3. EU directives and harmonisation work

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New standardisation tasks under the European Explosives Directive: electronic detonators, on-site mixed explosives

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ABSTRACT: Since the early drafting of the European standards for civil explosives, harmonised under directive 93/15/EEC and 2014/28/EU, blasting technology has developed notably. This is particularly evident for electronic detonators and electronic firing systems, and the EU commission agreed to initiate a standardisation initiative, also noting that the currently existing document on electronic detonators is ‘only’ a *Technical Specification* (CEN/TS). This paper addresses the current activities in the area of standardisation. The EU is about to launch a formal standardisation request to cover the most recent technological developments not addressed by the current standards. The request would also include various adjustments of references to the new directive for civil explosives, and in addition the task of developing a *Technical Specification* for on-site mixed explosives and corresponding manufacturing units. The latter has been included to address the nowadays frequently found mobile production on the basis of ammonium nitrate prills or emulsions.

1 INTRODUCTION

Two areas have been identified recently, where the technical evolution in the field of explosives has moved considerably further, significantly beyond what the harmonised European standards would fully cover. In the first place this concerns electronic blasting systems consisting of an electronic detonator being operated by electronic devices for programming and firing the detonators. Such systems offer a much greater flexibility in use, as compared with detonators with pyrotechnic delay components, while at the same time being usually also much safer against misfiring or misuse by unauthorised persons. However, the significantly higher inner complexity of electronic systems makes it much more difficult to understand and verify the technical provisions installed to guarantee the functional safety of the electronic blasting system. In addition, there is a tendency to use and trust streamlined applications where you only have to press buttons in a logical sequence, where the functioning is easily demonstrated by a hands-on demonstration. But what happens inside the system remains hidden. And it is extremely difficult to tell, which failures inside the system are possible (or impossible) to occur. This is the big challenge where the current redrafting of a standard comes into focus, the 'electronic detonators including remote firing systems' as it is currently written in the draft standardisation request by the EU commission.

The other main aspect of the planned standardisation work is on-site mixed explosives. The explosives are in principle covered by the existing standard series EN 13631 for high explosives. However, the manufacturing units used on-site are so highly integrated that the question arises, whether and how the properties of the produced explosives can be controlled. At the time of the drafting of the currently applied standards emulsion explosives were known, but not used as wide-spread as nowadays.

Both topics are dealt with in the CEN/TC with the number 321 and the title 'Explosives for civil uses'. This paper marks out various areas, where the author sees particular challenges to be addressed in the near future. This paper should be seen as a thought starter, and as the work in the CEN/TC 321 further develops, more information should become available to be shared.

2 ELECTRONIC BLASTING SYSTEMS AND STANDARDISATION

As already indicated in the introduction, there are various questions to be asked and solved as the drafting of a new standard for '*electronic detonators including remote firing systems'* is picked up. And these questions not only concern the non-explosive parts of the entire system and whether these can be subjected to the European Directive on placing on the market of civil explosives or not. In some countries, such as in Germany, the non-explosive parts are subject to national laws as 'blasting accessories' and not necessarily certified together with the explosive components, which are only the detonators. However, technical solutions are so varied, that some would combine a larger part of the functionality of the electronic blasting system with the explosive components, while other systems have electronics mostly in a firing box and the detonators could even be conventional. Therefore, it would be unsuccessful to try to standardise the electronic detonator singly, while having an artificial border line to the non-explosive devices operating the electronic detonator.

On this basis, firstly, several questions are raised from the perspective of the author:

– How much is the existing technical specification CEN/TS 13763-27 of help to draft the future standard '*EN 13XXX on electronic detonators including remote firing systems'* (as it is worded in the draft standardisation request)?
– Considering (and studying) current technical solutions for electronic and remote blasting, as produced by a number of renowned blasting system manufacturers, would they compare well, and could they be described by a common set of concepts? (Or do they differ too largely?)
– Will it be possible to implement features (or technical solutions) which allow the responsible blaster to maintain an ultimate control on the operation, i.e. the firing or not-firing fully to his decision, e.g. by some sort of hardware kill-switch?
– How can the 'functional safety' of a blasting system be thoroughly proven, given that the inner components are already highly complex? Is the effort for this endeavour manageable and justifiable?

With regard to some questions, the author has a preference in some directions. But it should be clearly seen, that the process of standards development is collaborative. It will be the responsibility of all experts in the CEN/TC 321 to find a consensus on the most appropriate approach to standards and technical requirements set out in the standards. And in the end, the standards will have to be assessed against the 'essential safety requirements' given in Annex II of the aforementioned directive.

Regarding the existing technical specification CEN/TS 13763-27, the author sees limited usability for the future work. For the purpose of the new standard, the terminology has to be revised and amended by new terms and concepts. The technical requirements are mostly addressing the same known mechanical verifications as they would apply to electric detonators, and this principle should be kept for the future standard. However, additional tests such as checking the sensitivity of the electronic parts incorporated in the detonator to shock from a neighbouring blast and the consequences on functioning may be necessary. And a significant part of the assessment suggested in CEN/TS 13763-27 addresses a risk-based analysis, which in the opinion of the author should at least be re-evaluated.

Overall the CEN/TS 13763-27 offers a fairly concise collection of relevant tests, but as it is worded now, leaves room for variations on the grounds of seen as applicable or not. Perhaps a more stringent list of mandatory verifications on the system level would be beneficial for both the manufacturers and the certification bodies – though the author admits not to have any precise suggestion so far.

Some further consideration should be given to what is mentioned in the third bullet of the above list. Two completely opposite designs can be conceived as models for discussion: (A) A system with all functions fully integrated into programmable electronics, which in turn drives power sources, relays, and electronically switched connections. The programmable electronics bridges between the user panel and the hardware ultimately firing the bridge wire in the detonator. Or (B) a system which is working very much on classical concepts, where electronics only assist the accuracy of the functioning, but the supply of power, switching to the firing cables etc. is done by mechanical switches hand-operated by the blaster.

It is quite evident, that both systems A and B would benefit or suffer from several issues. While A could offer a high level of fault analysis features and prevention of out of sequence operations, there remains a degree of uncertainty as to the software in the programmed circuits and the question, whether the software is free of errors. Ultimately no software can be proven to be error-free, and the relatively high rate at which software updates are issued by manufacturers, even for current electronic firing systems, demonstrates that the software ‘never’ is final. This is a persisting problem already implemented by choosing such design.

In version B, errors in parts of the control or software could be compensated by the ultimate control the blaster would have, and the blaster would remain responsible for any untimely ignition or error in operation. Here, safety is generated by organisational and procedural provisions. Possibly such a solution would be more costly, spacious, and less configurable. The principal questions are similar as with autonomously driving vehicles on roads. The autonomous system may statistically generate less car accidents due to its never-failing attention, as compared with the normal car driver whose behaviour is subject to random error. However, where a car accident occurs by cause of a system failure, which the ‘driver’ or passenger couldn’t prevent, questions of responsibility arise – this being one of the reasons why autonomous driving develops only slowly.

3 ON-SITE MIXED EXPLOSIVES

Explosives based on ammonium nitrate (AN) as prills or based on AN solutions, should fulfil all requirements already present in the existing standard series EN 13631. At the level of product development and type testing there is no general problem with applying the tests given in the standard. When it comes to monitoring the quality during or after production the situation changes, because the given tests can hardly be performed. One reason is, that the explosive is transferred immediately after production from a hose directly into the bore hole. i.e. the explosive is not available ‘from the shelf’ or storage for a later inspection or an inspection prior to loading. In addition, the explosive has a limited life-time and changes its properties quickly over time. Of course, sampling the explosive is not impossible at all, but the situation is quite different from a plant production. Another reason why it is impossible to use a subset of the existing tests for verification purposes, i.e. the same which were done during type examination for quality control, is that in the field situation none of the methods used during type examination are practically available.

This is the background why one should reconsider, which properties and examinations could be used, much better tailored to the specific nature of on-site produced explosives. Again, one may ask a number of questions:

- Which properties are specifically relevant for emulsion explosives, in contrast to what is already in the standards, and which should be examined for type testing and for verification during production?
- Which verifications are feasible on-site and are they sufficient to guarantee a product in accordance to the type as examined during module B?
- Which verifications are currently being used?
- How do the on-site verifications (as ultimately agreed to be suitable or necessary) impact on the need to have a specifically trained operator, and can there be given any guidance on qualification and authorisation?
- How would the newly required on-site verifications have an influence on the design of on-site machinery or accompanying equipment and can there be given guidance to those designing this machinery and at the same time to those inspecting on-site manufacture (namely Notified Bodies)?

One perhaps obvious aspect as a property to be observed, is the density. The emulsion is in most cases not explosive before it has been sensitised. The conversion to an explosive takes place by a reduction of density by various means such as chemical gassing or addition of glass micro-balloons. The use of glass micro-balloons is the more predominant solution for cartridged emulsion explosives produced in stationary plants, which is however not being discussed here. It is an intrinsic feature of chemical gassing that this process progresses once initiated and leads to a continuous reduction of density over time, within some bounds of course. The methods for the determination of density currently described in EN 13631-13 address free flowing materials and solid materials, but do not specifically address paste materials with a tendency to dissolve in water, and surely do not address materials with a density quickly changing over time. Also, in the requirements part, which is EN 13631-1, explosives with a changing density are not addressed.

Here perhaps guidance is needed, which densities are to be recorded during type examination, at which times, which densities are allowed at maximum to guarantee explosive properties etc. Without this information being established during the type examination phase, the later inspections during quality control monitoring remain somewhat at will of the people involved. To shortly address ammonium nitrate fuel oil (ANFO) explosives: owing the apparent extreme simplicity of the product, it is less obvious which verifications should be done or have to be done accompanying on-site production.

Second the fact, that the on-site machinery operator acquires the role of the person manufacturing the explosive, puts a higher responsibility on this operator and calls for a specific competence and training. What is in a normal production plant distributed over several members of staff, from raw product verification, to production, laboratory controls, etc., is now in the sole responsibility of the on-site machinery operator. And this responsibility should be expressed by corresponding documentation which the operator signs and thus takes full responsibility over his product, not least to mention the affixing of the CE mark upon successful confirmation of the product properties.

This second aspect may not be primary subject of a standard addressing explosive material, however, at the stage of drafting the *Technical Specification* such information should be collected. The steps taken during type examination, and the properties relevant for the product quality will also impact the construction of the machinery used for on-site manufacture, and elements to be inspected by a Notified Body. All this understanding should be retained in an Annex to the *Technical Specification*.

And another aspect brings the discussion back to what has been addressed with electronic and remote firing systems: due to the high degree of integration of technology of on-site production with automatic electronic controls, it is evident that the operator has, by design, little influence on the production process. This brings about the question, how he should take responsibility for something he seemingly cannot ultimately control. Therefore, one may have to consider possibilities of breaking down the on-site machinery into logical units with defined functions and entry points for verification.

4 CONCLUSIONS AND SUMMARY

The discussion showed, that a number of technological questions need to be addressed with regard to new standards for electronic and remote firing systems, but that perhaps also more general design principles should be reconsidered. The consideration on whether a risk-based approach is acceptable or a safe-by-design based approach is preferred needs to be part of the process. Concerning explosives produced on-site possibly some new aspects need to be addressed at the level of type examination, and test methods for properties so far and not addressed may have to be taken on board. And for any of the automated parts of the mentioned technologies, be it firing systems or on-site manufacturing machinery, a consensus has to be found, whether preference is given to a risk based approach or an approach fostering inherent safety by design.

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Directive 2014/28/EU of the European Parliament and of the Council of 26 February 2014. The harmonisation of the laws of the member states relating to the making available on the market and supervision of explosives for civil uses (recast), *Official Journal of the European Union* L 96/1.

EN 13631-1 Explosives for civil uses - high explosives – *Part 1: Requirements.*

EN 13631-13 Explosives for civil uses - high explosives – *Part 13: Determination of density.*

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Track and trace in Europe and worldwide, the beginning, the present and in the future

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ABSTRACT: Since the introduction of the explosives track & trace in Europe in 2014 for manufacturers and 2015 for end-users, a lot has changed in all areas of the supply chain and the use of explosives. The regional associations, manufacturers' organisations, and trade associations have proven that it is possible to overcome a hurdle, that looks almost impossible in the beginning, through consistent cooperation. This paper gives an insight into the problems involved in introducing such a requirement, identifies ways and solutions, and concludes them. When looking at the current situation, the paper describes the process by which a prescribed change in business processes are transforming into a solution that increases productivity, security, and handling. It shows examples from daily work, in which possibilities for optimisation, improved quality assurance, and work facilitation are explained. It presents the resulting potential by comparing process flows, before and after the introduction of track & trace (T&T) solutions. What challenges will we face in the future, concerning the use of T&T solutions? Will the tracking of explosives become the norm worldwide? What are future hardware and software developments to be expected? What impact will this have on the global supply chain? The paper summarises the developments in the explosives industry since the introduction of the obligation to track and trace explosives. The paper draws conclusions, and current, and future evolutions are taken into account.

1 TRACK & TRACE, A NEW CHALLENGE

In 2015, I had for the first time, the honor to speak during the EFEE conference in Lyon. The Title of my speech was ‘Experiences with the pan-European implementation of a track and trace software’.

This speech took place at a time of many challenges. They had to be solved by everyone involved in the process of introducing Tracking & Tracing.

Now, after five years of experience by using this this technology in the explosives industry, I would like to give a brief review, a look at the current situation and an outlook on possible trends and developments.

As a first impression, you can say that the European explosives industry has done an excellent job.

Based on the ‘EU Action Plan on Enhancing the Security of Explosives,’ the ‘COMMISSION DIRECTIVE 2008/43/EC for the identification and traceability of explosives for civil uses’ amended by the Directive 2012/4/EU the

European Commission gives the requirements.

However, these only defined the requirements, not the way to meet them.

It was clear at the beginning that only new software solutions can handle this expected massive amount of data, which is generated by the track & trace process.

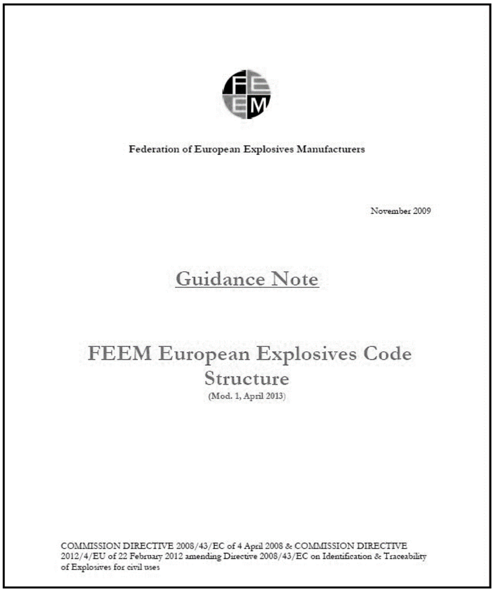
On this point, the European manufacturers, organized in the FEEM (Federation of European Explosives Manufacturers), decided to establish a project to create a 'Guidance note' which is the base for Europe-wide implementation of Track & Trace of civil explosives.

One of the main points was, to establish fundamentals, which can serve as a guide for all Member States. A significant part of this document was to create a harmonized code structure; everyone can follow within the European Union.

Additional difficulties, like the data exchange through the supply chain, the handling of small explosives and the handling of unmarked explosives stored in labeled repackaging such as boosters, have been overcome and sustainable solutions worked out.

Any difficulties, especially in the early days of the introduction of Track & Trace for marking explosives become essential. There was still no experience as to which type of marking would prove to be the most durable and best adapted to all environmental conditions in a particular environment in which explosives are used.

After some unsuccessful attempts and a relatively expensive learning process, it became clear for the majority of cases that the printing of labels and the subsequent labeling of the explosives is the preferred method.


Federation of European Explosives Manufacturers

November 2009

Guidance Note

FEEM European Explosives Code Structure

(Mod. 1, April 2013)

COMMISSION DIRECTIVE 2008/43/EC of 4 April 2008 & COMMISSION DIRECTIVE 2012/4/EU of 22 February 2012 amending Directive 2008/43/EC on Identification & Traceability of Explosives for civil uses

Figure 1. FEEM guidance note.

Field	Digits	Format	Application Identifier	AI Description	Length	Notes
Country & Production Site No.	5	Alpha-Numeric	(90)	Mutually agreed between trading partners	Variable but used as a fixed number to 5 digits	Mandatory to comply with Directive e.g. FR002 – France, 2nd site
Unique Item No. OR Logistical Unit No.	30	Alpha-Numeric	(250)	Secondary Serial No.	Variable up to 30 characters	Mandatory to comply with Directive
Determination of items and logistical units	2	Numeric	(20)	Product Variant	Fixed	Optional
Production Date	6	Numeric	(11)	Product Date (YYMMDD)	Fixed	Optional
Product Code	30	Alpha-Numeric	(240)	Additional Product Identification Assigned by Manufacturer	Variable up to 30 characters	Optional

Figure 2. Excerpt from the code structure.

The following examples illustrate the different marking types and their legibility.

Inkjet Printing:

Figure 3. Direct inkjet printing.

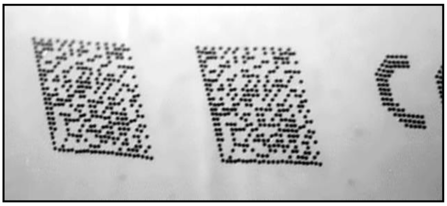


Figure 4. Readable after 2 to 5 attempts.

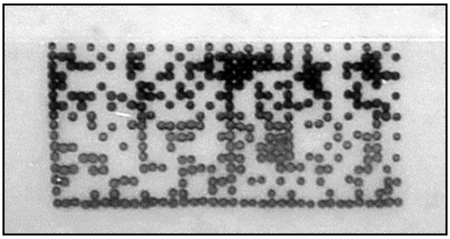


Figure 5. Cartridge diameter 65 mm.

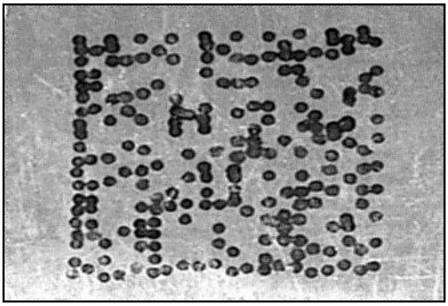


Figure 6. Cartridge diameter 25 mm, mostly not readable, cells without sharp contours and not aligned columns and rows.

Preprinted Label:

Figure 7. Readable immediately.

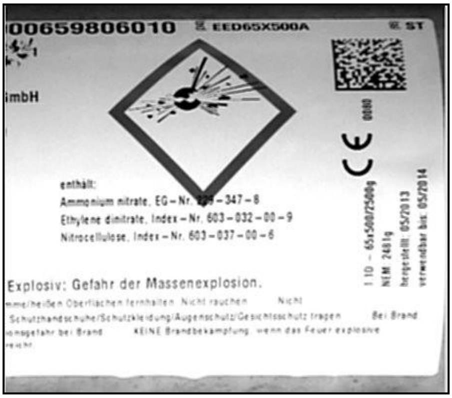


Figure 8. Readable immediately.

In addition to the problems with marking explosives, the creation of correct XML files for data transfer is still a common problem today. Although the FEEM Guidance Note provides all necessary parameters for XML creation, the implementation does not always achieve the required quality. In particular, the handling of unmarked explosives in marked outer packaging still poses problems for some manufacturers.

What we learned in the last years:

– it is possible to realise such a large project as the introduction of track & trace in a manageable time
– the decisive factor for this is the cooperation of all institutions involved, such as

government authorities, associations, manufacturers, wholesalers, end users, and IT service providers

– the prerequisite for a Europe-wide introduction is the harmonisation of the technical bases in the structure, transmission, and presentation of the data based on the jointly prepared FEEM-guidance note
– by maintaining the working groups even after the deadlines, it is possible to incorporate necessary adjustments and corrections into the work process in a coordinated manner
– problems that arise, for example, in the marking of explosives, must be communicated and solutions worked out independently of any competitive thinking
– the usability of software solutions for track & trace is an essential prerequisite for the acceptance and success of the entire project of transferring the European directives into real working life
– it is necessary to revise previously made specifications if it is determined in practical application that these cannot be implemented with justifiable effort. (for example: marking of small explosives)
– from the beginning of the project, it is necessary to analyse the effects of the implementation on existing work processes and, if necessary, to adapt software or processes. These are the only ways to minimise the additional financial and time effort.

2 TRACK & TRACE TODAY

At present, track & trace is no longer used exclusively to meet legal requirements. The further development of the functionalities of the software programs used has resulted in a considerable expansion of the areas of application. The track & trace software is useable as a warehouse management program, as software for optimising selected work processes and even for production control.

The data exchange with ERP (Enterprise-Resource-Planning) programs enables the integration of track & trace software into selected accounting and evaluation processes. Track and trace software helps empower processes and delivers accurate data about stock, movement, and shipping to customers.

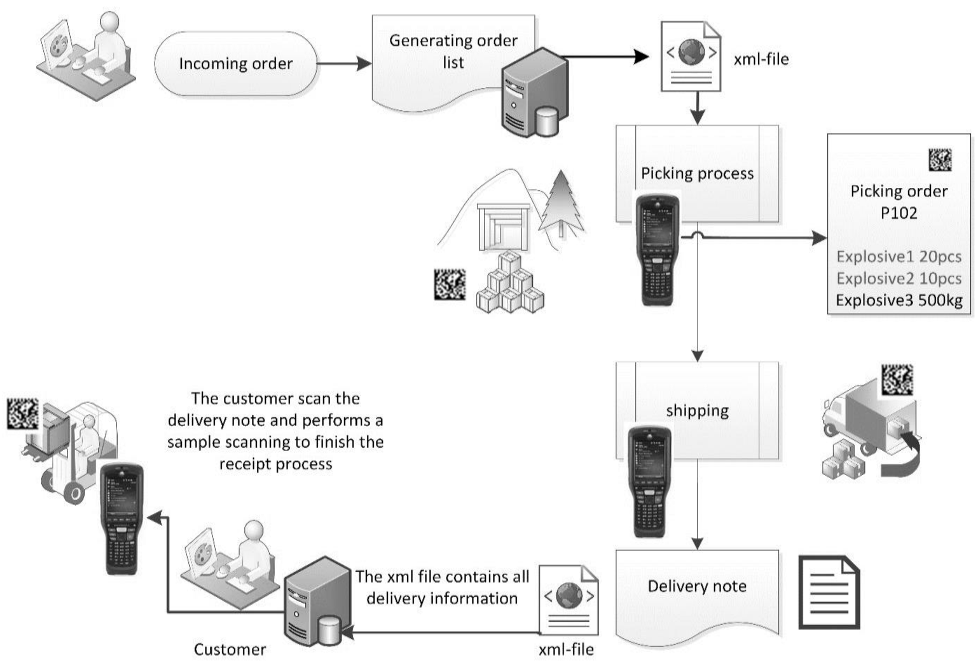


Figure 9. The simplified process from incoming order up to delivery using track & trace software.

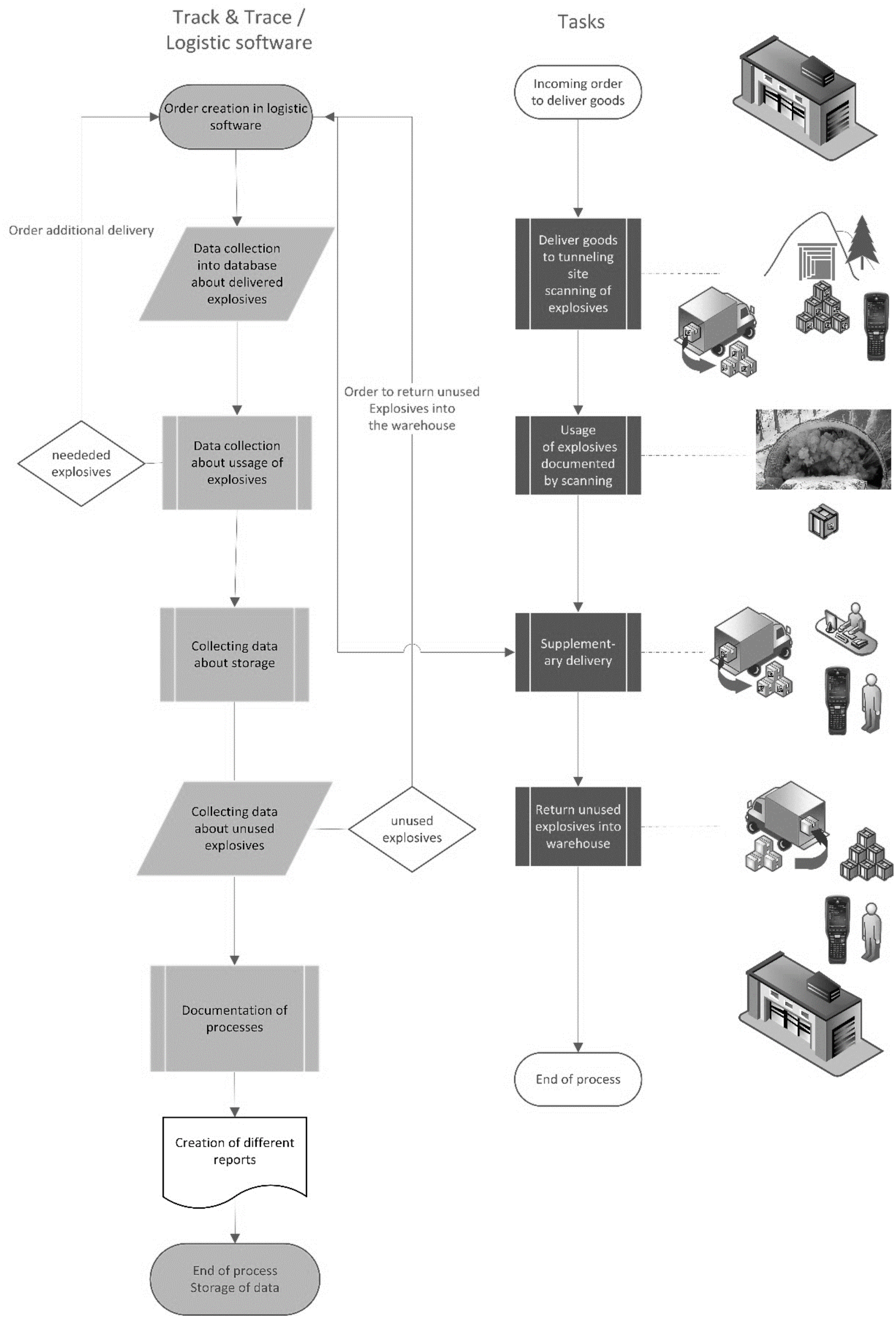


Figure 10. Example of process optimisation for delivery on time to a tunnel construction site.

The early detection of bottlenecks and the exact transmission of delivery data help speed up bookkeeping processes and can prevent supply problems. The data exchange must be possible on both sides. These enable delivering order data to the track and trace system and the performance of highly efficient guided processes like commissioning and shipping.

2.1 Track & trace from order to delivery

The example, shown in Figure 9, describes the normal processes on manufacturer or distributor side from receiving the order up to the shipping process to the end-user. By using track & trace software, it records all process steps, including all product data, movements, and persons involved.

Required documents are ready to be printed out. The XML-file, based on the FEEM guidance note, is automatically generated and can be transmitted to the customer on request without user intervention.

2.2 Process optimisation

The use of track & trace Software allows suppliers to deliver the required explosives in time, in the right quality and quantity. The supplier has an overview of all required, delivered, used, and returned explosives. This information enables the supplier to have the necessary goods delivered before bottlenecks occur. Interruptions in tunnel driving due to the lack of explosives are thus a thing of the past.

2.3 Order Management using track & trace and ERP software

Figure 11 shows an integrated track & trace solution into an existing ERP system. However,

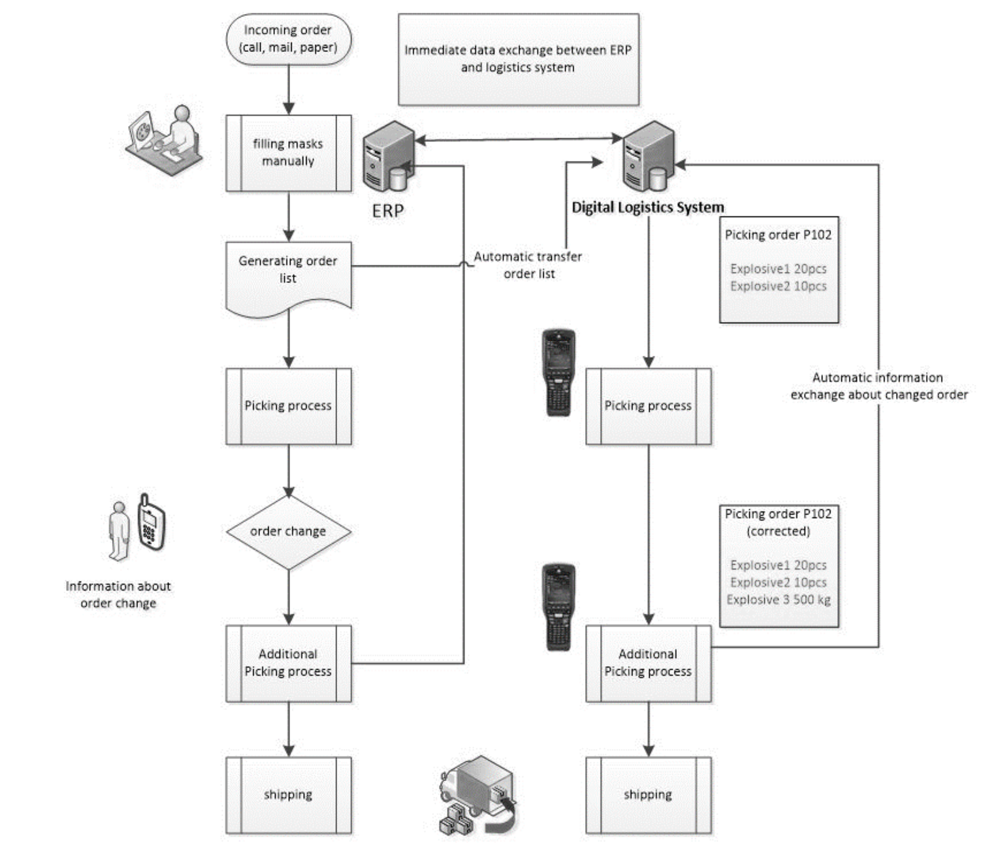


Figure 11. Order management using track & trace and ERP software.

integration does not stop at companies borders. In the pan-European explosives sector, there is a lively data exchange of shipment data across the whole supply chain from manufacturers via distributors until the final consumers. This data transfer is enabled and secured by a so-called Trust Center. The Trust Center is a vendor-independent data exchange platform that ensures barrier-free and secure data exchange between all partners in the sector. The availability of reliable data from manufacturers to end users saves much manual effort and increases quality at the same time. This integrated solution has been used by a Swiss manufacturer for more than two years. It allows the automated handling of orders and the required response directly into the bookkeeping system - the number of false invoices related to 'last minute' order changes has gone rapidly down.

In summary, the current situation on the explosives market in the European Union about the track & trace is consolidated.

However, the degree of implementation of the directive varies significantly from one member state to another. The reason for this is the often divergent interpretation of the directives. This situation applies in particular to the role of end users of explosives. The 'spirit' of the directive demands the application of the complete track & trace in the entire supply chain.

However, the corresponding transposition of the requirements into national legislation is not uniform. The necessary control measures are also not uniformly applied and implemented.

On the positive side, however, all manufacturers of explosives and the vast majority of wholesalers apply the directive consistently and prevent possible market distortions due to higher investments in track & trace systems.

3 WHERE WILL TRACK & TRACE GO IN THE FUTURE?

Of course, I'm not an oracle. However, already today, some paths are crystallising out, which will be taken in the coming years with high probability.

3.1 Global implementation of track & trace regulation

One of the most important views in my opinion is that the tracking of explosives is introduced step by step worldwide. In addition to Europe, other countries have started to implement similar solutions as well, such as Brazil, Chile, Peru, Saudi Arabia, and South Africa, which established analogical laws.

In a study named the 'UN Committee of Experts on the transport of dangerous goods and on the globally harmonised system of classification and labeling of chemicals' declared that a globalised system based on the EU solution is recommendable.

They stated:

- "The Subcommittee is invited to consider the following issues:
  (a) Inclusion of a note in the Model Regulations stating this subcommittee's recommendation that, when used, the format for explosives security markings should follow a single, globally harmonised format.
- "IME is of the opinion that since all explosives must be transported, inclusion of a note providing such a recommendation is appropriate.
- "(b) Is the format used within the European Union and proposed by IME the appropriate format?" (see Unique ID shown in Figure 12)
- "IME notes that there are various formats already in use; however, the format used within the EU is used by more individual countries and has been accepted for use in other countries such as the USA and Brazil. Therefore, IME is of the opinion that this format is the most appropriate upon which to base a globally harmonised format." (UN/SCETDG/49/INF.35, 2016)

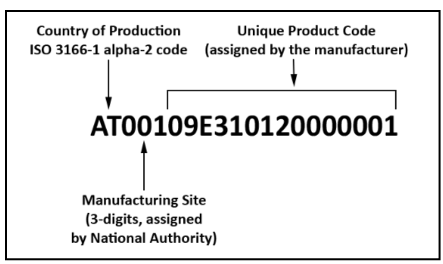


Figure 12. Unique ID format used within EU.

3.2 Software supported global supply chain

I expect that the track & trace solutions currently on the market will evolve into complex logistics software solutions. Warehouse management, in a simple form, is already a component of many track & trace solutions. With the increasing automation of production processes, the demands on logistical support will also be raised to a new level.

The globalisation of the supply chain, including that of explosives manufacturers, requires more digitalisation ever in production and sales. The complexity of the underlying processes cannot, or only with great difficulty, be represented in manual or independent software systems. Today, manufacturers of market-leading ERP systems already unite the most diverse application areas under one software core. In specialised business areas, the minimum requirement will be the provision of extensive interfaces as an essential prerequisite to survive in the market.

Already today explosives produced in Asia are offered on the European market. The manufacturers fulfill all obligations based on European regulations.

To be able to follow this trend towards global sales areas, considerable investments are necessary for the technical software support of the associated logistical processes. The main requirements to create a software solution are:

– the optimal and cost-efficient level of customer service
– the necessary management processes, to integrate the network of manufacturers, suppliers, warehouses, and end users
– a system that ensures the provision of the right type of goods, in the required quantities, at the required location, at the right time and in a high-quality condition.

All these (naturally incomplete) requirements have to be considered in software systems to be provided in the future and have to meet these criteria.

4 CONCLUSIONS

The paper gives a summary of the development of the track & trace of civil explosives in the period from the introduction and first implementation of the regulatory requirements to an outlook on possible future developments. We discuss, based on selected examples in the implementation phase, problems, and their solutions.

Some examples, including process optimisation in currently used applications, describe selected current use cases.

The possible future development path is briefly outlined. In particular, the possible worldwide introduction of regulations for the tracking & tracing of explosives is capable of transforming the existing regional supply chain into a global one.

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Figure 3 to 8 are from a presentation given by Jörg Rennert, at EFEE World Congress Moscow 2013 ‘Readability of the new Explosives Marking.’