In addition, the long range of the projectiles (7,000 m) and the danger of ricochet would represent a risk to personnel, since the minke whale hunt in Norway usually is carried out near land and with several boats on the same grounds.

In 1982, whalers were already required to carry heavy calibre rifles to kill wounded whales. Both observations and records *(Øen* 1994) have shown the recommended ammunition of a full jacketed projectile of minimum calibre 9 mm and minimum impact energy 350 kgm (3,433 joules) at 100 m, to be very effective for killing minke whales, which die instantaneously if hit in or near the brain. Although the areas in which hits are lethal and the shooting range could be expanded somewhat by using high-velocity projectiles instead of rifle ammunition, it was concluded that the method could not be recommended as an alternative to the killing methods that were in use in the Norwegian minke whale hunt in 1982.

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