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Terminal ballistics of 7.62 mm NATO bullets: experiments in ordnance gelatin

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Abstract Military rifle bullets are assumed to tumble 180° in the target and end up facing backwards, but intact. It has been claimed, however, that a German version of the 7.62 mm × 51 (7.62 mm NATO) bullet may fragment at ranges up to 100 m. A lack of strength in the jacket, causing it to break at the cannelure when hitting the target at high impact velocity, has been held responsible for this behaviour. The Danish Armed Forces use a 7.62 mm × 51 bullet, produced by Ammunitionsarsenalet (AMA), which is similar in design. Since the legality of this and similar bullets may be questioned in view of the Hague Declaration of 1899, we decided to supplement an investigation of actual fatal cases with an investigation using ordnance gelatin. In order to compare various makes of bullets on an equal basis, they were fired into ordnance gelatin at various ranges and, consequently with various impact velocities. Bullets manufactured by the US Government, Bofors (Sweden), Raufoss (Norway) and AMA were used. The AMA bullet M/75 used previously was found to fragment at ranges up to approx. 100 m, corresponding to impact velocities of approx. 715 m/sec, while all the other 3 types of bullets were intact at ranges down to 2.5 m, corresponding to impact velocities of approx. 810 m/sec. The final prototype of an AMA bullet to answer this criticism proved capable of withstanding fragmentation as well as the foreign makes previously tested. It will enter series production in late 1995.

Key words Forensic medicine · Gunshot wounds · Wound ballistics · Bullet fragmentation

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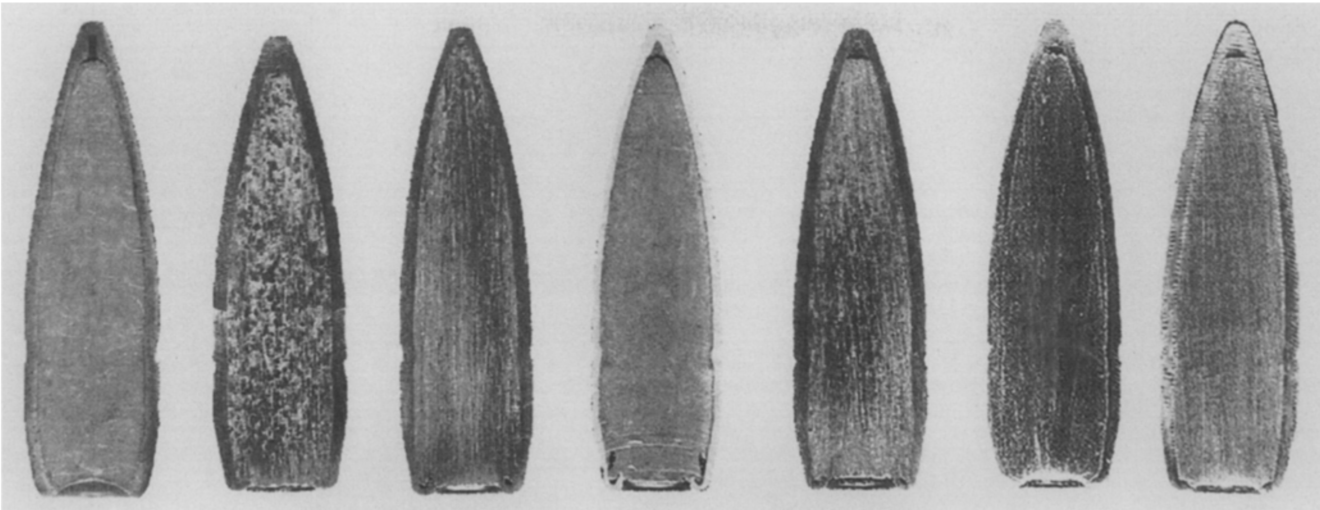
Introduction

For a number of years a standard for 7.62 mm × 51 ammunition has been established in NATO - STANAG 2310 (NATO 1976). Bullets adhering to this standard - 7.62 mm NATO in short - have been assumed to possess similar behaviour, tumbling 180° in the target and ending intact but facing backwards, no matter what country of origin or differences in detail of construction (Cooper and Ryan 1990; Di Maio 1985; Fackler 1989; Fackler and Malinowski 1985; Sellier and Kneubuehl 1994a). There have been reports, however, that some versions of this bullet will fragment in tissue or tissue simulants such as gelatin (Stiefel 1980; Fackler 1989; van Bree 1993, 1995 pers. comm.) and this effect has been documented in actual fatalities (Knudsen and Theilade 1993). Since the Danish version of this bullet produced by Ammunitionsarsenalet (AMA) has been incriminated, the manufacturer decided to undertake a series of experiments with a view to confirming the theory and, if possible, arrive at a solution to the problem. The experiments were performed at the Army Combat School at the request of AMA.

Material and methods

Inspired by the letter by Stiefel (1980) and the paper by Fackler (1989) a small scale pilot experiment confirmed unequivocally that the AMA M/75 bullet had an unwanted tendency to fragment. Accordingly it was decided to undertake a proper comparison between the original AMA bullet, a number of foreign products and a redesigned bullet.

The details of the bullets used are seen in Fig. 1. As can be seen, there were several variations in the design of the bullets. Within the common characteristics of a lead core encased in a full metal jacket, there were various concentrations of antimony in the lead core, and the jackets differed in material and thickness. The M80, the Raufoss and the final prototype of the redesigned AMA bullet, the M/94.3 used lead with a content of antimony of 10–14%. The Bofors, the AMA M/75 and the 2 first prototypes of the redesigned AMA bullet used lead with much less antimony i.e. 1–2%. The AMA M/75 was the only one using a steel jacket, although plated with gilding metal ("tombak", 90% Cu, 10% Zn), while the other 3 foreign made bullets had solid gilding metal jack-



M80	Bofors	Raufoss	M/75	M/94.1	M/94.2	M/94.3
M = 9.52 g	M = 9.45 g	M = 9.46 g	M = 9.43 g	M = 9.58 g	M = 9.68 g	M = 9.31 g
V_0 = 808.9 m/s	V_0 = 804.6 m/s	V_0 = 800.5 m/s	V_0 = 793.4 m/s	V_0=791.8 m/s	V_0=796.7 m/s	V_0=808.7 m/s
gilding metal	gilding metal	gilding metal	gilding metal plated steel	gilding metal	gilding metal	gilding metal
0.80 mm lead core, 12-14% Sb	0.65-0.75 mm lead core, 1% Sb	0.75 mm lead core, 10-12% Sb	0.55 mm lead core, 2% Sb	0.80 mm lead core, 2% Sb	0.80 mm lead core, 2% Sb	0.80 mm lead core,10-12% Sb

Fig. 1 The bullets investigated, their mass, muzzle velocity, jacket material and thickness and core material

Table 1 Results of the test firing of different 7.62 mm NATO bullets into 20% gelatin blocks from various distances. Impact velocity in m/sec, f = fragmentation, l = lead extrusion, i = intact, r = fragments torn off from rear of bullets, ir = intact but with fragments torn off from rear of bullets, ilr = intact but with lead extrusion and fragments torn off from rear of bullets, vnr = impact velocity not recorded. The number in brackets is the number of bullets with the same properties.

Range	M80		Bofors		Raufoss		AMA M/75		AMA M/94.1		AMA M/94.2		AMA M/94.3		M/94 Production	
0.1 m									vnr	il	vnr (2)	il (2)	vnr (2)	i (2)	vnr (2)	i (2)
2.5 m	vnr (4)	i (4)	vnr (2)	il (2)	vnr (4)	i (3) il	vnr	f	vnr (5)	il (4) ilr	vnr (4)	il (3) ilr	vnr (5)	i (4) ir	vnr (5)	i (5)
5 m	811 809 804	i i i	809 806	il il	809 801	il i	809	f	792 785 vnr	ilr il ilr	793 787 794	il (3)	802 795 vnr	il i i	vnr (5)	i (5)
10 m	800 796	i i	798 791	il il	805 803	il i	794 790 771	f (3)	791 vnr	il il	805 784	il i	801 vnr	i (2)	787 780	i(2)
25 m	788 787	i i	784	il	779	i	773 773 vnr	f (3)	785 780	il ilr	775 766	il (2)	801	i	771 758	i (2)
35 m							770 760	f (2)								
50 m	775	i	773	il	767	i	762 vnr 758 743	f (4)	763 759	il ilr	764 763	il (2)	771 764	ir i	770 754	i (2)
80 m							734 724	i il	737 731 724	il il ilr						
90 m							734 718	f i	725	ilr						
100 m							720 713 713 vnr (2)	f f i i (2)	709	il						
150m							682	i								

ets. The AMA M/75 also had the thinnest jacket, only the Bofors coming close with a lower limit of 0.65 mm, 0.10 mm thicker that the AMA M/75. For the AMA M/94.1 it was decided to change the thickness of the jacket from 0.55 mm to 0.8 mm and replace the material of the jacket with the more ductile gilding metal. The third alternative, to strengthen the part of the bullet where it breaks, i.e. the cannelure where the case is attached to the bullet (Berlin et al. 1988), was not chosen since Raufoss uses the same form of attachment of the bullet to the case. AMA were prepared to change that as well, should it have become necessary. For both the M/94.2 and M/94.3 a reinforced folding at the rear end of the bullet was introduced and a lead core strengthened by a higher content of antimony was used in the M/94.3, which differed only in minute details from the final M/94 production bullet.

The bullets were fired at ranges of 0.10–150 m (see Table 1) against cylindrical blocks of 10% or 20% ordnance gelatin with a diameter of 36 cm and a length of 70 cm to include the total length of the channel. The weapon used was the M/75 standard infantry rifle, the Heckler & Koch G3 introduced in Denmark in 1975. The rifle is a reasonably modern type, capable of single and fully automatic firing (G3HK 324484 1/84).

The majority of the gelatin blocks were produced with 20% gelatin in accordance with the usual practice in NATO, since this is the type authorized. In the first experiments 10% gelatin was tried as well (Fackler and Malinowski 1988), and there was no discernible difference in fragmentation. This was confirmed by Dr. ML Fackler (Fackler 1993 pers. comm.) who introduced the 10% gelatin, and who would not expect any difference with respect to fragmentation. After the shots had been fired, the blocks of gelatin were sectioned and photographed. The distance of penetration of the bullet or the major fragments, if any, was determined and the bullet and/or fragments of the bullet were retrieved from the gelatin. The parts were weighed, since we could not be sure to retain all fragments.

The muzzle and impact velocities were measured by an EV 100 photocell transducer system (mounted on a 2 m base) in connection with a CC 2000 Velocity meter or a Doppler radar, "X-band Radar Antenna ED900" in connection with a "DR5000 Trajectory Analyzing System" (Knudsen and Svender 1994).

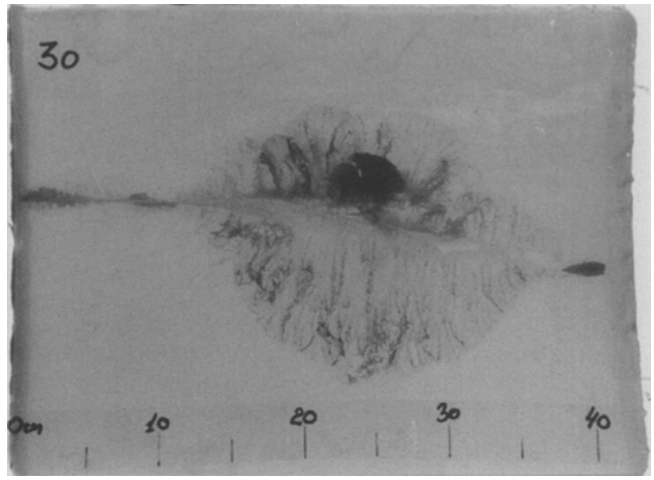


Fig. 3 Bofors in gelatin, range 10 m, v_i = 797 m/s

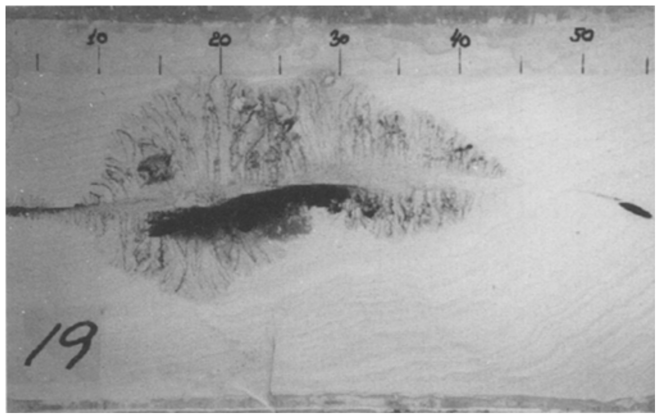


Fig. 4 Raufoss in gelatin, range 2.5 m, v_i = 800 m/s (approx.)

Results

The results of the investigations are composed of the results of several test sessions, which all have been incorporated into Table 1. The first test sessions using the AMA M/75 at various ranges confirmed fragmentation at up to 100 m, however the bullet was intact at 150 m. The results of the test session comprising 4 different bullets, the M80, the Bofors, the Raufoss and the AMA M/75, showed a similar picture in that no fragmentation at the ranges investigated was observed in the M80, the Bofors and the Raufoss. Some of the bullets showed significant lead extrusion, defined as loss of bullet mass or recovered lead fragments of more than 0.50 g (Figs. 2–4). In contrast the AMA M/75 bullet was seen to fragment at ranges up to 100 m. The fragmentation occurred at the same part of the bullet, namely the cannelure where the case is attached (Fig. 5). The modified AMA bullet M/94, was tested in 3 prototype versions and a final production type. The first version (M/94.1) had a performance similar in principle, if not in detail, to the Raufoss or the Bofors bullet, in that the bullet did not break at any of the ranges employed (Fig. 6). The bullet was flattened from side to side to a much greater extent and the degree of lead extrusion was also much greater than the Norwegian or Swedish bullets. Furthermore, in 7 out of 20 cases minute fragments of the rear part of the jacket were torn off. The extrusion of lead and fragments breaking off at the rear of the bullet was judged to be unacceptable. Accordingly, the M/94.2 and M/94.3 were tested.

Fig. 2 M80 in gelatin, range 2.5 m, v_i = 805–810 m/s

The M/94.2, using a stronger rear end as the only difference to the M/94.1, produced results that were better

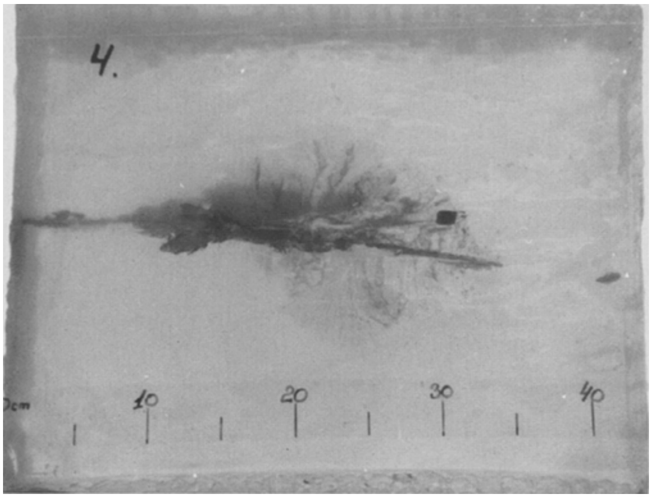


Fig. 5 M/75 in gelatin, range 50 m, v_i = 758 m/s

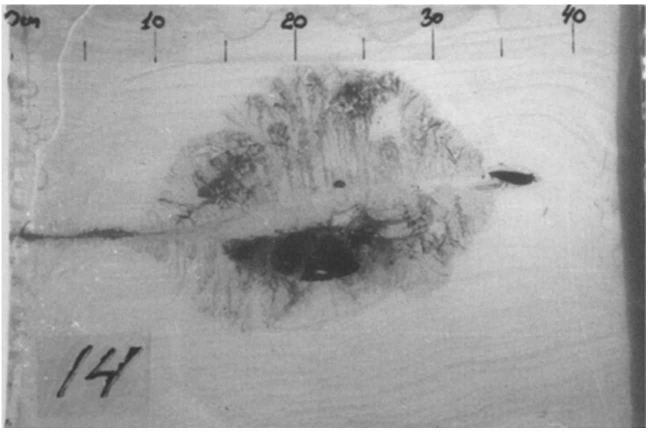


Fig. 6 M/94.1 in gelatin, range 2.5 m, v_i = 795–800 m/s

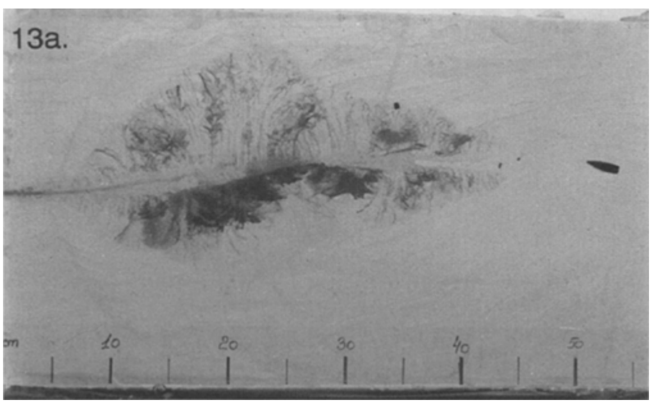


Fig. 7 M/94.2 in gelatin, range 2.5 m, v_i = 800–810 m/s

than the M/94.1; the lead extrusion was less, but still rather large, and there was an admittedly minute fragment broken off the rear part of one of the 15 bullets. Only one of the M/94.2 bullets had less than 0.50 g lead extrusion (Fig. 7). The M/94.3 was better still, in that only one out of 15 bullets had more than 0.50 g lead extrusion, and 2

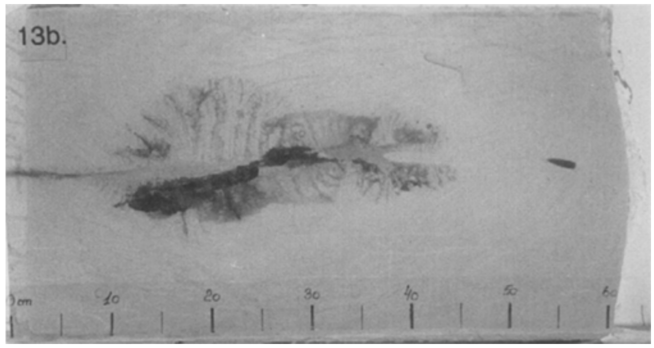


Fig. 8 M/94.3 in gelatin, range 2.5 m, v_i = 795–800 m/s

bullets had very minute fragments broken off the rear end (Fig. 8). The production M/94 had detail work done to the rear folding, but was otherwise identical to the M/94.3, and the lead extrusion was all but eliminated, one bullet losing less than 0.01 g lead.

Discussion

The purpose of a weapon is to inflict bodily harm if deterrence is unsuccessful. Much ingenuity has been expended in this field, the result being the modification of bullets to cause more damage by expansion, fragmentation or early yaw. While the latter is a relatively new aspect, the former aspects are well known in the shape of the dum-dum bullet, which was outlawed in 1899 by a number of countries. Since the early 1960s there has been discussion among wound ballisticians and lawyers about the effect of certain small calibre bullets i.e. 5.56 mm. They fragment at impact velocities as low as 769 m/sec (Fackler 1989), and this has been interpreted by some as a contravention of the spirit, if not the letter, of the Hague Declaration of 1899 (Granat 1993; Sellier and Kneubuehl 1994b). There have, however, been reports in the literature (Stiefel 1980; Fackler 1989; van Bree 1993, 1995 pers. comm.) that some German 7.62 mm NATO bullets might also display this characteristic. Since the Danish design of bullet is very similar to the German design (Dynamit Nobel DM 41), all autopsied Danish fatalities from 1977 to 1991 were published to demonstrate fragmentation in real life (Knudsen and Theilade 1993). A tendency to fragment has been reported with a Swedish version of the NATO bullet, the 7.62 mm sk ptr 10 prj (Berlin et al. 1988; Nordstrand et al. 1979), and Yugoslavian researchers have noted fragmentation of an unidentified 7.62 mm NATO bullet (Albreht et al. 1979). The US version (M80) does not fragment at comparable velocities (Ragsdale and Sohn 1988), and the difference was ascribed to the fact that the jacket of the M80 is 0.8 mm thick, while that of the European bullets investigated by Fackler (1989) is only 0.55 mm. The lack of fragmentation in other investigations may be explained by the fact that many of them have been performed at ranges of 100 m (Berlin 1977; Berlin et al. 1976, 1977, 1988; Nordstrand et al. 1979), which may well be near the lower limit of impact velocity for a break-up of this bullet. The study by Albreht et al. (1979) revealed fragmentation in most cases when shooting from 50 m, a phenomenon which has also been described by Cooper and Ryan (1990) and at short range by van Bree (1993).

Looking at the design of the bullet we find that although the substitution of gilding metal for steel of a thickness of approx 0.80 mm will prevent fragmentation, it will however, not prevent a significant lead extrusion. While one may tend to dismiss the wounding potential of such minute, mostly rounded particles of lead, this phenomenon must be considered undesirable. Since the M80 and the Raufoss use a higher content of antimony than the M/75, the M/94.1 and the M/94.2, it was obvious to try this solution to the question of lead extrusion in the M/94.3 with good, and in the M/94 production type excellent results.

The results presented here demonstrate without reasonable doubt that the present bullet made by AMA fragments at ranges up to 100 m and impact velocities as low as 713 m/sec. This is very different from similar bullets made by other manufacturers. It indicates that the design of the present AMA bullet is deficient and since it is possible to manufacture a bullet in accordance with NATO standards that does not fragment, we regard the fragmentation of the bullet as contrary to the spirit, if not the letter, of the Hague Declaration of 1899. Our experiments also confirm that the M/94 production type bullet has properties that equal or surpass the bullets of different manufacture and may thus be regarded as well suited to replace the AMA M/75 bullet. It may be argued that since the fragmentation is not intentional, it does not represent a contravention of the Hague Declaration. While this may be the strictly legal opinion (Defence Command 1994 unpublished but unclassified), we found it hard to accept. If the manufacturer had willfully produced a bullet that fragmented, then it would have been "illegal". When we have discovered that this bullet fragments, we are obliged to take steps to change it, and this is what the AMA decided to do. It might also be said that the ranges at which the fragmentation takes place are so short that they have no military significance. Again we disagree. Not considering dedicated sniper rifles, ranges encountered in modern warfare, especially urban warfare, are often much less than 100 m (Torre 1994). If 7.62 mm NATO bullets can be made not to fragment by some manufacturers, this is the standard against which we should measure the performance of the Danish bullet.

It has been assumed that the bullet was not yet stabilized in flight ("yawing") at these short ranges under 100 m and has therefore hit the target at an angle (Berlin 1977; Berlin et al. 1976; Cooper and Ryan 1990; Hopkinson and Marshall 1967; Knudsen and Sørensen 1994). This phenomenon has been much exaggerated in the past (Fackler 1989), and although the yaw angle will decrease with increasing range, the greater the yaw at impact, the earlier the bullet will tumble in the target producing larger lesions (Sellier and Kneubuehl 1994a).

It should be noted that, as far as we can ascertain, the history of the Danish bullet goes back to 1962, when a light machine gun - the German MG3, called LMG M/62 - using the 7.62 mm NATO bullet was adopted. The bullet was modified in the late 1970s for use in the Danish version of the Heckler und Koch G3, the M/75. This explains the designation of the cartridge as 7.62 mm × 51 SKPT M/75 while the bullet is 7.62 mm SKPJT M/62.

Another question arises in this connection: should not the *effect* of the bullet in soft tissue be part of the NATO standard? If the proof of the pudding is in the eating, certainly the proof of the bullet is in the effect on the intended target. We suggest that wound ballistics parameters be included into the NATO STANAG for bullets or similar publications. If simple tests with gelatin had been performed, the effect of the AMA bullet and similar ones would have been detected years ago, and we dare to ask if all other NATO bullets by whichever manufacturer have been tested in this way. If not some readers may take a leaf out of our book and check it! Although the adherence to conventions is a national responsibility, the problems mentioned in this article are being seriously considered in NATO.

Wound ballistics has often been seen as a very specialized and theoretical subject. The story of the Danish 7.62 mm × 51 NATO bullet demonstrates that something useful may come out of it. Stiefel (1980), Fackler (1989) and Knudsen and Theilade (1993) indicated the problem of this particular bullet, and the experiments herein illustrate the solution.

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