The Future of Civil Explosives

Introduction

The Secretary General of the European Federation of Explosives Manufacturers has written and updated the Chapter concerning the Civil Explosives of the Ullmann's encyclopedia of industrial chemistry. Extracts of this chapter have been used to draw up the conference below which was given on the Future of Civil Explosives. The conference is reflecting on three themes:

- The Civil Explosives as a product: how did civil explosives develop historically, and are there still possibilities for further major developments?
- The Civil Explosives as a market: what have the production trends been in Europe and throughout the world in the last decade, why should this trend change?
- The Civil Explosives and their future

The Civil Explosives as products:

The end user of explosives requires a product which can at a determined instant free the maximum energy in the minimum period of time using a minimum volume. The development of explosives must therefore always be based on the research for the maximum density of strength, combined with increased safety in use. An explosive is not particularly energetic, and its combustion energy is far less than that of a normal combustible, however, 140 grams of an explosive with a 1.2 density and a detonating velocity of 5000 metres per second will easily smash one ton of rock in a few millionths of a second.

The object of any research on explosives has always been to satisfy this density of strength, taking into account the safety characteristics and cost considerations.

The history of commercial explosives started in 1650 when it is recorded that the very old Chinese Black Powder, used until then for military purposes, was adapted for mining in Hungary and England. 100 years later the French chemist Berthollet experimented by mixing Potassium Chlorate with Black Powder formulations, but the results were disastrous. In 1847,
Sobrero an Italian chemist, discovered a very powerful explosive, a "blasting oil” called Nitroglycerine. Nitro Glycerine is an extremely powerful explosive which detonates at the speed of more than 7000 metres per second, and which is extremely sensitive to any shock. Its use was limited by many serious accidents and Alfred Nobel, with his genius for invention, tried to find a way to de-sensitize the pure Nitro Glycerine to enable safer handling. The first dynamite was obtained by the absorption of 75% of Nitro Glycerine into 25% of Kieselguhr. Dynamites were born and developed all over the world....

During about 100 years the dynamites were constantly improved and Kieseguhr was replaced by other types of more efficient and reactive absorbent products such as wood meal, or even by absorbent products with explosive properties such as Nitro Cellulose, and with the addition of Salt Oxidants which modify the oxygen balance of the product, such as Ammonium Nitrate, or combustible products such as BNT and TNT. In the 30s in order to reduce the freezing point of Nitro Glycerine and allow a better resistance to cold weather Nitro Glycol was substituted for Nitro Glycerine.

With the development of dynamites, the addition of Ammonium Nitrate was one of the major advances. Ammonium Nitrate, a powerful oxidiser, has been considered as an inert substance, but it is well known after some famous disasters, that although its sensitivity is very low when the product is pure, its sensitivity increases greatly in the presence of combustible impurities, and can therefore be detonated with an appropriate booster. Some European manufacturers tried at the beginning of the 20th Century, to replace dynamite with so-called Ammonal explosive in which the main raw material is Ammonium Nitrate, sensitised with TNT instead of Nitro Glycerine.
Dynamites remained the most effective commercial explosives until the discovery in the 1950s of Ammonium Nitrates fuel oil and in the 1960s of Water Gels. The Ammonium Nitrates fuel oil, so called Anfo, which entered the market on a large scale around 1955, was the first commercial explosive to really capture an important part of the dynamite market. It is a very simple product based on Ammonium Nitrate. Since the disaster at Oppau in 1921, it has been discovered that Ammonium Nitrate contaminated with paper and paraffin can detonate. Dupont Nemours in the USA was the first company to try to develop a product based on this observation, they used coal, BNT or wood meal as inert solid combustibles. After the 2nd World War the industry was able to mix Ammonium Nitrate with liquid combustibles, avoiding two major problems, the prise en masse, and improving the retention of the liquid oil by the Ammonium Nitrate to get a better mix. Being inexpensive and safe to handle, Anfo is low in density, strength, detonation velocity and detonating pressure. As Anfo cannot be used in the presence of water, its use is limited to dry holes.

In the early 1960s, Garfield Cook, a Canadian engineer tried to overcome the desensitisation by controlling its direct mixture with some water, many improvements have taken place since the first patents were issued, and the future of industrial explosives is certainly linked to further developments aimed at more detonating strength. At the beginning slurries and water gels were made of aqueous solutions of Ammonium Nitrate gelled by the addition of cross-linking agents, the gels were sensitised by explosives such as TNT powder or Black powder or Hexogene. The critical diameter of such water gels was so wide that the usage of these products was limited to very large bore-holes. A few years later the explosive ingredient was replaced either by very fine aluminium powder or by Amine Nitrates. At that time Dupont Nemours claimed all over the world that 'the last days of dynamite have arrived! As Amine Nitrates or powder aluminium have to be considered as potentially dangerous, researchers tried to find a different way to sensitise the water gels. Emulsions were born! The water-in-oil, or oil-in-water emulsion provides a very stable product whose sensitivity is due to the presence of air bubbles. The density, and therefore the sensitivity is provided by the introduction of hollow glass bubbles, or by specific chemical gassing techniques. Like Anfo or the first generation of water gels, emulsions are totally insensitive to shocks or impact, their density can be changed easily as can their sensitivity to detonators. They are manufactured either in cartridge form or more and more, directly at the site of usage, with pump-trucks which deliver the sensitised products directly into the mine-holes.
All through the years the explosives manufacturers have always tried to provide their customers with more powerful but safer explosives. Are emulsions the last step in the evolution of explosives? Probably not, as they are still less powerful than dynamite from 100 years ago. Even after 40 years of developments dynamite still remains the best product when a lot of strength is needed or the bore-hole are small. However over the next few years new research will bring to the market more energetic emulsions. If some manufacturers, particularly those still running dynamite plants do not endeavour to replace all their dynamite products, other manufacturers, specialising in emulsions, are already testing and even selling very energetic emulsion with a detonating velocity of around 5,800 metres per second for a density of around 130 and a theoretical detonating energy of 1200 calories per gram.

How can the energy of emulsions be increased without adding well known explosives sensitizers such as DNT, TNT, Amine Nitrate, Perchlorates which are considered to be dangerous during manufacturing cycles? The formulation of energetic emulsions are principally based on very specific raw materials allowing the reduction of the size of the droplet in the aqueous phase which will be dispersed in the oil phase. The addition of aluminium powder also increases the energy of these emulsions. Another advantage of this energetic emulsion by comparison with dynamites, is that the fumes produced by their explosion are far less toxic, which is a major advantage in underground operations.

The Civil Explosives as a Market

The energy provided by civil explosives are mainly used to break rocks either in quarries, mines, or on civil works sites...

The future of the civil explosives markets is therefore directly related to the evolution of this industry and it is easy to understand that this evolution will vary considerably from one country to another and from one continent to another. As regulations regarding the transportation of explosives are more and more restrictive, the localisation of manufacturing will probably be a major factor for success in the future. It is clear that the ‘old’ Europe is
affected by the reduction or simply the disappearance of most of the mines, iron, coal, uranium mines. The construction of motor-ways is well advanced even if the principle of road safety will mean further motor-way construction. The same applies to tunnelling, and the recent fire in the Mont Blanc Tunnel has lead governments to envisage the construction of a second tube for the most frequently used tunnels. The construction of railway tunnels which will allow a reduction in lorry transport across the mountains, will also be a challenge for the next 50 years. In the new European countries and of course in the under-developed countries throughout the world, mining and civil works is generally the first sign of their development efforts, and explosives consumption develops in parallel.

Let us try to gather some available data on the explosives markets.

![U.S.A. Explosives Consumption in Billion Pounds](image)

The first chart will show statistical information on the quantities of explosives used in the United States since 1910. Of course the product list has been modified as the complexion of the industry changed, Black powder was no longer used by the end of the 60s. Permissible explosive and Dynamites, after a continuous increase in use until 1955 saw their market decrease by 90%. On the other hand, the market for Ammonium Nitrate fuel oil, and Water Gel and Emulsion is constantly on the increase. Un-processed Ammonium Nitrate transformed directly into an explosive on-site, is now taking by far the biggest share of the market. As we can see from the chart, the overall trend has always been upwards.

The second and third charts show more details of the market trends for the last 10 years, with the USA on one side and Europe on the other. The consumption of explosives in the US reported by the Institute of Makers of Explosives is approximately 2.4 million metric tons of which Cap-sensitive high explosives such as Dynamites only represent 2% today, whereas blasting agents and Oxidisers represent 98%. Amongst these, bulk products have taken by far the largest share of the market with 90%, whereas packaged products only represent 8%. However today the consumption of packaged products represents 4 times the consumption of dynamite.
In Europe the situation is very different, this is due to the fact that bulk products have only been recently authorised by local legislation and are often not as competitive as the cartridge products because of the small sizes of holes in quarries where the quantity fired per shot is usually small due to environmental considerations.

NG based products still represent approximately 15% of the market, but this figure will probably decrease in the coming years. Some dynamite factories have closed over the last 5 years after fatal accidents, and this has led the companies involved to push for the
replacement of dynamite by emulsions. Emulsion, both cartridged and bulk represents 37% of the European market today whereas Anfo represents close to 50% and this situation has been stable over the last 5 years. However further development of more energetic emulsion will lead to a further shrinking of the market for dynamite.

No precise data are available as regard the consumption of civil explosives in the other parts of the world, but it is well known that the consumption of explosives in quarries and open pit mines in the developing areas of the world explode! This has been the case in Australia and will probably also happen in China, Russia, India and in the new Eastern European countries.

Therefore it can be expected explosives to have a rosy future in the global market. It is still necessary however, for explosives manufacturers to bring their production units closer to the site of use.

As regards quantity produced and sold, the situation should remain stable, competition exists outside the explosives manufacturers, but will not disturb our market too much. Manufacturers are producing more and more powerful diggers, rock-breakers are more and more effective, tunnelling machines are used more often for the construction of tunnels but this does not significantly encroach on the explosives market.

The situation however is less cheerful if we look at the market in terms of turnover and profitability. The development of very simple Ammonium Nitrate products, with the possibility in some areas for the end user to produce his explosive on-site, constrains the traditional manufacturers to cut drastically their average price per ton. There are many examples where the average price per ton has been cut by 50-75% to prevent the end-user from buying bulk equipment and becoming his own manufacturer.

How can the industry react against this trend? By providing more services to the customer, by taking on the responsibility for the complete shot, going as far as to sell tons of rock after detonation instead of explosive, this means installing the shot in the quarry, boring the holes, filling the holes with bulk products, installing the firing accessories, and setting off the explosion.

Another way of retaining profit has been a vertical integration on both sides, by becoming industrial Ammonium Nitrate manufacturers and by developing a line of firing accessories.
After the use of Black Powder safety fuses which were introduced by Bickford in 1831, electrical detonators have been used since 1900 and detonating cord since 1930. An interesting development was made in 1945 with the first delayed detonator, and in the 1960s with the discovery of non-electric systems. Today there is a new challenge for all manufacturers: Increasing their production of electronic detonators which will allow a better and more rational on-site use of the explosive energy, choosing the best delays according to the mechanical and geological parameters of the rocks. Using electronic detonators for blasting and mainly for mass blasting means simplicity, total accuracy and convenience as you will assign a specific delay time to each hole. What are the advantages of electronic detonators despite current market prices which are still much more expensive than for electric or non-electric detonators.

Using electronic detonators for any blasts means:

- Reduced vibration and therefore environmental protection.
- Improved productivity due to a better fragmentation with less oversize and fine, and increased crusher throughput and reduced ore dilution.
- A better handling of the quarry's configuration by allowing much larger blasts and improving wall control.
- Far less chance of a mis-fire due to cut off and hole desenitisation by dead pressing.
- Even if the prices of accessories will be higher within an electronic blast any current producers claim that the overall costs for large blasts will be lower.

The Future of Civil Explosives

The future evolution of the explosives industry is directly linked with its past history which of course starts with Alfred Nobel. He was not only a brilliant inventor, but a genius in business. As early as 1865, realising the importance of his discovery of dynamite, he patented it all over the world, and decided very cleverly to exchange his patent against shares in any of the companies willing to commercialise dynamite outside Sweden. He also gave them the right to use the Nobel name, that is the reason why you can still find today Nobel companies in many different countries. In 1887, in order to better control his various share Holdings, he decided to consolidate them by putting them into two industrial trusts. The English Trust became the very large ICI Group which was involved in the production and sale of explosives until the very end of the last century. The second one called the Latin Trust, broke up mainly due to World War 1, leaving in each country a strong Noble Company. If we try to find common strategies for the various Nobel companies we notice:

- They developed celluloid and products related to celluloid by using Nitrocellulose, which is one of the components of dynamite. Nobel companies were often manufacturers of celluloid dolls, so if you find in your attic dolls belonging to your mother or grandmother, don't throw them away, they are worth a lot of money as genuine antiques!
• Celluloid was a good start but as this product is highly inflammable explosives manufacturers became plastics manufacturers as soon as plastics were found to be far less flammable and became the huge consumer products we all know today.
• As manufacturing dynamite obliged producers to master dangerous industrial processes they generally became producers of fine chemicals.
• I do not know if it is because Nitroglycerine was found to be good for preventing heart attacks and is therefore used as a medicine, but most of the Nobel companies were involved in the development of pharmaceuticals.

All this diversification led to explosives manufacturers becoming large chemical companies. For example ICI in the UK, Dyno Nobel in Norway, Dynamit Nobel AG in Germany, SIPE Nobel in Italy or Nobel Bozel in France, and this list could certainly be extended to many other companies worldwide.

In the second part of the 20th century it was a good principle of management to focus on core businesses and to prevent too much diversification. Today all the large groups have been broken up and their explosive business have been isolated. Therefore the explosives manufacturers are looking for geographical diversification which will be most worthwhile if they intend to follow the developing markets. Today some international groups are emerging:

• The Australian group Orica which has taken over any ICI business related to explosives, Dynamit Nobel Germany and more recently the European part of the Norwegian Dyno group,
• The Spanish group UEE which recently changed its name to MAXAM
• The US group Austin which is in the process of expanding its activities to other continents.
• The French E.P.C. group which is expanding in Europe and extending its activities to drilling and blasting.

In each European country smaller companies co-exist with these groups but due to the size of the leaders will there be room for small independent companies in the next 20 years or will those companies sooner or later join forces with each other?
• The future of civil explosives is very difficult to predict. Nevertheless, some lines of development can be advanced for the near future:
  A better and more rational use of the explosive strength by the use of electronic detonators allowing the choice of the right delays necessary for the rocks to be broken.
  A better mastering of the emulsifying process for cartridged or bulk emulsion products, a reduction in the water content of emulsions which will allow higher density and therefore more energy.
  The development of bulk products and techniques to avoid transport of dangerous products by mixing inert products and having them sensitised in the holes to be filled.
  Making sure that the explosives used will detonate in 100% of the holes whatever the condition of the shot may be, which means finding the right way to prevent desensitisation and dead-pressing.

5/ To become more aware that the environmental problems related to vibration and noise during blasting in quarries or civil works are more and more complicated to overcome and therefore develop in consequence the right firing systems.

Before concluding it might be interesting to remind that there are other ways to use the high energy provided by an explosive. Unfortunately the consumption of explosives of other industries, besides mining and the military is just a few thousand tons worldwide.

These other applications concern:

• Production of industrial diamonds by using the high pressure generated by shock waves to transfer graphite into small diamond crystals used as an abrasive.
• By a process of rapid compression, heating and cooling, a piece of steel can be hardened and shock hardening is used in the railway industry for some rail parts which have to sustain a lot of stress
• Metal forming which allows it to give a specific shape to a metal plate.
• Metal cladding, in order to weld two metal plates, due to the heat and pressure of the detonation. This technique is used to produce transition joints for electrical purposes, as well as other applications in the shipping industry. But the main market for explosion cladded plates relates to the chemical industry, whenever the manufacturing process needs pressure vessels on the one side and is handling corrosive ingredients on the other side. Stainless steel, Titanium or even Zirconium must be then used in the vessel manufacturing and it becomes less expensive to use cladded plates with a thick steel plate on the outside and a thin exotic metal plate on the inside.