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Explosive materials and devices in forensic examinations over the years

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Abstract

This article presents the development of methods for examining explosive materials and explosive devices in Poland from the late 1950s to the present day. It discusses the evolution of post-blast residue identification techniques, from classical chemical reaction to modern instrumental methods such as gas chromatography with mass spectrometry (GC-MS). The article also describes changes in the design of explosive devices, the impact of advances in information technology and legal regulations on forensic practice. Scientific and technological progress has significantly enhanced the effectiveness of forensic investigations of incidents involving explosive materials and the identification of post-blast residues.

Keywords: explosive material, post-blast residue, explosive devices

The origins of forensic examination of explosives in Poland date back to 1959-1960

Earlier on, post-explosion traces – apart from examination of gunshot residues – had been analysed primarily from an ordnance disposal perspective. Initially, though often successfully, aimed at identification of the type of explosive used in an incident. This mainly concerned situations where unconsumed particles of material were detected. The examination methods used at the time did not provide for carrying out chemical analyses at the level of sensitivity required for detection and identification of explosive traces in the debris left after a detonation. Consequently, investigators usually limited themselves to a general identification of the type of explosive, for example, based on the intensity of soot stains in the vicinity of the blast epicentre. Numerous incidents, ranging from accidents involving the handling of wartime unexploded ordnance to bomb attacks, led to increasing attention being paid to issues relating to post-explosion investigations.

At this point, it is worth mentioning Dr. Tadeusz Baran, an expert at the Forensic Department of the National Police Headquarters in the People's Republic of Poland (KG MO), a lecturer at the Academy of Internal Affairs and the author of numerous forensic opinions and specialist publications on the examination of explosives, whose professional achievements have greatly contributed to the development of this field of forensics in our country.

A review of archive expert reports compiled by T. Baran suggests that the underlying motives and modi operandi of perpetrators of crimes involving explosives during the People's Republic of Poland did not differ greatly from those of today: the most common incidents were ones involving reckless handling of found wartime ammunition, experiments with production of home-made explosives, and bomb attacks motivated by personal vendettas or acts of vandalism. Occasionally, however, there were incidents that one would describe today as highly „media-friendly", such as the blowing up of the Higher School of Education in Opole in 1971 with the use of a charge of approximately 70 kg of

TNT, or the tragic attempt by Rudolf Olma to hijack an aeroplane in 1970 with the use of an improvised explosive device hidden in a cake (Photo 1).

Fig. 1. A reconstruction of the explosive device used by Rudolf Olma in 1970

When analysing the design solutions of the explosive devices themselves, one can say that they were similar to the ones made at present. They were characterised by significant diversity, primarily due to the varying levels of knowledge and skill among the makers, ranging from solutions that were practically unusable and blatantly demonstrated engineering incompetence, to simple yet ingenious devices, e.g. ones disguised as weights (Photo 2) or household items, right up to highly sophisticated designs containing electronic timing mechanisms or radio-controlled trigger systems.

The range of explosives examined in the cases at that time was similar to that of today and included: - military-grade materials, such as TNT, hexogen, pentrite and their compounds, acquired through theft or ob-

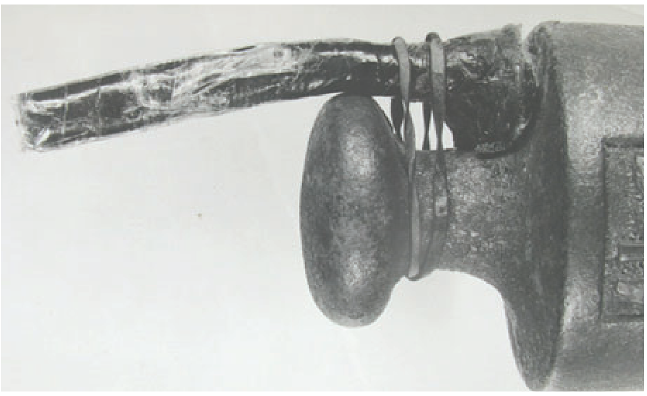

Fig. 2. An improvised grenade made from a 1-kilogram weight (1970)

tained from wartime ammunition, - mining explosives, pyrotechnic mixtures obtained from commonly available products, such as matches or caps for cap guns, - home-made materials.

Dominating in the latter group of materials, just as today, were pyrotechnic mixtures home-made by combining various fuels and oxidisers. Between 1969 and 1972, out of the approximately 200 post-explosion cases compiled by T. Baran, 50% involved a detonation of pyrotechnic products, mainly home-made ones.

Despite many similarities, there are significant differences between forensic examinations of explosives of yesteryear and those of today, which are particularly evident in the field of chemical examination. The chemical analysis methods once used in the past for detection and identification of explosives during laboratory tests included mainly classic analysis based on colour tests and other characteristic reactions, and thin-layer chromatography (TLC). Nowadays, these methods, if used at all, tend to be employed for preliminary or supplementary examinations. In the past, however, they formed the basis of the entire analytical process. Although instrumental techniques, such as gas chromatography and UV-Vis spectrophotometry, were available in forensic laboratories since the 1970s, their sensitivity was insufficient for the purposes of post-explosion trace analysis. Particular attention is drawn to the wide range of TLC and classic analytical techniques used at the time, which are now largely a forgotten art, yet which, although being highly labour-intensive, enabled detection levels that were quite good even by today's standards, in the range of 0.2–0.5 micrograms for most of the explosives encountered at that time.

Nowadays, instrumental methods play an essential role in explosives examination labs, particularly those from the area of coupled methods, which combine separation techniques,-which enable separation of complex chemical mixtures, with spectroscopic techniques, which provide information on the molecular structure of the detected substances. Examples include gas chromatography coupled with mass spectrometry (GC-MS) or capillary electrophoresis with a PDA detector that records spectra in the UV-Vis range. From today's perspective, the analytical achievements of the 1970s no longer seem so impressive: the gas chromatography method with a chemiluminescent detector (GC-TEA) used at CLKP provides for detecting explosives from the nitro compound group in quantities as low as 0.1 nanograms, i.e. several thousand times smaller than the detection limit for the TLC technique cited above. The costs associated with purchasing and operating modern analytical equipment are incomparably higher than those of the old, simple methods.

Advances in laboratory techniques extended also to methods of preparing samples for testing. The simplest approach still in use, which involves extracting the sample with a suitably chosen solvent and then concentrating the extract by partially evaporating it, was supplemented by such techniques as solid-phase extraction (SPE) and solid-phase microextraction (SPME). Invented in the 1990s and used primarily in the analysis of post-fire residues, SPME proved particularly useful in the post-explosion analysis of triacetone triperoxide (TATP), an example of a new, home-made explosive that both domestic and Western forensic services had to confront in the second half of the 1990s.

Continuous scientific and technological progress, as well as the revolutionary changes in the country's economic landscape brought about by the political transition, brought benefits not only to the services combating bomb terrorism, but also to criminals. In the past, anyone who did not have access to factory-made explosives but intended to construct an explosive device had to make ingenious use of the limited options available on the market, e.g. by converting miniature light bulbs into electric detonators. Building a more sophisticated device, e.g. a radio-triggered one, required specialist knowledge. At present, the general retail market offers pyrotechnic cords, electric fuses and even radio-controlled firework kits that do not require a licence. Despite their seemingly harmless purpose, these items are used by criminals in such enterprises as, for example, explosive ATM break-ins. This is an example of a new type of incident, unknown at the time of the People's Republic of Poland. Another new development involves the use of mobile phones as explosion trigger or fire devices, which can act both as a delay mechanism and as receivers enabling remote detonation of a charge from virtually anywhere in the world. The most technically complex trigger systems found in modern-day cases use programmable, miniature electronic circuits equipped with a microprocessor. An example of this is shown in Photo 3: a microcontroller-based electronic device that reacts to movement, equipped with a digital accelerometer and a lithium-ion battery with a USB-C charging port. Building such a device is well within the capabilities of a skilled amateur today.

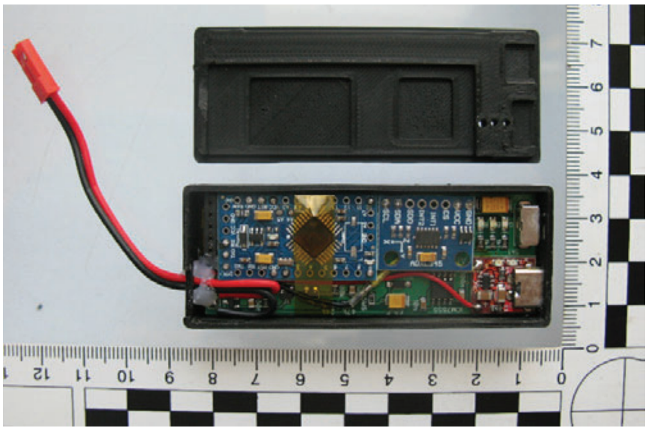

Fig. 3. A microcontroller-based motion-activated device (2025)

Today's economic freedom means, among other things, easy access to a wide range of chemicals that were previously difficult for the average consumer to obtain, and which can be used for making explosives. Despite efforts to introduce legislation restricting access to key precursors for explosives, forensic practice shows that the range and quantities of chemicals found at sites where explosives are made illegally are often significantly greater than they were under the planned ecconomy. However, the change is most evident in the segment of entertainment pyrotechnics, which once existed in a rudimentary form - comprising practically only toy caps, sparklers and the aforementioned „cap gun caps" - but now constitutes a significant part of the economy and ranks Poland third in the global ranking of pyrotechnics exporters (data for 2024). There is a vast range of such products available on the market, and many of them - particularly flash bangs - have become a popular source of pyrotechnic mixtures for the construction of improvised explosive devices, having virtually completely replaced the once-common matchstick mixture.

The profound social changes brought about by the development of information technology, notably the advent of the Internet, have had an impact both on the activities of criminals who use explosives and on the work of persons who combat crime. Easy access to technical information has led to a relative decline in its value. In the past, anyone seeking to learn about making and detonating explosives had to rely either on specialist publications, available only in print in specialised reading rooms, or on the results of their own risky experiments. Nowadays, it is easy to obtain information on the properties and synthesis methods of various explosive substances. The ease with which information is shared means that various „novelties" in the field of making improvised explosive devices (IED) rapidly gain international popularity. A case in point is the „rediscovery" among amateur circles of erythritol tetranitrate (ETN), a long-known powerful explosive which gained in appeal following the widespread use of erythritol, a sugar substitute, which is its precursor. This material has also been found in Poland on several occasions in recent years.

The obvious benefits of easy access to information are enjoyed also by experts. Nowadays, thanks to online resources, it takes just a few minutes to find the properties of any chemical substance or to identify an unknown product from a photograph alone – a task that used to require spending hours poring over hard-to-find reference books and catalogues.

From the perspective of an expert's work, major changes have also taken place over the years in the legal framework regulating access to explosives. Between 1961 and 2000, all matters in this regard were governed by the Act of 31 January 1961 on weapons, ammunition and explosives, which was in force at the time. Over time, that Act, which ran to four pages on the day of its promulgation, was replaced by a series of legislative acts, namely: the Act of 21 May 1999 on weapons and ammunition, the Act of 21 June 2002 on explosives intended for civilian use, the Act of 13 April 2016 on the safety of trade in explosive precursors, the Act of 13 June 2019 on the conduct of business activities relating to the manufacture of and trade in explosives, weapons, ammunition and products and technology intended for military or police use. In addition to the above regulations, there are many other implementing acts.

Nowadays, an expert specialising in the examination of explosive materials and devices should have a sound understanding of the broader field of high-energy materials chemistry, explosive device electronics, as well as the legal aspects unique to their specialisms. In the above light, it can be concluded that the process of training experts in this field is becoming increasingly demanding. Candidates acquire theoretical knowledge and undertake numerous practical training sessions in the field (training at a training ground). An invaluable aspect is the exchange of knowledge and experience among experts, particularly those with many years of experience, who actively participate in numerous training courses.

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