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Working Group on Integrated Water Resources Management

Thirteenth meeting*

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Item 12 of the provisional agenda
Water and industrial accidents

Draft safety guidelines and good practices for the management and retention of firefighting water: technical and organizational recommendations

Prepared by the Joint Ad Hoc Expert Group on Water and Industrial Accidents, in cooperation with the secretariat**

Summary

In 1986, as a result of a fire at the Sandoz pharmaceutical company near Basel, Switzerland, 30 tons of toxic chemicals were released into the Rhine owing to the lack of firefighting water retention. This caused vast transboundary water pollution, suspended drinking water supplies, devastated fish stocks in Switzerland, France and Germany, and reached as far as the Netherlands — approximately 700 kilometres downstream.

At a seminar on the occasion of the twenty-fifth anniversary of the accident (Bonn, Germany, 8–9 November 2011) Parties to the Convention on the Protection and Use of

* Second joint meeting of the two working groups.

** The present document is being submitted without formal editing and late owing to resource constraints.

Transboundary Watercourses and International Lakes (Water Convention) and the Convention on the Transboundary Effects of Industrial Accidents (Industrial Accidents Convention) noted with concern the continuing lack of guidance for preventing similar accidents in the future. To address this need, in 2016, the Bureaux to the two conventions tasked the Joint Ad Hoc Expert Group on Water and Industrial Accidents (Joint Expert Group) to develop safety guidelines and good practices for the management and retention of firefighting water. This proposal was endorsed by the Conference of the Parties of the Industrial Accidents Convention at its ninth meeting in November 2016 (see ECE/CP.TEIA/32/Add.1, workplan and resources for the Convention for 2017–2018) and by the Working Group on Integrated Water Resources Management at its eleventh meeting in October 2016 (see ECE/MP.WAT/WG.1/2016/2).

The objective of the safety guidelines is to enhance existing practices with regard to firefighting water retention and to promote harmonized safety standards in the United Nations Economic Commission for Europe region. The safety guidelines and good practices are split in two parts: general recommendations (ECE/MP.WAT/WG.1/2018/8-ECE/MP.WAT/WG.2/2018/8) and technical and organizational recommendations for the management and retention of firefighting water (contained in the present document).

The Working Group on Integrated Water Resource Management and the Working Group on Monitoring and Assessment are invited to review, comment and endorse both parts of the safety guidelines and good practices. It is subsequently envisaged that the documents will be presented to the Meeting of the Parties to the Water Convention at its eighth session (Astana, 10–12 October 2018) for endorsement and to the Conference of the Parties to the Industrial Accidents Convention at its tenth meeting (Geneva, 4–6 December 2018).

Contents

I. Technical and organizational recommendations for the management and retention of firefighting water

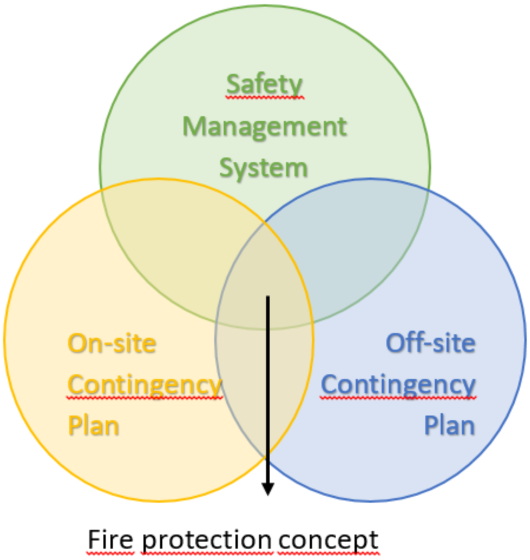
1. This part of the Safety Guidelines and Good Practices for the Management and Retention of Firefighting Water contains specific technical and organizational recommendations for the management and retention of firefighting water for operators and competent authorities. As firefighting water is hazardous to water irrespective of the burned material, the occurrence of fires should be prevented in the first place. Should a fire occur, despite stringent safety measures, it needs to be detected quickly, the design of the facility needs to prevent the further spread of the fire, and staff need to know how to react and operate the fire-related equipment in case of an emergency. These and further aspects are part of a sound fire protection concept which should be in place. In particular, the fire protection concept at a hazardous activity is composed primarily of the following aspects:

(a) Active fire protection, which can include manual or automatic fire detection systems and fire suppression;

(b) Passive fire prevention, which includes compartmentalization of the overall site i.e., through the use of fire-resistance rated walls and floors. Organization into smaller fire compartments, consisting of one or more rooms or floors, prevents or slows down the spread of the fire from the room in which the fire origins to other building spaces, limits building damage and provides more time to the building occupants for emergency evacuation or to reach an area of refuge.

2. Furthermore, the fire protection concept includes minimizing ignition sources and training the occupants and operators of the facility on the operation and maintenance of fire-related systems, so that they can ensure the correct functioning and activation of the systems in case of emergency. The correct procedures should be followed, such as the notification of the fire response service and emergency evacuation. These elements are addressed as part of the safety management system and contingency planning. As such, the fire protection concept is part of the safety management system and the on-site and off-site contingency plans (see figure 1 below). The fire protection concept should be based on the fire brigade response plan and a firefighting water retention concept.

Figure 1
Fire protection concept



A. Fire protection concept

3. As part of the on-site contingency plan, operators should elaborate and implement a sound fire protection concept that should be adjusted to technical and organizational needs and new developments. The personnel should be trained regularly according to this concept.

4. The fire protection concept can be divided into general and specific measures, as well as structural and plant-specific fire protection measures. Together these measures make the occurrence of a fire a low probability. The measures will also allow for earlier detection and suppression of fire outbreaks so that the minimum quantity of firefighting water is needed.

5. The fire protection concept should include a firefighting strategy and a concept for the retention of firefighting water and it should integrate or include references to the following organizational plans:

(a) Waste and rain water sewage plan, including intervention points and discharge points into surface waters or public sewer systems;

(b) On-site contingency plan, including alarm and evacuation organization;

(c) Fire brigade response plan, including firefighting techniques, firefighting water management strategies, emergency contacts, access routes, floor plans and chemical inventories, etc.

6. The concept for the retention of firefighting water comprises the documentation of the layout, dimensioning and functioning of all measures implemented by the operator in order to adequately retain the firefighting water that is used.

1. General measures

7. The role of emergency planners and emergency responders also needs recognition, in consideration of the environmental impacts of accidents and thus developing contingency plans that mitigate environmental harm (e.g., appropriate firefighting strategy).

8. If an adequate defensive fire protection system exists (intervention time, class of fire brigade, local knowledge), the installation of a fire detection and fire alarm system and the resulting early detection of a fire can restrict the extent of fire and thus the required quantity of firefighting water.

9. The use of non-combustible building materials reduces the fire load and the fire spread in the building and, consequently, the quantity of firefighting water required to extinguish the fire. Therefore, non-combustible and heat resistant building materials should always be used and the area should be divided into fire compartments, separated by fire-resistant materials.

10. By means of automatic extinguishing systems (sprinklers, deluge systems, high expansion foams and extinguishing gases) the fire can be extinguished or its spread can be stopped at the earliest stage of development (and possibly even without additional firefighting water being used by the fire brigade). The quantity of firefighting water required by the fire brigade can then be up to factor 10 less than when compared to a developed fire without an extinguishing system. However, whilst fixed systems can often effectively reduce firefighting water volumes, there is a probability that these arrangements fail. Thus, for contingency planning at high hazard sites even worst-case scenarios may be considered, if the escalation of the fire would lead to significantly larger volumes of firefighting water.

2. Specific measures

11. The specific fire protection measures consist of:

(a) Constructional measures;

(b) Facilities for detection and notification of fires;

(c) Mobile and stationary firefighting equipment (Operator and external fire brigade);

(d) Provision of suitable firefighting agents and water in adequate quantities, including high-volume pumps;

(e) Administrative measures such as regulations for storage facility, fire prevention plans, training of personnel;

(f) A well-trained and equipped fire brigade that is familiar with the fire-protection plan and the special aspects of the hazardous activity, e.g., a fire in a pesticide storage; and

(g) Facilities and measures for the retention of contaminated firefighting water (both installed and mobile systems).

3 Structural fire protection

12. Constructional measures aim to contain fires within a limited area of the facility.

13. Fire-compartment areas are among the most critical issues to limit the spread of potential fires and subsequently limiting the needed firefighting water and the firefighting water retention capacity.

14. For all measures applied to reduce the risk of fire and subsequent damages by firefighting water, technical specifications should be taken into account and a maintenance and periodic test programme should be conducted that ensures the continued operability of the corresponding components. This involves intelligent drainage systems (e.g., for flammable liquids in open plants), fire barriers, etc.

15. To reduce the risk of fire, plants should be adequately subdivided into fire compartments and fire cells. The size of fire compartments is a key factor in limiting the volume of firefighting water needed. Based on past experience, the volume is somewhat directly proportional to the fire surface area. Calculation examples and numerical relations are given in annex.

4. Plant-specific fire protection

16. Technical measures aim to limit fires by providing rapid detection or intervention.

(a) Automatic fire detection and alarm: Automatic fire detection systems will shorten the intervention delay time, enabling an intervention before the fire can spread excessively;

(b) Automatic fire-extinguishing system: Sprinklers, carbon dioxide extinguishing systems, deluge systems and other automated extinguishing devices will extinguish fires or contain them within a smaller area. This very effectively minimizes the volume of firefighting water;

(c) Smoke and heat venting system: Smoke and heat venting systems prevent excessive overheating of fire compartments, thus helping to keep containments intact and limiting the amount of water needed for cooling.

17. Storage height and density: Storage height and density (kg combustible goods per m2 storage area) affect the firefighting water volume in two ways. A higher storage density obviously causes a higher thermal load and thus a more intense fire, requiring more firefighting water. On the other hand, effective firefighting becomes increasingly difficult with greater storage heights. This also means more firefighting water, unless specific protective measures are taken.

18. Stored liquids: Due to their probable release during a major fire, the volume of any liquids stored or contained within production equipment should be added to the retention volume needed for firefighting water.

19. Flammable substances: The fire risk and the fire spread velocity are dependent on the flammability (flash point) of the stored goods. Highly flammable liquids generally lead to more rapidly spreading and larger fires. Where practicable, containers containing flammable liquids should be designed to minimize risk of failure in fire.

20. Hazardous properties of substances: Certain properties (e.g., corrosiveness) of hazardous chemicals may limit the choice of materials used for the firefighting water retention systems. Likewise, some substances may cause hazardous chemical reactions, when released or may demand the use of other extinguishing agents than water (in which case, there may be a need for a smaller volume of firefighting water retention).

21. Combustible installations, packaging and construction materials: Not only the goods in storage and production equipment contribute to the thermal load. Often, large amounts of packaging materials (cardboard, plastics, wood, etc.) are present. A significant contribution, frequently overlooked, may come from combustible installations (cables, pipes, ducts, etc.), building materials or furniture. Combustible wastes (especially liquid flammable wastes) can also contribute to the escalation of fires.

22. Some polymers exhibit exothermic pyrolysis in fire (e.g., rubber) and form a self-heating mass difficult to extinguish and releasing hazardous pyrolysis products in liquid form. Long-time cooling is then necessary, leading to extensive volumes of firefighting water.

B. Firefighting water retention dimensioning

23. Several approaches for calculating the needed retention volume of firefighting water exist. However, the methods are not mandatory within the countries and differ significantly in the resulting retention volumes. Also, the methods developed mainly take into account "standard fires" which comprise up to 90 per cent of fires experienced. The so-called catastrophes, which have an unusual fire development, are not taken into account in the methods.

24. Considering a number of catastrophic fires at hazardous activities in the ECE region, the amount of firefighting water used during those accidents was much higher than calculated in most of the known models, highlighting the need for larger firefighting water retention volumes.

25. The following calculation approaches for firefighting water are among the most validated and are based on scientific and empirical evaluation of actual fire events by independent experts:

(a) Planning and Installation of Facilities for Retention of Extinguishing Water. Guidelines for Loss Prevention by the German Insurers, No. VdS 2557, Koln, 2013 (see reference list);

(b) Swiss Intercantonal Guideline /Interkantonaler Leitfaden. Löschwasser-Rückhaltung – Leitfaden für die Praxis. 1. Auflage, Zürich, 1. Auflage, 2015 (see reference list).

26. Amongst the various parameters affecting the volume of needed firefighting water to extinguish a fire, the total area of a designated fire compartment, seems to have the most important influence (see chapter C.1.3. and annex).

27. Based on these experiences, a stepwise approach for the calculation of firefighting water retention facilities is proposed (see annex):

(a) Step A: For a quick, rough estimation, a direct proportionality of the firefighting water volume needed for the largest fire-compartment area can be assumed. This can be roughly equated to one square meter of the fire compartment area resulting in one cubic meter of retention volume (i.e., 5,000 m² fire compartment area needs 5,000 m³ of retention volume).

(b) Step B: Up to 10-fold smaller retention volumes are needed, if the facility is equipped according to an advanced fire protection concept (i.e., automatic sprinkler, high expansion foams, extinguishing gases, etc.). Accordingly, a 5,000 m² fire compartment area would require 500 m³ of retention volume. In most cases, all kinds of liquids that are present in the fire compartment will spill into the firefighting water and increase the requested retention volume. These volumes should be added.

(c) Step C: If there are specific additional data available, such as the density and form of stored goods and the thermal load of potentially affected materials, a more advanced methodology may preferably be used, e.g., the German VdS or Swiss Intercantonal Guideline, bearing in mind the restrictions of these methodologies (see annex).

28. Steps A and B above can be applied to facilities in all countries, especially when critical data about the hazardous materials is limited or not available. This rough estimation will show the order of magnitude of the needed retention volume.

29. In developed and industrialized countries, the more advanced methodologies according to step C are recommended for the calculation of firefighting water retention volumes.

30. If the firefighting water retention volume calculated according to steps A to C is too large for realization, alternative extinguishing methods should be considered, such as sprinklers. High-tech firefighting systems, such as ultrafine water drops or carbon dioxide extinguishing systems, may bring additional advantages by diminishing the firefighting water volume and reduce smoke.

31. The below flowchart (see fig. 2.) provides an overview of the proper dimensioning of the retention capacity needed. Various factors influence the calculation of this volume, most importantly the following:

(a) The surface area of the fire (normally this would correspond to the largest fire compartment – or in case of bundled storages the bund area) (fig. 2, No. 2);

(b) The thermal load of the materials within the fire (including combustible construction materials and building materials, packaging materials etc.), respecting the size of fire as pool fire size and location;

(c) The presence (or absence) and efficiency of extinguishing devices, such as sprinklers/deluge systems;

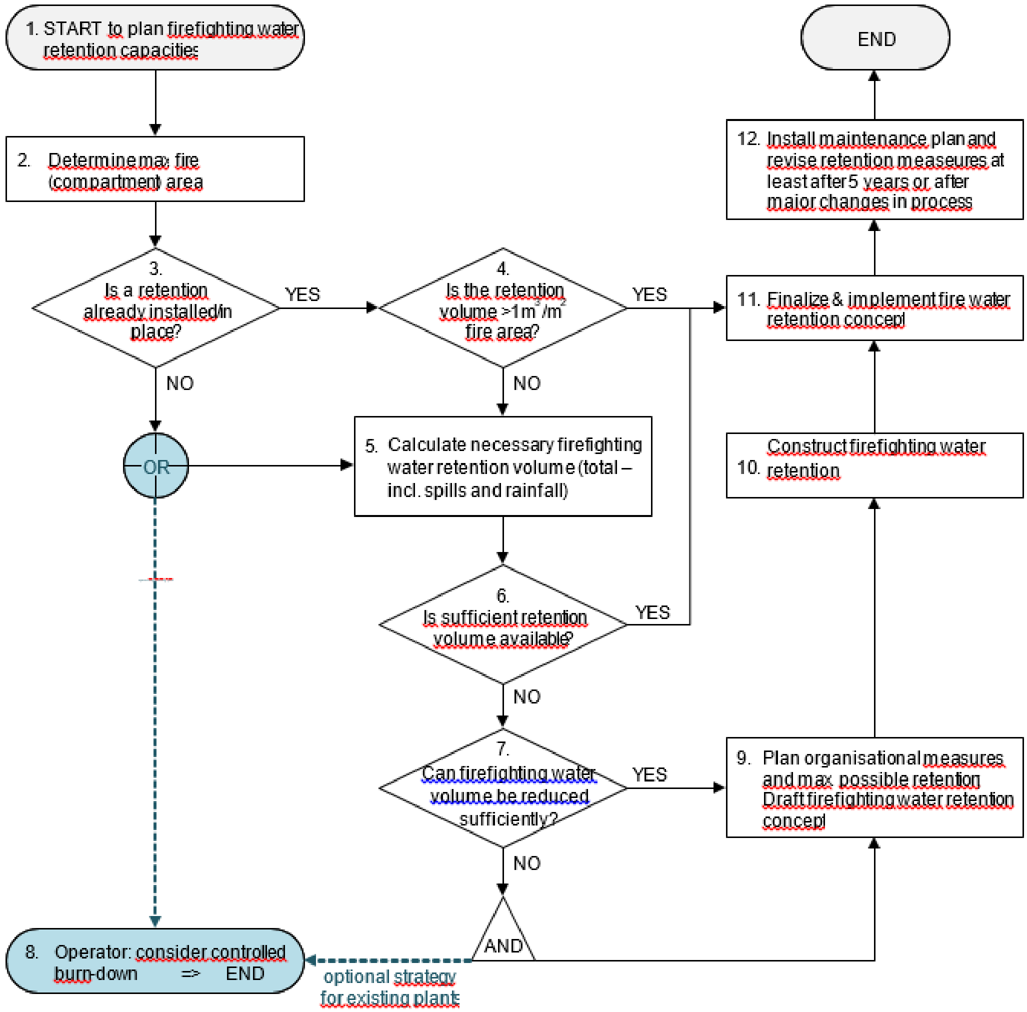
(d) The volume of all chemicals and liquids in production, operation and storage that can be released into the firefighting water;

(e) The maximum water delivery rate and duration for firefighting purposes;

(f) The possible amount of rainfall during and after the event, until the firefighting water can be properly disposed of (this may be anything from a few days up to several weeks; the maximum precipitation rate for the appropriate time may be used to determine the additional volume);

(g) Waves and shift of water (liquids) levels due to wind.

Figure 2
Flow chart for firefighting water retention dimensioning



32. In general, the retention volume can be drastically reduced by implementing efficient measures (fig. 2, No. 7) to prevent fires from spreading, by using automated fire detection in combination with automatic extinguishing systems and by applying efficient firefighting techniques. If this is not done, the firefighting water volume can be extremely large. The approximate volume, based on experience, is up to 1 m^3 per 1 m^2 of fire surface area (not accounting for rainfall or the volume of released chemicals).

33. If a retention volume of more than 1 m^3 per 1 m^2 of the maximum possible fire (compartment) surface area is already available and effectively usable, this may be considered as adequate, and further dimensioning considerations may be omitted (fig. 2, No. 4) unless the hazards noted above indicate that a greater volume of firefighting water will be required under that circumstance. It is nonetheless recommended to employ as many measures as practicable to reduce the actual volume of firefighting water (fig. 2, No. 7), since the construction of large retention volumes is very expensive and since any contaminated water will have to be disposed of eventually — usually at high cost.

34. Finally, if an adequate retention volume cannot be achieved (on-site), the maximum attainable volume should nonetheless be installed and complemented with additional organizational measures (e.g., specific instructions and training for firefighting brigades, special firefighting techniques, extinguishing agents other than water, special contingency planning, planning for external retention volumes, and disposal of firefighting water during the fire) (fig. 2, No. 9). In certain cases where human health and safety is not at risk, allowing for a controlled burn-down (fig. 2, No. 8) of parts of the facility should be considered as well — using only a minimum of water to cool adjacent buildings/structures and prevent the fire from spreading. This can be an option to prevent damage to ground and surface waters, but the operator must always consult the competent authorities and external firefighting brigades and this decision must not expose people to additional hazards.

C. Planning and design of retention systems

35. In protecting people and the environment from contaminated firefighting water, the design of the retention system is one of the most important topics. The following chapter refers to the Guidelines for Loss Prevention by the German Insurers: Planning and Installation of Facilities for Retention of Extinguishing Water (VdS 2557: 2013), and provides a short overview of the issues to which planners, operators and competent authorities should pay attention. Other guidance covering these issues include "Containment systems for the prevention of pollution. Secondary, tertiary and other measures for industrial and commercial premises, CIRIA" (C736)[1] and various Industrial Emissions Directive BREFs.[2]

36. It is important that retention systems are adjusted to conditions of the location of the production site. The retention system should also be designed as a logically coherent, integral system, considering fire protection and reduction measures, firefighting water collection, storage and disposal.

37. To avoid damages caused by contaminated firefighting water, the implementation of appropriate technical equipment is required.

38. There are several possible types of systems for the retention of contaminated firefighting water. The systems can be installed permanently (i.e., pre-installed water barriers or permanent retention basins, if necessary with pumping installations) or be provided as mobile facilities (i.e., firefighting water barriers, drain sealing pads and devices, mobile storage tanks).

39. Due to safety and reliability aspects, permanently installed retention systems should be preferred, if possible.

40. The permanently installed retention systems can be subdivided into passive, self-activating and manually triggered systems. The automatically triggered systems need to have two different independent triggering lines to ensure functionality and to avoid activation by accident. Manually activated systems are generally less reliable in stressful situations.

41. When using mobile facilities, it needs to be guaranteed, that they can be installed rapidly and can be managed with minimum effort, i.e., their set up should be possible with two people maximum.

[1] Available from https://www.ciria.org/Resources/Free_publications/c736.aspx.
[2] E.g., http://eippcb.jrc.ec.europa.eu/reference/BREF/esb_bref_0706.pdf.

1. General requirements

42. Regarding stability, tightness and durability, facilities that are used as retention devices (i.e., retention ponds, contingency basins etc.) should be resistant to any contaminated firefighting water and the necessary impermeability needs to be assured. Retention facility components that can be exposed to a fire should be resistant to high temperatures and other physical and chemical impacts.

43. Besides stability and durability, the functional safety of retention systems should be considered. When using self-acting retention systems, it needs to be ensured that the shutdown position can be guaranteed at any time. Therefore, two independent power supply systems should be provided.

44. When using manual systems, a sufficient permanent on-site work force should be available, so that the retention devices can be activated as soon as possible.

45. If firefighting water will be held in underground systems or cellar basins, it needs to be ensured that no flammable or explosive vapours are present.

46. All connections to the retention facility, if indoors, must be fire-resistant, including doors and inspection shafts.

2. Installation of retention systems

47. Generally, retention devices should be arranged in such a way that they cannot be damaged by daily operations and are accessible for maintenance at any time.

48. Water barriers should be installed inside buildings (in gateways or floors) and other facilities, so that fire fighters can enter the building or facility during the extinguishing procedure. If the water barriers need to be installed manually, they should be stored near the corresponding gateway or floor and be easily accessible. They should also be protected against damage. If no permanent on-site work force can be guaranteed, the water barriers should be installed in advance.

49. If the sewer is used as a part of a retention system, it should be ensured that the sewer is stable, resistant to the contaminated firefighting water, and tight. Furthermore, the sewer should be closed-up in an emergency without causing backflow into connected systems. When the sewer is also used for draining waste- or cooling-water, this fact should be taken into account during planning and dimensioning of the possible retention volume. If the firefighting water can be mixed with flammable liquids, draining through the sewer is allowed only if the build-up of an explosive atmosphere can be excluded.

50. Furthermore, inspection shafts should be installed at the sewer for controlled sampling by the operator.

51. In case of open retention basins or other systems, which are exposed to rainfall, there must be a system to control accumulated liquid volume during ordinary operations to avoid overflow and to ensure sufficient available retention capacity is maintained.

52. When pumps are used for the transport of contaminated firefighting water to a retention basin, they should be designed to deliver the required output even under extreme conditions. Pumps need to be installed permanently. If this cannot be provided for, the operator should ensure that well trained workers can install mobile devices at any time. Pumps can be triggered automatically or manually dependent on the existing emergency concept. Furthermore, a reliable power supply is to be guaranteed even in the case of a fire. Associated transfer drains and pipes similarly need to be sized to handle anticipated liquid volumes.

53. When installing permanent or temporary retention basins, the existing legislation in terms of building, water protection and hazardous goods should be considered. The basins should be equipped with ventilation and air extracting devices, which are designed for maximum in- and output flows inside the basin.

54. In principle, retention devices should be located outside of the production and storage units. Especially when flammable substances are used, a fast and safe removal of these substances during a fire is very important, so that they do not cause a further expansion of the fire.

55. Furthermore, the secondary containment of the chemical could be used as retention device. However, it should be dimensioned in such a way that in addition to the leakage volume of the hazardous substances, the volume of the firefighting water (including cooling water, rainwater and any foam blanket) can be retained (i.e., an additional free board should be considered). Catchment areas and retention devices for the retention of contaminated firefighting water should be arranged and equipped to detect overfilling immediately in order to prevent the overflow of the spilling liquid to adjacent fire-compartment areas. Additionally, they should be accessible at any time to initiate further actions, if necessary, e.g., the removal of liquids to prevent overfilling.

56 For the retention of firefighting water containing flammable liquids, the guidelines for explosion prevention should be respected.

57. The retention basins and all barriers used for firefighting water retention need to be stable, tight, and mechanically, thermally and chemically resistant.

3. Retention devices

58. Retention devices should have overfill detection or alarms. Retention devices can be, for example, firefighting water bulkheads or other mechanically shut-off-barriers which only lead to a retention basin when being activated in the event of a fire. A retention basin is normally a basin that is permanently available.

59. The shut-off devices should be accessible at any time and need to be easily operable. In some cases, for example, the containment of flammable liquids, an automatic or remotely operated system may be necessary since risks to people might indicate that the local operation is not appropriate. Automatically operating safety devices, such as pumps and gate valve, should have an independent power supply. In case of a failure of these safety devices precautions need to be taken (e.g., redundancy, duplication, fail-safe installations, mobile equipment).

60. Generally, it should be distinguished between two different types of retention devices:

(a) Central retention devices for a number of facilities on a site (e.g., discharging through rain- and cooling-water sewers into a central retention/contingency basin). Central retention devices are not located on the property of the operator and their running is the responsibility of someone else than the operator, for example a water treatment plant; and

(b) Local retention devices directly connected to a facility (e.g., retention basins). Local retention devices are located on the property of the operator who is also in charge of the necessary maintenance.

61. Local retention devices should be constructed in a way that:

(a) A secure retention is ensured — impermeability and durability need to be assured, and

(b) Additional retention volume for possible leakage is provided.

62. If no local retention device can be provided/realized, a central retention device (e.g., contingency basin of a wastewater treatment plant or of an industrial area) can be chosen. In this case, it needs to be guaranteed, that a secure discharge of the firefighting water is possible and the impermeability and durability of all construction materials (including the sewer systems) is assured.

4. Planning and maintenance of firefighting water retention systems

63. Sewerage system: Especially in existing facilities, the internal sewerage system of the plant can be part of the firefighting water retention concept. If flammable liquids can be released into the firefighting water or explosive vapours can evolve, sewerage systems and underground parts of buildings must not be used for retention, unless complete explosion protection can be guaranteed. If the sewerage system is to be integrated into the firefighting water retention concept, it must be safeguarded that the system:

(a) Is proved to be leak-tight and can resist any chemical attack from the firefighting water, and

(b) Does not discharge into a surface water body directly (storm water sewerage) or indirectly (waste water sewerage) via a storm water overflow in case of heavy rain.

64. Tightness of storage basins: A local retention of firefighting water in the affected building itself is generally preferred. Periodic checking of the condition and functioning of stationary and temporary shut-off devices and immediate repair of detected defects should be ensured.

65. The penetration of rainwater pipes for roof drainage, pipelines or other pipes (e.g., for waste water) or cables floors or walls of facilities used for the retention of firefighting water or affected fire compartments should be avoided, otherwise the openings need to be structurally waterproofed or situated above the maximum flooding level. If this is not possible, the pipes must be constructed of fireproof materials or be covered by suitable protective coatings.

66. The internal wastewater treatment facility of an affected company will normally not be able to treat the contaminated firefighting water. This is due to the fact that the firefighting water has a much more complex composition and higher contamination load than the normal wastewater of that plant/operation, and the volumes are likely to be higher than normally handled. The wastewater treatment unit might also be compromised or out of function due to the fire and impact of contaminants and foams.

67. In many industrial processes, connecting plastic pipes or other infrastructure can be damaged by fire. It must be assumed that all production chemicals, cooling-, rinsing- and wastewater, located in the area affected by fire, will leak simultaneously.

68. Maintenance and quality assurance: When firefighting water retention measures have been installed and a retention concept is in place, it is essential to secure the continued functioning of this system. To this effect, an inspection and maintenance plan (fig. 2, No. 19) should be implemented, covering at a minimum the following aspects:

(a) The constructional integrity of the retention volume(s);

(b) The constructional integrity of fire compartments;

(c) The integrity and functioning of all firefighting water conduits;

(d) The functional testing and maintenance of barriers, pumps, slide valves and other technical devices needed for the firefighting water retention to be effective;

(e) The testing and maintenance of fire-detection and extinguishing systems;

(f) The testing and maintenance of explosion protection equipment and installations;

(g) The testing and maintenance of ventilation systems and smoke and heat vents;

(h) The compliance with storage concepts for hazardous substances and combustible goods;

(i) The knowledge of and compliance with fire-relevant operation procedures, safety instructions and contingency plans, etc.; and

(j) Periodic cleaning to remove silt and debris, especially from any transfer pipework and drains.

69. Weather (wind, rain): A significant additional retention volume will be needed in case of heavy rain during a fire event, and in the period after the fire until the firefighting water can be disposed of. This can last from a few days up to some weeks. These external factors can obviously not be accurately foreseen, but the prevailing conditions in the geographic area should nevertheless be taken into account in the fire protection concept. Normally the calculations are based on the local maximum 10-year rainfall intensity, but due to the climate change, an experience with floods in the geographic area should be considered as well.

D. Firefighting water disposal

70. Firefighting water must always be considered as contaminated. Special considerations are to be taken into account when disposing of it. A proper assessment of the firefighting water, in most cases accompanied by a qualified laboratory analysis of the degree of the contamination, should be undertaken prior to its disposal.

71. Most wastewater treatment plants (on- or off-site) should be able to treat cooling water without additional measures. However, before the treatment an assessment of the degree of the contamination of the cooling water should be undertaken.

72. For any other type of firefighting water, it must be evaluated whether the contamination is sufficiently low that a disposal in a wastewater treatment plant is possible. This must always be in consultation with the competent water authority and the wastewater treatment plant operator. When the firefighting water contains toxic or corrosive chemicals (including extinguishing foams e.g., with fluorinated carbon chains), or toxic combustion products, a pre-treatment — either on-site or at a specialized treatment facility is likely to be needed. Very heavily contaminated water may have to be disposed of at a dedicated chemicals waste disposal facility.

73. Proper transport logistics of firefighting water to disposal unit(s) should be the part of safety management system. This must include adherence to any applicable waste legislation.

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Annex

Different models for calculating the volume of firefighting water

1. This annex presents different calculations models of firefighting water. It is intended to present alternative, accepted models to calculate firefighting water. In addition, this annex includes a new calculation model proposed by the ECE Joint Expert Group on Water and Industrial Accidents.

2. Each model represents different approaches and comes from widely available sources. The characteristics of each model are briefly described. The models are presented in sequence according to their complexity, starting with the easiest one.

3. If there are several fire compartments within a facility, the one with the highest thermal load is decisive. If the input data is just the surface of the fire compartment, then the surface of the largest fire compartment needs to be chosen. The letter "R" in equations always means calculated volume of contaminated firefighting water that must be retained.[1] At the end of the annex several simple comparisons of the models' results are presented. Graphs show the differences between the results of all models. The comparison should only be considered demonstratively keeping in mind a different input data for each model.

A. Sandoz and Ciba (S&C) method

4. This method estimates 3 m^3 to 5 m^3 of needed firefighting water delivery per ton of stored material depending on the quantity of the flammable materials, hazard categories of stored products and expected fire duration. It is a very simple method to apply that requires little input data. It is based on only a few case studies so the method could not be extended to every potential scenario. In the end of this annex, in the charts, the method is converted to fire load as a non-liquid material with the burning energy estimated to be 18 MJ/kg (like cellulose).

R [from 3 m^3 to 5 m^3] = 1 ton of stored material

Sources

International Organization for Standardization. *Environmental damage limitation from fire-fighting water run-off*. ISO/TR 26368: 2012. May 2012. Available from https://www.iso.org/standard/43530.html.

Walton Ian and others. *Containment Systems for the Prevention of Pollution (C736)*. London, Construction Industry Research and Information Association, 2014. Available from https://www.ciria.org/Resources/Free_publications/c736.aspx.

B. The Buncefield method

5. While the Sandoz and Ciba methods were derived from relatively small incidents involving production and storage of particularly hazardous materials, the Buncefield method

[1] In accordance with the obligations under the Water and Industrial Accidents Conventions to prevent accidental water pollution and its transboundary effects, contaminated firefighting water must be retained.

was developed from an incident involving a simpler, larger scale fuel storage premises. The best estimate for firefighting water demand is represented by equation below.

R [from 1 m^3 to 3 m^3] = 1 ton of stored material

6. In the end of this annex, in the charts, the method is converted to fire load as a material with the burning energy estimated to be 47 MJ/kg (average for petrol).

Sources

Dickinson, *Review of the total firewater containment capacity required for industrial premises*, 2018, pending publication

More detailed guidance for estimating the full fire-fighting water demand can be found in *EI Model Code of Safe Practice: Part 19 "Fire precautions at petroleum refineries and bulk storage installations"* (2012).

C. The Imperial Chemical Industries (ICI) method[2]

7. The Imperial Chemical Industries (ICI) method was developed for internal use at company called ICI for assessing the flow rate and duration of fires at chemical plants. The difference between this method and the other methods referenced in this annex is that it refers to the fire of a whole chemical plant as distinct from a discrete area of a fire compartment. The method estimates the different volumes of firefighting water required according to the three possible hazard ratings of an industrial facility, as represented in the following table.

Demand of firefighting water based on the hazard severity of an industrial facility

Hazard rating of an industrial facility	*Demand of firefighting water in m^3 for 4 hours*
High severity	1,620–3,240
Medium severity	1,080–1620
Low severity	540–1080

Notes:"High severity" includes plants with:
- over 500 tons of flammable liquid above its flashpoint
- over 50 tons LPG above its boiling point and over 50 bars
- over 100 tons combustible solid with ready flame propagation
- other factors that increase severity

"Medium severity" covers plants that fall between the high and low severity ratings
"Low severity" includes plants with:
- less than 5 tons of flammable liquids above or below flashpoint
- less than 100 kg of flammable gas under 1 bar or a flash liquid
- less than 5 tons of readily combustible solids
- other factors that decrease severity.

[2] Walton Ian and others. Containment Systems for the Prevention of Pollution (C736). London, Construction Industry Research and Information Association, 2014. Available from https://www.ciria.org/Resources/Free_publications/c736.aspx.

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D. Dimensioning according to thermal load

8. Another very easy and simple method is based on the thermal load and the water warmth-binding capacity. This method determines the total fire load as a sum of the mobile thermal loads Q_m (i.e., products, storage materials, equipment etc.) and the immobile thermal loads, Q_{im} (i.e., thermal load of buildings, insulation, damping and cladding).

$$Q_{total} \text{ [GJ]} = Q_m \text{ [GJ]} + Q_{im} \text{ [GJ]}$$

9. To define the required volume of firefighting water that has to be retained, the calculated total thermal load has to be divided by the water warmth-binding capacity - 2,6 GJ/m^3. According to scientific investigations, only half of the firefighting water is reaching the burnt material due to evaporation. Therefore, the double volume of the required calculated volume of firefighting water is needed. The equation of the model is presented below.

$$R \text{ [m}^3\text{]} = Q_{total} \text{ [GJ] / 2,6 [GJ/m}^3\text{] } V = Q_{total} \text{ [GJ] / 2,6 [GJ/m}^3\text{]}$$

10. It is clear from the context and assumptions made in the method that it only applies to fires restricted by buildings and will apply mainly to fully developed fires being fought by water sprays – the by-passing of a fire by applied water jets will be a lot more variable than the 50 per cent assumed by this method.

11. In the charts at the end of this annex, the input data of this method is simplified in such a way that only thermal load of stored materials has been taken into consideration.

Source

Argebau, *Rules for the Calculation of Fire Water Retention Facilities with the Storage of Materials Hazardous to Water*, 1992. Available from: https://umwelt.hessen.de/sites/default/files/HMUELV/handlungsempfehlung_loeschmittel_im_brandfall.pdf.

E. German Federal State Hessen

12. The method, developed by the German Federal State Hessen in 2011 (Hessenweit abgestimmte Empfehlung, 2011) for industrial sites, is based on empirical data or assessment of the fire load. The dimensioning of firefighting water retention basins can be calculated for this case according to following:

For fire areas under 100 m^2, the extinguishing agent rate was 10 L min/m^2

For fire areas from 100 - 200 m^2, the extinguishing agent rate drops to 3 L min / m^2

For 200 m^2 < Fire Area < 600 m^2 R (m^3) = fire area (m^2) * 0,135

For objects or fire compartments larger than 600 m^2, the equation changes as follows:

R (m^3) = fire area (m^2) * 0,18

13. This is based on sound empirical data on 312 fires, taking into account the realities of firefighting operations rather than theoretical predictions with experienced assessors. Unfortunately, neither the source data nor a statistical analysis of it was published, so it is not possible to tell how accurate it is and what design margins to allow for.

Source

Argebau, *Rules for the Calculation of Fire Water Retention Facilities with the Storage of Materials Hazardous to Water*, 1992. Available from: https://umwelt.hessen.de/sites/default/files/HMUELV/handlungsempfehlung_loeschmittel_im_brandfall.pdf.

F. Swiss Intercantonal Guideline (Swiss Model)

14. The Swiss Intercantonal Guideline (Swiss Model) is used by the local authorities of 23 Swiss cantons and the Principality of Liechtenstein. The volume of firefighting water depends on the fire protection arrangements provided, the storage system, the risk of fire of the stored materials, and the size of the fire compartment. The calculation is based on empirical data taken from, inter alia, European Insurance Industry sources and looks as follows:

R [m^3] = theoretical volume [m^3] x storage factor

Notes

Theoretical volume – from a table, based on empirical data

Storage factor – depends on mass per square meter (0,5; 0,8; 1,0; 1,2)

Source

Switzerland, Konferenz der Vorsteher der Umweltschutzämter der Schweiz. *Swiss Intercantonal Guideline /Interkantonaler Leitfaden. Löschwasser-Rückhaltung – Leitfaden für die Praxis*. 1. Auflage, Zürich, 1. Auflage, Oktober 2015 (Juni 2016: Ergaenzt mit Kanton BL). Available in German, French and Italian from https://www.kvu.ch/de/arbeitsgruppen?id=190.

G. German insurance industry (VdS)

15. A very advanced and complex method is the VdS Formula, developed by the German insurance industry and published in Guideline “VdS 2257”. It takes into account a multitude of influencing factors and is based on an extensive evaluation of empirical data, scientific studies and industrial experience. This method is based on the type and quantity of combustible materials, the presence of the fire detection systems, the size of the biggest fire compartment, the type of fire brigade and the fire protection technical infrastructure. The equation is the following:

R = {(A x SWL x BAF x BBF) + M} / BSF

Notes

A – object surface or biggest fire compartment [m^2]

SWL – is the specific water input [m^3/m^2]

BAF – fire section area factor [dimensionless]

BBF – fire load factor [dimensionless]

M – volume of all stored materials [m^3]

BSF – fire protection factor [dimensionless]

16. The coefficients of the equation are dependent on the other tabulated values. Due to the complexity of the method and the number of dependent tables, they are not indicated in this annex.

17. An automatic calculation sheet to calculate the volume for contaminated extinguishing water has been developed and can be downloaded free of charge from https://shop.vds.de/en/download/4985801dafb52f4d08e8aa83b5bc0e90.

Source

VdS 2557 VdS Schadenverhütung GmbH., *Planning and Installation of Facilities for Retention of Extinguishing Water*. Guidelines for Loss Prevention by the German Insurers, No. VdS 2557, Koln, Germany, 2013. Available from: https://vds.de/fileadmin/vds_publikationen/vds_2557en_web.pdf.

H. Models by the Joint Expert Group on Water and Industrial Accidents (JEG Model and Advanced JEG Model)

18. The method proposed by the Joint Expert Group on Water and Industrial Accidents (JEG) is easy to use and safe. The JEG Model estimates 1 m^3 of the retention basin per square meter of the protected object surface or its biggest fire compartment (1):

R [m^3] = A_f [m^2] (1)

A_f – largest fire compartment surface area [m^2]

19. The calculated volume can be reduced to 10 per cent by providing a constantly operating factory fire service (Advanced JEG Model) (2):

R [m^3] = 0,1 * A_f [m^2] – if a constantly operating factory fire service is provided (2)

Af – largest fire compartment surface area [m^2]

20. The model outcome shown at the end of the annex is reduced to 10 per cent (Advanced JEG Model). The volume of all liquids in the fire compartment areas should be summed. By comparing the Advanced JEG Model to the other models, it is concluded that within lower fire densities, this model provides results that are in the middle of the other models' results. In case of higher fire densities, the model achieves comparatively lower values.

I. Comparison

21. Bearing in mind the differences between all models and their complexities, the comparisons were made with some simplifications (see annex). Every model is represented in the graphs by one line. The graphs represent the smallest achievable volumes, e.g., due to the use of the maximum fire protection (VdS, JEG, Swiss Model) and/or the presence of the relatively less hazardous materials or lowest risk (Swiss Model, S&C method, Buncefield, ICI method). The ICI method is represented by a straight line due to not depending on the surface of the fire zone. The Swiss Model is limited to an area of 4,500 m^2 since Swiss fire

protection regulations do not normally allow for larger fire compartments. As an exception, larger areas must be evaluated within an individual fire risk analysis.

22. Chosen input data:

(a) fire loads expressed in [MJ/m^2]: 500 and 1,296 as an upper reliable boundary for VdS model;

(b) fire compartment area: from 500 m^2 up to 20,000 m^2 – enlarging by 500.

The results are expressed in m^3.

Figure 1

Comparison of methodologies for determining the firefighting water volume with a fire load of 500 MJ/m²

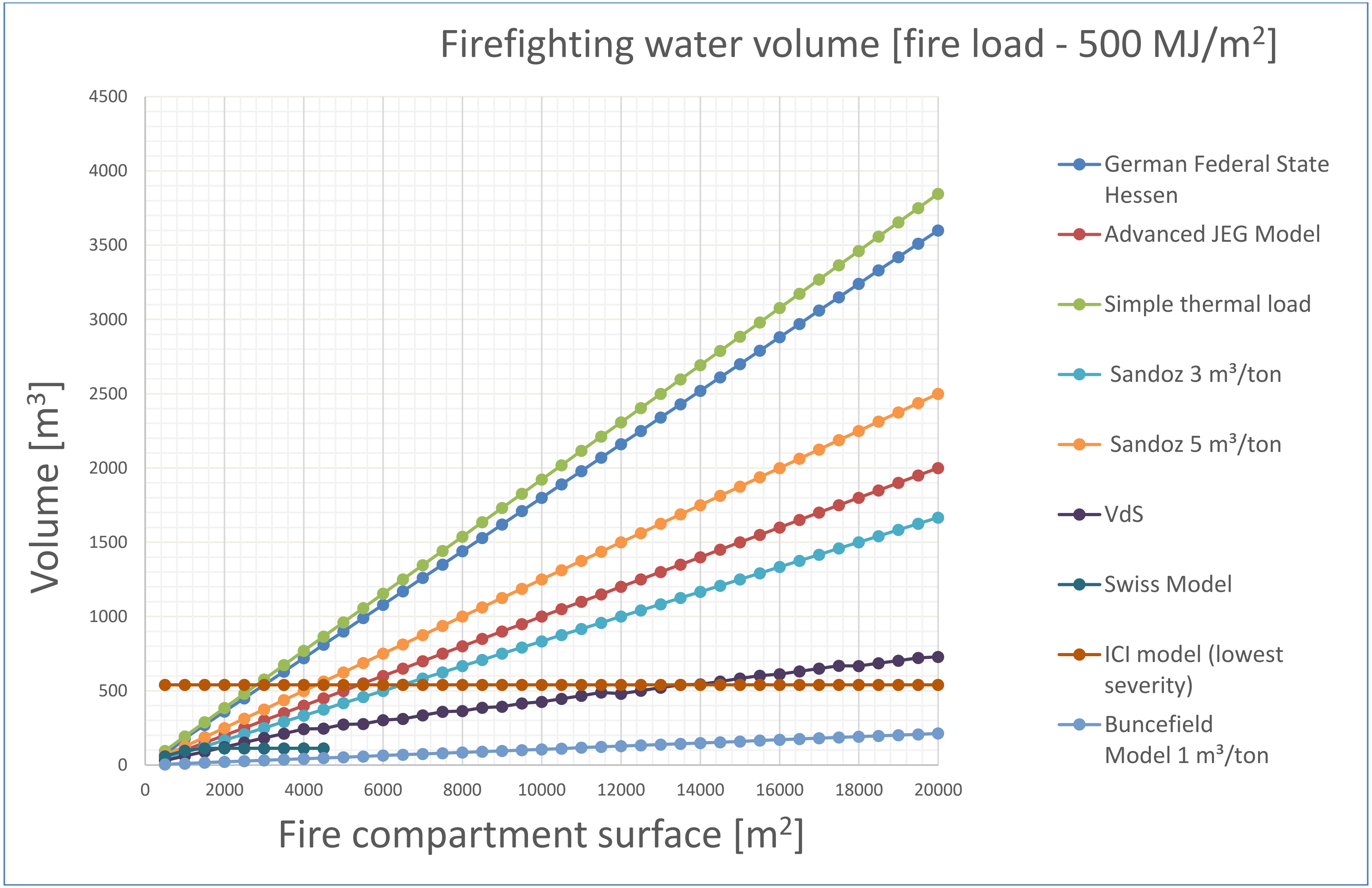

Figure 2
Comparison of methodologies for determining the firefighting water volume with a fire load of 1296 MJ/m²