2. EU directives and harmonisation work

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Danish experiences with obtaining regulatory approval for explosives storage facilities

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ABSTRACT: In 2008 Denmark introduced new legislation regarding the commercial use of explosives. The legislation introduced new requirements to explosives storage facilities, including specifying safety distances to various types of objects like schools, hospitals, major roads and housing. The safety distances are based on the *AASTP-1 Manual of NATO Safety Principles for Storage of Military Ammunition and Explosives* and its guidelines for storage of more than 500 kg NEQ, but are applied to all storage of more than 0.5 kg NEQ.

The legislation poses a challenge to users of explosives as Denmark is a fairly densely populated and urbanised country without large tracts of undeveloped land and therefore there are practically no areas that meet the safety distance to roads or housing. This, combined with the fact that permits given under the previous legislation were usually valid for 5 years, has led many Danish users of explosives into a limbo in recent years, where permits for storage of explosives expired but no new permits could be given.

The legislation however allows for exemption from the safety distances if a risk analysis deems the storage facility safe. Usually risk is defined as likelihood multiplied by consequence but this alone does not solve the problem, as there are no risk acceptance criteria set.

Currently the only solution is to design new explosive storage facilities in such a way that the facility itself will contain or mitigate the consequences of an accidental explosion, to a level where the consequences at nearby objects will be less than if the safety distances had been met.

Some of the possible parameters that affect the projection of consequences include the NEQ, orientation, size, ventilation areas and possible burial of the facility, along with earthworks and terrain features between the facility and the object in question.

Up to now, half a dozen storage facilities have been approved using this method.

Recently, the Danish Emergency Management Agency (DEMA) has proposed risk acceptance criteria, giving the possibility to include likelihoods in the risk analysis. The criteria are pending approval by the Danish Ministry for Justice and so far no storage facilities in Denmark have been approved based on this.

1 INTRODUCTION

Denmark is generally a flat country with an underground consisting of gravel and clay. Apart from the small island of Bornholm, the bedrock is far below the surface and therefore the use of explosives is generally less common than in some of the neighbouring countries.

The main civilian use of explosives in Denmark is in the construction industry for cutting concrete piles, removing unwanted concrete, demolition or landscaping.

This leads to a relatively low number of civilian users of explosives, spread around the country and to a relatively low knowledge of the properties of explosives amongst the authorities and population in general.

2 LEGISLATION

The current Danish legislation on the civilian storage of explosives are given in the *Administrative Order on Explosive Materials (Bekendtgørelse om eksplosivstoffer) BEK 1247 of 30 October 2013*.

For the storage of more than 500 g of regular explosives (Hazard Division 1.1), the relevant requirements are given in Table 1.

The safety distances referred to in article 7.1.2 are based on *AASTP-1 Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives* and are calculated using the formula:

$$D - k \cdot Q^n \tag{1}$$

where D is the safety distance and Q is the quantity of explosives. k and n depend on the nearby object in question and are shown in Table 2.

Table 1. Requirements for the storage of more than 500 g of HD 1.1 explosives in Denmark. Excerpt from BEK 1247.

Article	Requirement
5.1	Police approval
5.2	Storage must be inaccessible to third parties
5.3	Stored articles must not be subjected to impact, friction, heat etc.
5.4	Storage may not be in the same building as dwellings
5.6	Stored articles must be kept in the original packaging
7.1.2	Safety distances must be observed, See Table 2
7.1.3	Storage must be in a cast (concrete) vault or in a safe
7.1.4	Vault or safe must be locked at all times
7.1.5	Storage facility must have an automatic burglar alarm
7.1.6	The storage facility may not be used for storing other items
7.1.7	Compatibility groups must be observed
7.1.10	Signage: Danger, Explosives, No smoking etc.
7.1.11	Firefighting equipment must be present
14.1	The police can under certain circumstances grant an exemption from the regulations in Article 7
14.2	Exemption from the safety distances in Article 7.1.2 requires the applicant to submit a risk analysis that shows that the storage facility is safe. The police submits the risk analysis to the Danish Emergency Management Agency for approval

3 APPROVAL PROCEDURE

Before an explosives storage facility can be built, a regulatory approval must be obtained. The applicant must submit an application to the police, containing plans for the storage facility, specifying the location and intended amount of explosives to be stored.

The police will then forward the application to the Danish Emergency Management Agency (DEMA) for commenting. DEMA will then check whether the regulations, including the safety distances are observed and issue recommendations to the police on whether to approve or reject the application. The police will then inform the applicant of the decision.

In cases where the safety distances are observed, this process is relatively easy and straightforward.

The challenge is that Denmark is a highly urbanised and relatively densely populated country with a population density of ~130 per km^2 and a developed road network. Therefore, it is almost impossible to find any areas where the safety distances to dwellings and roads can be observed. Consequently, all applicants have to ask for exemption under Article 14.2 of BEK 1247 and produce a risk analysis showing that the site is safe.

3.1 Risk analysis

In general, risk is defined as shown in Equation 2.

$$\text{Risk} = \text{Probability} \cdot \text{Consequence} \quad (2)$$

Risk is often expressed in terms of the expected number of fatalities per year. A standard method for conducting a risk assessment is to estimate the probabilities and consequences of the adverse events and compare the product thereof to a set

Table 2. Safety distances for the storage of more than 500 g of HD 1.1 explosives in Denmark. Excerpt from BEK 1247.

No	Object	Calculation parameters	Minimum safety distance
1	Hospitals, schools, kindergartens, tall buildings and similar	k = 44,4, n = ⅓	D_{min} = 800 m
2	Dwellings	k = 22,2, n = ⅓	D_{min} = 400 m
3	Buildings and other activities not related to the storage facility, cf. row 1 and 2.	k = 22,2, n = ⅓	D_{min} = 270 m
4	Public roads, ports, railroads and similar without constant dense traffic	k = 14,8, n = ⅓	D_{min} = 180 m
5	Public roads, ports, railroads and similar with constant dense traffic	k = 22,2, n = ⅓	D_{min} = 270 m
6	Occupied buildings within the same site as the storage facility	k = 22,2, n = ⅓	D_{min} = 270 m
7	Other storages of explosives without traverse protection	k = 22,2, n = ⅓	D_{min} = 90 m
8	Other storages of explosives without traverse protection	k = 2,4, n = ⅓	D_{min} = 9 m

threshold value or acceptance criteria. This method is, for instance, used for risk assessments for sites containing dangerous substances in accordance with Directive 2012/18/EU (the Seveso III Directive).

The challenge is that in the current Danish regulations there are no set acceptance criteria, a criteria that can be administratively defined by the Danish Ministry for Justice.

Therefore, a slightly different approach is needed, where it is assumed that an explosion of the largest possible magnitude will definitely take place (probability set to 1) and then designing the storage facility in a way that ensures that the consequences (overpressure) at any nearby object will be equal to or less than if the safety distances of BEK 1247 had been observed.

4 DESIGN OF STORAGE FACILITIES

There are six parameters that influence the magnitude of the pressure at a certain distance from an accidental explosion in an explosives storage facility. They are:

- Charge weight [kg]
- Stand-off distance [m]
- Room volume [m^3]
- Vent area (door) [m^2]
- Orientation in relation to the storage facility [front, side, rear]
- Interlaying terrain [-]

For a planned explosives storage facility, all of the nearby objects mentioned in Table 2 must be identified and the overpressure at each object must be determined and shown to be lower than if the safety distances of BEK 1247 had been observed.

The American Defence manual UFC 3-340-02 Structures to Resist the Effects of Accidental Explosions (formerly known as TM 5-1300) provides graphs of the relationship between pressure, scaled distance and scaled venting to the front, side or rear of a partially vented four-wall cubicle. Scaled distance is defined as seen in Equation 3:

$$Z = \frac{R}{W^{\frac{1}{3}}} \tag{3}$$

where Z is the scaled distance, R is the stand-off distance and W is the charge weight.

Scaled venting is defined as seen in Equation 4:

$$A_{v,s} = \frac{A}{V^{\frac{2}{3}}} \tag{4}$$

where $A_{v,s}$ is the scaled venting, A is the venting area and V is the room volume.

The NATO manual AASTP-1 Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives provides guidelines to whether an object should be considered to be in front, to the side or rear of the storage facility.

The above relations are then used to determine a set of related values for the room volume, vent area, allowable charge weight and facility orientation, that will produce tolerable pressures at all nearby objects. This is an iterative process that is not easily automated.

4.1 Terrain

The method presented above is generally valid for flat open terrain. Any permanent terrain features present between the explosives storage facility and a nearby object can be taken into account, say if there is a hill between the storage facility and an object.

4.2 Fragments

The legislation specifies minimum distances (see Table 2) due to possible fragments. As the civilian use of explosives rarely includes cased explosives like grenades, only secondary fragments from the storage facility are considered.

If the storage facility is built as a buried structure with an earth cover and the cover is free from rocks or stones, it is possible to neglect the minimum distances. AASTP-1 also specifies minimum criteria for cover thickness.

4.3 Other considerations

Apart from the safety distances, the storage facility must also be designed to meet a number of other criteria with regard to:

– general construction standards and codes (Eurocode)
– ventilation
– indoor climate (temperature, humidity)
– burglary prevention and alarms

Table 3. Risk based acceptance criteria proposed by DEMA.

	Acceptance criteria
Individual risk	
Persons directly involved in work with explosives	Rules for general labour safety (Rules set forth by the Danish Working Environment Authority)
Other persons employed in the same business	10^{-5} per year
Third person	10^{-6} per year
Risk to society	A curve of accumulated frequencies where the frequency for 1 death is 10^{-4} per year and which decreases in relation to the square of the number of deaths. The frequency for 1,000 deaths must be 0.

– fire safety
– lightning conduction
– etc.

5 OUTLOOK

The current practice only includes the consequence aspect of the risk analysis. Therefore all the explosives storage facilities designed using this method are several orders of magnitude safer than they might have to be. DEMA is aware of this and work is currently ongoing to define risk based criteria, that will also allow the probability of an explosion to be taken into account in the risk analysis.

DEMA has proposed risk based criteria as shown in **Error! Reference source not found.**:

Formally the risk criteria must be issued by the Danish Ministry for Justice, so DEMA's proposed criteria have not yet been approved but work is already ongoing for at least one company to submit an application for approval based on the risk based approach.

6 CONCLUSIONS

Since the implementation of the Administrative Order on Explosive Materials in 2008, civilian users of explosives have had difficulty in obtaining the required permits and approval to store explosive materials.

The legislation provides safety distances between explosives storage facilities and nearby objects, that cannot be kept in practice. Therefore users must provide a risk analysis that shows that the facility is safe. The legislation is very conservative, as it only considers the potential consequences of an accidental explosion and does not allow for the probability of occurrence to be taken into account.

Therefore a practice of designing explosive storage facilities in such a way that the facility itself will contain or mitigate the consequences of an accidental explosion, to a level where the consequences at nearby objects will be less than if the safety distances had been met, has been developed and implemented. Currently, half a dozen explosives storage facilities have been approved using this method.

A process has been started by DEMA to allow the probability of occurrence to be taken into account. Work is ongoing to get the first approval based on this method, but the proposed risk criteria have yet to be confirmed.

A new risk based method will reduce the overall cost of construction because facilities could be placed closer to other objects and would not have to be as sturdy as before. Even though the

cost of the risk analysis would be higher, the overall cost will be lower.

REFERENCES

Danish Ministry for Justice, 2013. Administrative Order on Explosive Materials (Bekendtgørelse om eksplosivstoffer) BEK 1247 of 30 October 2013 incl. addenda and corrigenda.

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