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Item 14 of the provisional agenda
Prevention of accidental water pollution

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 River owing to the lack of firefighting water retention. This caused extensive transboundary water pollution, suspended drinking water supplies, devastated fish stocks in Switzerland, France and Germany and had effects reaching as far as the Netherlands (approximately 700 kilometres downstream).

At a seminar held on the occasion of the 25th anniversary of the accident (Bonn, Germany, 8–9 November 2011), Parties to the Convention on the Protection and Use of 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. In order to address this need, in 2016, the Bureaux of the two Conventions tasked the Joint Ad Hoc Expert Group on Water and Industrial Accidents (Joint Expert Group) with developing safety guidelines and good practices for the management and retention of firefighting water. This proposal was endorsed by the Conference of the Parties to the Industrial Accidents Convention at its ninth meeting in November 2016 (see the workplan and resources for the Convention for 2017–2018, contained in the report of the Conference of the Parties (ECE/CP.TEIA/32/Add.1)) 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 (ECE) region. The safety guidelines and good practices are divided into two parts: general recommendations (ECE/MP.WAT/2018/9-ECE/CP.TEIA/2018/12) and technical and organizational recommendations for the management and retention of firefighting water (contained in this document).

The Joint Expert Group, in cooperation with the Expert Group on Fire-water Retention and supported by the ECE secretariat, developed the draft safety guidelines, which were shared for comments with the focal points of the Water Convention, the Industrial Accidents Convention, international organizations, industry associations and other partners in the last quarter of 2017. Their comments, inputs and feedback were considered by the Expert Group and, where feasible, included or otherwise addressed during the process of finalizing the guidelines. At their second joint meeting (Geneva, 28–30 May 2018), the Working Group on Integrated Water Resources Management and the Working Group on Monitoring and Assessment took note of the draft safety guidelines and entrusted the secretariat with the task of including the comments received and submitting them to the eighth session of the Meeting of the Parties (ECE/MP.WAT/WG.1/2018/9-ECE/MP.WAT/WG.2/2018/9) (see the report of the second joint meeting of the Working Group on Integrated Water Resources Management and the Working Group on Monitoring and Assessment (ECE/MP.WAT/WG.1/2018/2-ECE/MP.WAT/WG.2/2018/2, forthcoming)). At its thirty-eighth meeting (Bern, 26–27 June 2018), the Bureau of the Industrial Accidents Convention took note of the draft safety guidelines.

The Meeting of the Parties to the Water Convention, at its eighth session (Astana, 10–12 October 2018), and the Conference of the Parties to the Industrial Accidents Convention, at its tenth meeting (Geneva, 4–6 December 2018), are invited to take note of the safety guidelines and to recommend their use and implementation by countries in order to prevent accidental pollution of soil and water, including pollution causing transboundary effects.

Contents

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

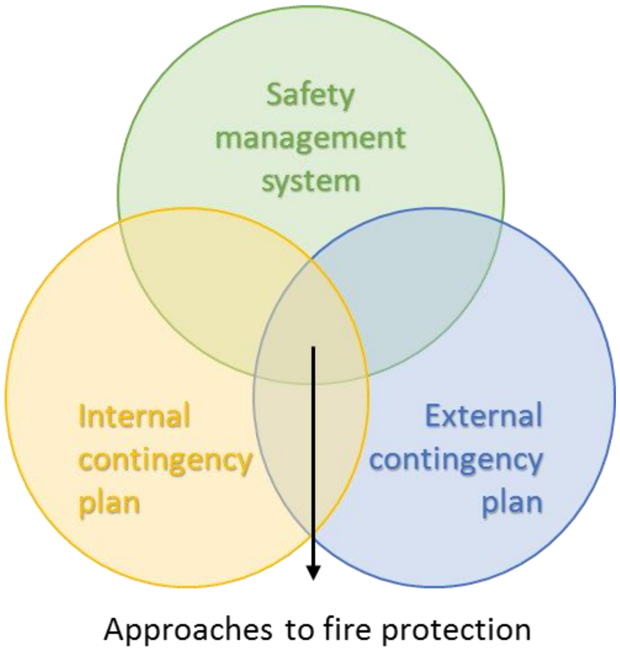
1. Since firefighting water, irrespective of the material burned, is hazardous to water, the occurrence of fires should be prevented. Where, despite stringent safety measures, a fire occurs, it must be detected quickly. Facilities should be designed so as to prevent the further spread of a fire and staff should know how to react and, specifically, to operate the fire-related equipment in the event of an emergency. These and other measures are part of the sound fire protection strategy that should be in place. In particular, fire protection for hazardous activities is composed primarily of the following elements:

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

(b) Passive fire prevention, which includes compartmentalization of the overall site, e.g. through the use of fire-resistance-rated walls and floors. Organization into smaller fire compartments comprising one or more rooms or floors prevents or slows the fire's spread from the room in which it originated to other building spaces, limits building damage and gives the occupants more time to evacuate the building or reach an area of refuge.

2. Fire protection also entails minimizing ignition sources and training the facility's occupants and operators in the operation and maintenance of fire-related systems so that they can ensure their correct functioning and activation in an emergency. The correct procedures, such as notification of the fire response service and emergency evacuation, should be followed and fire protection should be addressed as part of the safety management system and contingency planning (see figure I below), based on the fire brigade response plan and the firefighting water retention strategy.

Figure I
Approaches to fire protection



A. Approaches to fire protection

3. As part of the on-site contingency plan, operators should elaborate and implement a sound approach to fire protection, which should be adjusted to technical and organizational needs and new developments. The personnel should be trained in using this concept on a regular basis.

4. This approach may be both general and specific and may include structural and plant-specific fire protection measures which, taken together, make the occurrence of a fire a low probability and allow for earlier detection and suppression so that the minimum quantity of firefighting water is required.

5. The approach should include a firefighting strategy, a procedure for the retention of firefighting water and the following organizational plans:

(a) A wastewater and rainwater sewage plan, including points of intervention and of discharge into surface waters or public sewer systems;

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

(c) A fire brigade response plan, including, among other things, firefighting techniques, firefighting water management strategies, emergency contacts, access routes, floor plans and chemical inventories.

6. The approach to the retention of firefighting water should comprise documentation of the facility's layout, dimensioning, and all measures implemented by the operator in order to adequately retain the firefighting water used.

1. General measures

7. In light of the environmental impact of accidents, the role of emergency planners and emergency responders should also be recognized and contingency plans (e.g., an appropriate firefighting strategy) developed in order to mitigate environmental harm.

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

9. The use of non-combustible building materials also reduces the fire load and spread, and thus the quantity of firefighting water required to extinguish the fire. For this reason, 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), a fire can be extinguished or its spread stopped at the earliest stage, perhaps even without additional firefighting water being used by the fire brigade). The quantity of firefighting water required may be up to 10 times less than in the absence of an extinguishing system. However, while fixed systems can often reduce firefighting water volumes effectively, these arrangements can potentially fail. Thus, for contingency planning at high-hazard sites, worst case scenarios should be considered if escalation of the fire would require a significantly larger volume of firefighting water.

2. Specific measures

11. The specific fire protection measures include:

(a) Constructional measures;

(b) Fire detection and notification facilities;

(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 storage facility regulations, fire prevention plans and training of personnel;

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

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

3 Structural fire protection

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

13. Fire compartment areas are among the most critical means of limiting the spread of fires and the amount of firefighting water and firefighting water retention capacity needed should a fire occur.

14. For all measures designed to reduce the risk of fire and subsequent damage from firefighting water, technical specifications should be taken into account and a maintenance and periodic test programme be implemented in order to ensure the continued operability of the corresponding components. This entails, among other things, intelligent drainage systems (e.g., for flammable liquids in open plants) and fire barriers.

15. In order 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 required. Based on past experience, the volume is roughly proportional to the fire’s surface area (For calculation examples and equations, see annex).

4. Plant-specific fire protection

16. Technical measures that seek to limit fires through rapid detection or intervention include:

(a) **Automatic fire detection and alarm systems**: 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 extinguish fires or contain them within a smaller area and are effective in minimizing the volume of firefighting water;

(c) **Smoke and heat venting systems**: Smoke and heat venting systems prevent excessive overheating of fire compartments, thus helping to preserve containment and limiting the amount of water required for cooling.

17. **Storage height and density**. Storage height and density (kilograms (kg) of combustible goods per square metre (m^2) of storage area) affect the firefighting water volume in two ways: on the one hand, higher storage density results in 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 height and will generate more firefighting water unless specific protective measures are taken.

18. **Stored liquids**. Owing 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 fire spread velocity are dependent on the flammability (flashpoint) of the goods stored; highly flammable liquids generally lead to more-rapidly-spreading and larger fires. Where practicable, containers containing flammable liquids should be designed to minimize the risk of failure in the event of a fire.

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

21. **Combustible installations, packaging and construction materials**. In addition to goods in storage and production equipment, large amounts of packaging materials (cardboard, plastics, wood, etc.) can contribute to the thermal load. Combustible installations (cables, pipes, ducts, etc.), building materials, furniture and combustible wastes (especially liquid flammable wastes) are another significant and frequently-overlooked factor in fire escalation.

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

B. Dimensioning of firefighting water retention facilities

23. Several approaches for calculating the retention volume of firefighting water required exist. While countries may require that this volume be calculated, specific methods are not always prescribed and the retention volumes calculated using the different methods differ significantly. Moreover, most these methods were developed for “standard fires”, which account for up to 90 per cent of all fires; so-called “catastrophic fires”, which have an unusual fire development, are not taken into account in the methods.

24. Examination of a number of catastrophic fires involving hazardous activities in the ECE region shows that the amount of firefighting water used during those accidents was far greater than calculated under most of the known models. This highlights the need for larger retention volumes.

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

(a) **German (Verband der Schadenversicherer e.V. (VdS)) model**: set out in *Planning and Installation of Facilities for Retention of Extinguishing Water: Guidelines for Loss Prevention by the German Insurers*, No. VdS 2557 (see below, *Sources*);

(b) **Swiss model**: in accordance with *Löschwasser-Rückhaltung – Leitfaden für die Praxis* (Firefighting Water Retention: A Practical Guide) (see reference list).

26. Among the various parameters affecting the volume of firefighting water required to extinguish a fire, the total area of a designated fire compartment seems to have the most important influence. Based on these experience, a stepwise approach to the calculation of firefighting water retention facilities is proposed (for an explanation of the various calculation models, see annex):

(a) **Step A**: For a quick, rough estimate, direct proportionality of the firefighting water volume required for the largest fire compartment area may be assumed. This can be roughly equated to one square metre (m^2) of fire compartment area resulting in one cubic metre (m^3) of retention volume (e.g. a 5,000 m^2 fire compartment area requires 5,000 m^3 of retention volume);

(b) **Step B**: The retention volume required is up to 10 times smaller if the facility is equipped according to an advanced fire protection concept (e.g. automatic sprinklers, high expansion foams or extinguishing gases). A 5,000 m^2 fire compartment area would require 500 m^3 of retention volume. In most cases, any liquids present in the fire compartment will spill into the firefighting water, increasing the retention volume. This additional volume should be added;

(c) **Step C**: If specific additional data such as the density and form of stored goods and the thermal load of potentially-affected materials are available, the use of a more advanced methodology, e.g. the German VdS or Swiss model, is preferable, bearing in mind the limitations of these methodologies (see annex).

27. Steps A and B above can be applied to facilities in all countries, especially where critical data about the hazardous materials is limited or unavailable. This rough estimate will show the order of magnitude of the retention volume required.

28. In developed and industrialized countries, the more advanced calculation methodologies (step C) are recommended for the calculation of firefighting water retention volumes.

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

30. The following flow chart (see figure II below) provides an overview of the proper dimensioning of the retention capacity required. The most important factors that influence the calculation of this volume are:

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

(b) The thermal load of the materials within the fire (including, among other things, combustible construction, building and packaging materials), taking the size and location of the fire into consideration;

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

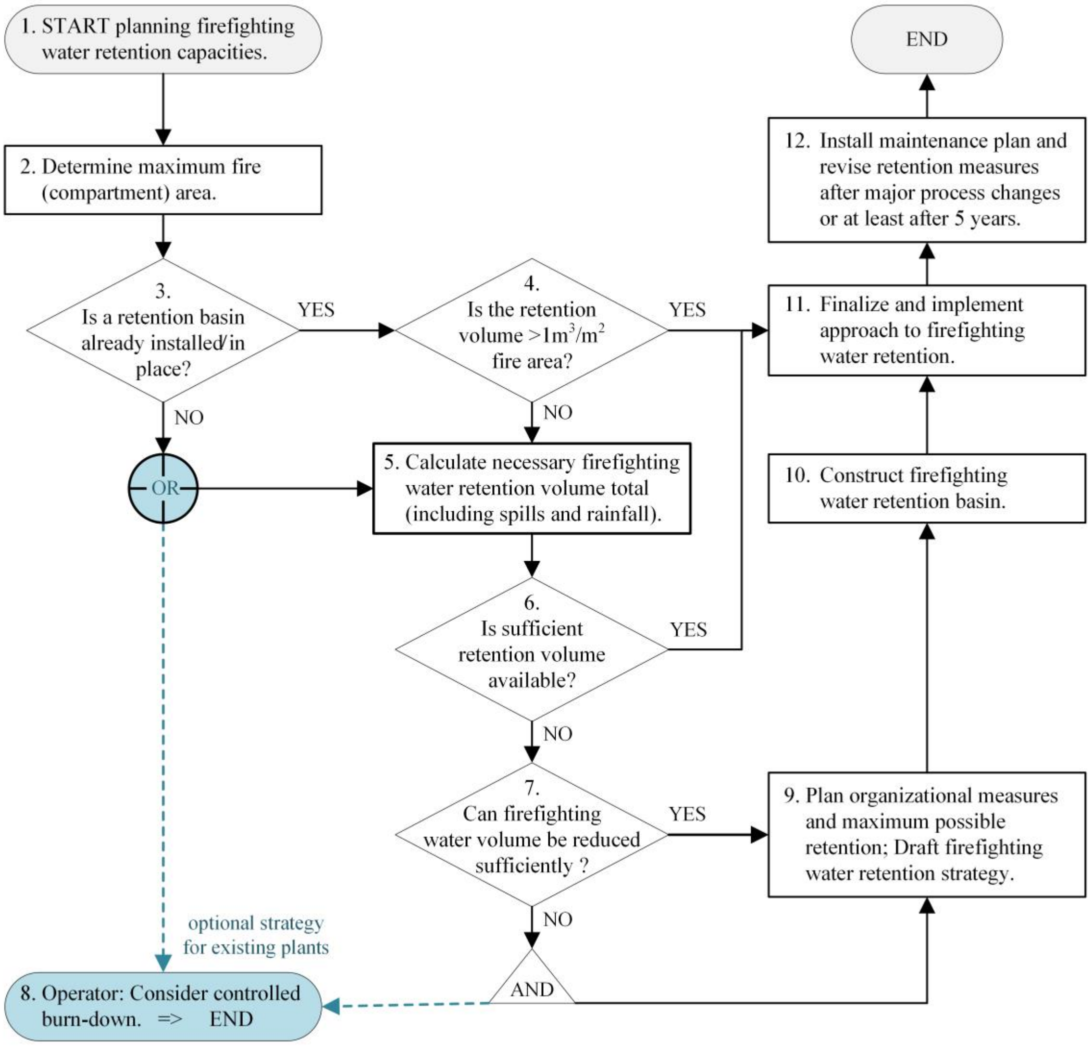
(d) The volume of all chemicals and liquids in production, operation and storage that might be released into the firefighting water;

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

(f) Potential amount of rainfall during and after the event until the firefighting water can be properly disposed of (this may range from a few days to several weeks; the maximum precipitation rate for the time period in question may be used to determine the additional volume);

(g) Waves and shifting of water (liquid) levels owing to wind.

Figure II
Flow chart for the dimensioning of firefighting water retention facilities



31. Generally speaking, the retention volume can be drastically reduced by implementing efficient measures (fig. II, 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 may be extremely large. The approximate volume, based on past 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).

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

33. Lastly, 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. II, No. 9). In certain cases where human health and safety are not at risk, a controlled burn-down of parts of the facility, using only a minimum of water to cool adjacent buildings or structures and prevent the fire from spreading, should also be considered (fig. II, No. 8). This option may prevent damage to groundwater and surface waters, but the operator must always consult the competent authorities and external firefighting brigades and the decision-makers must not expose people to additional hazards.

C. Planning and design of retention systems

34. In protecting people and the environment from contaminated firefighting water, the design of the retention system is one of the most important issues. The following chapter refers to the German VdS model and provides a short overview of the points to be considered by planners, operators and the competent authorities.[1]

35. 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 that includes fire protection and reduction measures, firefighting water collection, storage and disposal in light of the on-site conditions.

36. In order to avoid damage caused by contaminated firefighting water, appropriate technical equipment is required.

37. There are several possible types of systems for the retention of contaminated firefighting water. They may be installed permanently (e.g. preinstalled water barriers or permanent retention basins, with pumping installations where necessary) or provided as mobile facilities (e.g. firefighting water barriers, drain-sealing pads and devices or mobile storage tanks).

38. Owing to safety and reliability considerations, permanently installed retention systems should be preferred wherever possible.

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[1] For additional guidance, see *Ian Walton*, *Containment Systems for the Prevention of Pollution: Secondary, tertiary and other measures for industrial and commercial premises*. Construction Industry Research and Information Association (CIRIA) Report No. C736. London. Available at www.ciria.org/Resources/Free_publications/c736.aspx. See also the reference documents prepared within the framework of the European Union Industrial Emissions Directive (Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), 2010 O.J. (L 334), pp. 17–119), available at http://eippcb.jrc.ec.europa.eu/reference/.

39. Permanently installed retention systems may be automatically (passive or self-activating) or manually triggered systems. Automatically triggered systems have two different independent triggering lines in order to ensure functionality and avoid accidental activation. Manually activated systems are generally less reliable in stressful situations.

40. Where mobile facilities are used, care must be taken to ensure that they can be installed rapidly and can be managed with minimal effort, i.e., their set up should be possible with two people maximum.

1. General requirements

41. With regard to stability, watertightness and durability, facilities used as retention devices (e.g. retention ponds and contingency basins) should be impermeable and resistant to contaminated firefighting water. Retention facility components that might be exposed to a fire should be resistant to high temperatures and to physical and chemical impact.

42. In addition to stability and durability, the functional safety of retention systems should be considered. When using self-acting retention systems, it is important to ensure that the shutdown position can be guaranteed at any time. Therefore, two independent power supply systems should be provided.

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

44. If firefighting water will be held in underground systems or cellar basins, it is important to ensure that no flammable or explosive vapours are present.

45. Any indoor connections to the retention facility, including doors and inspection shafts, must be fire-resistant.

2. Installation of retention systems

46. Generally speaking, 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.

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

48. If the sewer is used as a part of a retention system, it must be stable, resistant to contaminated firefighting water and watertight. Furthermore, the sewer should be closed up in an emergency without causing backflow into connected systems. Where the sewer is also used for draining wastewater or cooling water, this fact should be taken into account during the planning and dimensioning of the potential retention volume. If the firefighting water may be mixed with flammable liquids, draining through the sewer is allowed only where the build-up of an explosive atmosphere can be excluded.

49. Inspection shafts should be installed in the sewer for controlled sampling by the operator.

50. For open retention basins or other systems that are exposed to rainfall, a system for controlling accumulated liquid volume during ordinary operations is required in order to avoid overflow and ensure that sufficient available retention capacity is maintained.

51. Where 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 and should be permanently installed. Where this is impossible, the operator should ensure that well-trained workers are available to install mobile devices at any time. Pumps may be triggered automatically or manually, depending on the existing emergency concept. Furthermore, a reliable power supply must be ensured even in the event of a fire and transfer drains and pipes must be of a size that can handle the anticipated volume of liquid.

52. When installing permanent or temporary retention basins, the existing legislation on construction, water protection and hazardous goods should be consulted. The basins should be equipped with ventilation and air extraction devices designed for maximum input and output flows inside the basin.

53. In principle, retention devices should be located outside the production and storage units. Where flammable substances are present, their rapid and safe removal is important so that they do not cause further expansion of the fire.

54. Furthermore, the secondary containment of the chemical may be used as a retention device. However, the containment should be dimensioned so that, in addition to the leakage volume of the hazardous substances, the volume of firefighting water (including cooling water, rainwater and any foam blanket) can be retained (i.e., additional freeboard space should be envisaged). Catchment areas and retention devices for the retention of contaminated firefighting water should be arranged and equipped so as to detect overfilling immediately in order to prevent the liquid from overflowing into adjacent fire compartment areas. Additionally, they should be accessible at any time in the event that further action (e.g. the removal of liquids) is required to prevent overfilling.

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

56. Retention basins and barriers used for firefighting water retention must be stable, watertight and mechanically, thermally and chemically resistant.

3. Retention devices

57. Retention devices should have overfill detection systems or alarms and may include, for example, firefighting water bulkheads or other mechanical-shut-off barriers that only lead to a retention basin when activated during a fire. A retention basin is normally a basin that is permanently available.

58. The shut-off devices should be accessible at any time and should be easily operable. In some cases, such as the containment of flammable liquids, an automatic or remotely-operated system may be necessary since local operation might be too dangerous. Automatically-operated safety devices such as pumps and gate valves should have an independent power supply. Because these safety devices can fail, precautions (e.g. redundancy, duplication, fail-safe installations and/or mobile equipment) must be taken.

59. Generally speaking, there are two different types of retention devices:

(a) Central retention devices for multiple facilities at the same site (e.g. discharging through rainwater and cooling-water sewers into a central retention or contingency basin). These devices are not located on the operator’s property and are managed by someone else (e.g. a water treatment plant);

(b) Local retention devices directly connected to a facility (e.g. retention basins). These devices are located on the property of the operator, who is also responsible for maintaining them.

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

(a) Secure retention – impermeability and durability – are ensured;

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

61. Where no local retention device can be provided, a central retention device (e.g. the contingency basin of a wastewater treatment plant or industrial area) may be selected. In this case, the secure discharge of firefighting water and the impermeability and the durability of all construction materials (including the sewer systems) must be ensured.

4. Planning and maintenance of firefighting water retention systems

62. **Sewerage system**. Especially in existing facilities, the plant's internal sewerage system may be part of the approach to firefighting water retention. If flammable liquids can be released into the firefighting water or explosive vapours can develop, 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 strategy, the system must:

(a) Be watertight and able to resist any chemical attack from firefighting water;

(b) Not discharge storm water overflow into a surface water body directly (storm water sewerage) or indirectly (wastewater sewerage) in the event of heavy rain.

63. **Watertightness of storage basins**. Local retention of firefighting water in the affected building is generally preferred. Periodic checking of the condition and functioning of stationary and temporary shut-off devices and immediate repair of any defects found should be ensured.

64. The penetration of rainwater drainage pipes, pipelines (or other pipes, e.g. for wastewater) or cables into the floors or walls of facilities used for the retention of firefighting water or affected fire compartments should be avoided; otherwise, the openings should be structurally waterproofed or situated above the maximum flooding level. Where this is impossible, the pipes must be constructed of fireproof materials or covered by a suitable protective coating.

65. The internal wastewater treatment facility of an affected company will normally be unable to treat contaminated firefighting water, which has a far more complex composition and higher contamination load than the normal wastewater of the plant or operation and is likely to produce a higher volume than is normally handled. The wastewater treatment unit might also be compromised or rendered non-functional owing to the fire and the impact of contaminants and foams.

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

67. **Maintenance and quality assurance**. Where firefighting water retention measures have been installed and a retention concept is in place, it is essential to ensure the continued functioning of this system. To that end, an inspection and maintenance plan (fig. II, No. 12) covering at least the following issues should be implemented:

(a) Constructional integrity of the retention volume(s);

(b) Constructional integrity of fire compartments;

(c) Integrity and functioning of all firefighting water conduits;

(d) Functional testing and maintenance of barriers, pumps, slide valves and other technical devices required in order for the firefighting water retention to be effective;

(e) Testing and maintenance of fire detection and extinguishing systems;

(f) Testing and maintenance of explosion protection equipment and installations;

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

(h) Compliance with storage regulations for hazardous substances and combustible goods;

(i) Knowledge of and compliance with the relevant operation procedures, safety instructions and contingency plans;

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

68. **Weather (wind and rain)**. A significant additional retention volume will be required in the event of heavy rain during a fire event, and in the period after the fire until the firefighting water can be disposed of; this may range from a few days to several weeks. Obviously, these external factors cannot be accurately foreseen, but the prevailing conditions in the geographic area should be taken into account in the fire protection concept. The calculations are normally based on the maximum local 10-year rainfall intensity but, owing to climate change, previous flooding in the geographic area should also be considered.

D. Firefighting water disposal

69. Because firefighting water must always be considered contaminated, special considerations must be taken into account when disposing of it. A proper assessment of the firefighting water, accompanied in most cases by a qualified laboratory analysis of the degree of the contamination, should be conducted prior to its disposal.

70. While most wastewater treatment plants (on- or off-site) should be able to treat cooling water without additional measures, the degree of contamination should be assessed prior to treatment.

71. For any other type of firefighting water, it is necessary to determine whether the level of contamination is sufficiently low to permit disposal through a wastewater treatment plant. This determination must be made in consultation with the competent water authority and the wastewater treatment plant operator. Where the firefighting water contains toxic or corrosive chemicals (including extinguishing foams, e.g. with fluorinated carbon chains), or toxic combustion products, pre-treatment – either on site or at a spec

ialized treatment facility – is likely to be required. Very heavily contaminated water may need to be disposed of through a dedicated chemical waste disposal facility.

72. The logistics for the proper transport of firefighting water to the disposal unit(s) should be part of the safety management system and include compliance with any applicable waste legislation.

Annex

Models for calculating the volume of firefighting water

1. This annex presents several accepted models for calculating the volume of firefighting water required in the event of a fire, as well as a new calculation model proposed by the Economic Commission for Europe (ECE) Joint Expert Group on Water and Industrial Accidents.

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

3. Where there are several fire compartments within a facility, the calculation should be based on the one with the highest thermal load. If only the area of the fire compartments is known, the largest one should be considered relevant. The letter “R” in equations means the 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 provided. The graphs show the differences in the results achieved using the various models. The comparison should be considered only for purposes of demonstration, bearing in mind that the input data is different for each model.

A. The Sandoz and Ciba model

4. The Sandoz and Ciba model estimates that 3 m^3 to 5 m^3 of firefighting water needs to be delivered per ton of stored material, depending on the quantity of the flammable materials, hazard categories of stored products and expected fire duration. While this methodology is very simple and requires little input data, it is based on only a few case studies and thus could not be extended to every potential scenario. In the charts located at the end of this annex, the model is converted to fireload as a non-liquid material with an estimated burning energy of 18 megajoules (MJ) per kilogram (MJ/kg) (e.g. cellulose).

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

Sources

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[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.

B. The Buncefield model

5. While the Sandoz and Ciba model is derived from a relatively small number of incidents involving the production and storage of particularly hazardous materials, the Buncefield model was developed as a result of an incident involving simpler but 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 graphs at the end of this annex, the mass is converted to an equivalent fire load using an estimated energy of combustion of 47 MJ/kg (corresponding to an average value for petrol).

Sources

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C. The Imperial Chemical Industries (ICI) model

7. The Imperial Chemical Industries (ICI) model was developed by ICI for internal use in assessing the flow rate and duration of fires at chemical plants. Unlike the other methods mentioned in this annex, it is based on a fire in an entire chemical plant rather than a discrete area of a fire compartment. It estimates the different volumes of firefighting water for three potential hazard ratings of an industrial facility, as seen from the following table:

Firefighting water demand based on the hazard severity rating of an industrial facility

Hazard rating of the industrial facility	*Four hours of firefighting water demand in m^3*
High severity	1,620–3,240
Medium severity	1,080–1,620
Low severity	540–1,080

"High severity" includes plants with:

- Over 500 tons of flammable liquid above its flashpoint;
- Over 50 tons of flammable gas above its boiling point and over 50 bars;
- Over 100 tons combustible solids 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 liquid above or below its flashpoint;
- Less than 100 kg of flammable gas under 1 bar or flash liquid;
- Less than 5 tons of readily combustible solids;
- Other factors that decrease severity.

Sources:

Walton, Ian. Containment Systems for the Prevention of Pollution: Secondary, tertiary and other measures for industrial and commercial premises. Construction Industry Research and Information Association (CIRIA) Report No. C736. London. Available at www.ciria.org/Resources/Free_publications/c736.aspx.

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D. The thermal load model

8. Another easy and simple method is based on thermal load and specific heat-binding capacity (the total amount of energy needed to heat 1 m^2 of water from 20º C to 100º C and subsequently evaporate it). The "dimensioning according to thermal load" method calculates the total fire load as the sum of the mobile thermal loads Q_m (e.g. products, storage materials, equipment and similar) and the immobile thermal loads, Q_{im} (e.g. the thermal load of buildings, insulation, damping and cladding).

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

9. In order to calculate the required volume of firefighting water that must be retained, the calculated total thermal load has to be divided by the specific heat-binding capacity: 2.6 GJ/m^3. Research has shown that as a result of evaporation, only half of the firefighting water reaches the burned material; thus, twice the volume of the firefighting water calculated is required.

$$R\ [m^3] = Q_{total}\ [GJ] / 2.6\ [GJ/m^3]\ V = Q_{total}\ [GJ] / 2.6\ [GJ/m^3]$$

10. It is clear from the context of the method and the assumptions made in the method that it applies only to fires that are limited to buildings, and primarily to fully-developed fires being fought by water sprays. The bypassing of a fire by applied water jets would be far more variable than the 50 per cent assumed for this model.

11. In the charts at the end of this annex, the input data for this method is simplified; only the thermal load of the stored materials has been taken into consideration.

Source

Germany, Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection (2011). *Handlungsempfehlung: Vollzug des Gebotes zur Rückhaltung verunreinigter Löschmittel im Brandfall – Hessenweit abgestimmte Empfehlung (Policy recommendation: Compliance with the instructions to retain contaminated extinguishing agents in the event of a fire – Recommendation of the German Federal State of Hessen).* Available at https://umwelt.hessen.de/umwelt-natur/wasser/gewaesserschutz/rueckhalt-von-verunreinigtem-loeschwasser.

E. The German Federal State of Hessen model

12. The method developed for industrial sites by the German Federal State of Hessen in 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 as follows:

For fire areas under 100 m^2, an extinguishing agent rate of 10 litres per minute per square metre (L min/m^2)

For fire areas measuring 100–200 m^2, an extinguishing agent rate of 3 L min/m^2

For fire areas measuring 201–600 m^2, 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. These equations are based on sound empirical data from 312 fires, taking into account the realities of firefighting operations rather than theoretical predictions by experienced assessors. However, since neither the source data nor a statistical analysis of it has been published, it is impossible to assess its accuracy or to determine the design margins required.

Source

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

Germany, Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection (2011). *Handlungsempfehlung: Vollzug des Gebotes zur Rückhaltung verunreinigter Löschmittel im Brandfall – Hessenweit abgestimmte Empfehlung (Policy recommendation: Compliance with the instructions to retain contaminated extinguishing agents in the event of a fire – Recommendation of the German Federal State of Hessen).* Available at https://umwelt.hessen.de/umwelt-natur/wasser/gewaesserschutz/rueckhalt-von-verunreinigtem-loeschwasser.

F. The Swiss model

14. The Swiss model is used by the local authorities of 23 of the 26 Swiss cantons and by the Principality of Liechtenstein. The volume of firefighting water required is calculated based on the fire protection arrangements provided, the storage system, the fire risk of the stored materials, and the size of the fire compartment using empirical data taken from European Insurance Industry and other sources. The theoretical volume is taken from a table based on empirical data and the storage factor is based on mass per square metre (0.5; 0.8; 1.0; 1.2).

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

Source

Konferenz der Vorsteher der Umweltschutzämter der Schweiz (Conference of Chiefs of Environmental Protection Services) (2015). *Löschwasser-Rückhaltung – Leitfaden für die Praxis* (Firefighting Water Retention: A Practical Guide), 1st ed. Zurich. Available in French, German and Italian at: www.kvu.ch/de/arbeitsgruppen?id=190.

G. The Verband der Schadenversicherer e.V. (Association of Non-Life Insurers) (VdS) model

15. A very advanced and complex model is the Verband der Schadenversicherer e.V. (Association of Non-Life Insurers) (VdS) formula, developed by the German insurance industry and published as Guideline VdS 2257. It takes many influencing factors into account and is based on an extensive evaluation of empirical data, scientific studies and industrial experience. This method takes into consideration the type and quantity of combustible materials, the presence of fire detection systems, the size of the largest fire compartment, the type of fire brigade and the fire protection technical infrastructure.

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

Key:

A = object surface or largest fire compartment [m^2]

SWL = 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. Owing to the complexity of the method and the number of dependent tables, they are not included in this annex.

17. An automatic calculation sheet for calculating the volume of contaminated extinguishing water can be downloaded free of charge.[2]

Sources

Verband der Schadenversicherer e.V. (Association of Non-Life Insurers) (VdS) (2013). *Planning and Installation of Facilities for Retention of Extinguishing Water: Guidelines for Loss Prevention by the German Insurers*, VdS No. 2557 (Cologne, VdS Loss prevention GmbH. Available at https://vds.de/fileadmin/vds_publikationen/vds_2557en_web.pdf.

H. The Joint Expert Group on Water and Industrial Accidents model

18. This method, proposed by the Joint Expert Group on Water and Industrial Accidents (JEG model), is easy to use and safe. The JEG model estimates 1 m^3 of the retention basin per square metre 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]

[2] https://shop.vds.de/en/download/4985801dafb52f4d08e8aa83b5bc0e90. See also the calculation sheet contained in annex to VdS, *Planning and Installation of Facilities for Retention of Extinguishing Water: Guidelines for Loss Prevention by the German Insurers* (under *Sources* below), available at https://shop.vds.de/en/download/4985801dafb52f4d08e8aa83b5bc0e90.

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)

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

20. The model outcome shown in the graphs at the end of this annex represent the advanced JEG model. The volume of all liquids in the fire compartment areas should be combined. A comparison of the advanced JEG model with the other models shows that with lower fire densities, this model provides results within the mid-range of the other models. In the event of higher fire densities, the model achieves comparatively lower values.

I. Comparison

21. Bearing in mind the differences between and the complexity of these models, the comparisons were made with some simplifications. Every model is represented on the graphs by one line. The graphs represent the smallest achievable volumes, e.g. owing to the use of the maximum fire protection (the German VdS model and the Advanced JEG and Swiss model) and/or the presence of the relatively less hazardous materials or lowest risk (the Swiss, Sandoz and Ciba, Buncefield and ICI models). The ICI model is represented by a straight line because it is not dependent on the surface of the fire zone. The Swiss model is limited to an area of 4,500 m^2 because 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. Selected input data:

(a) Fire loads expressed in [MJ/m^2]: 500 and 1,296 as an upper reliable boundary for the German 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 I

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

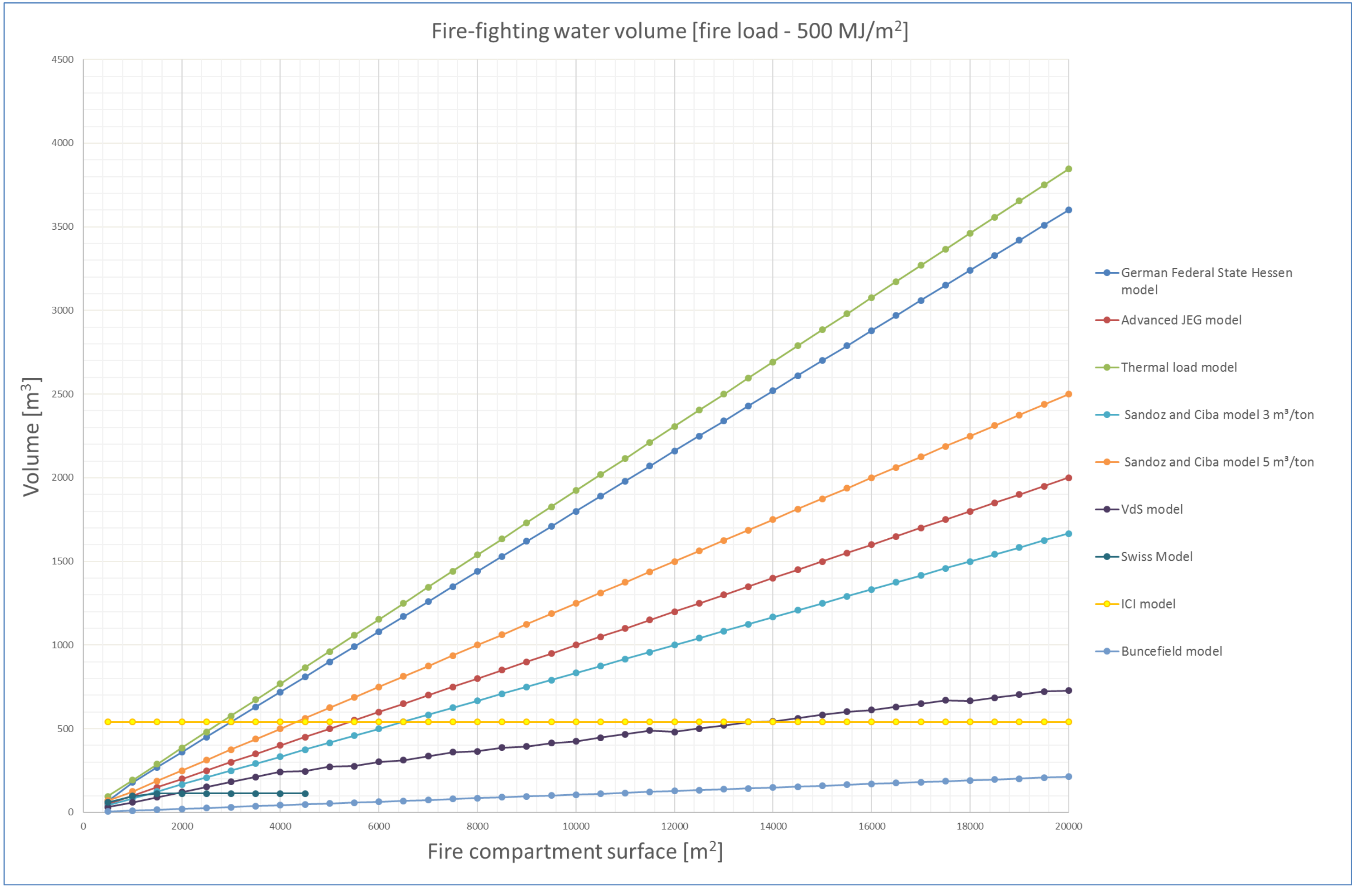
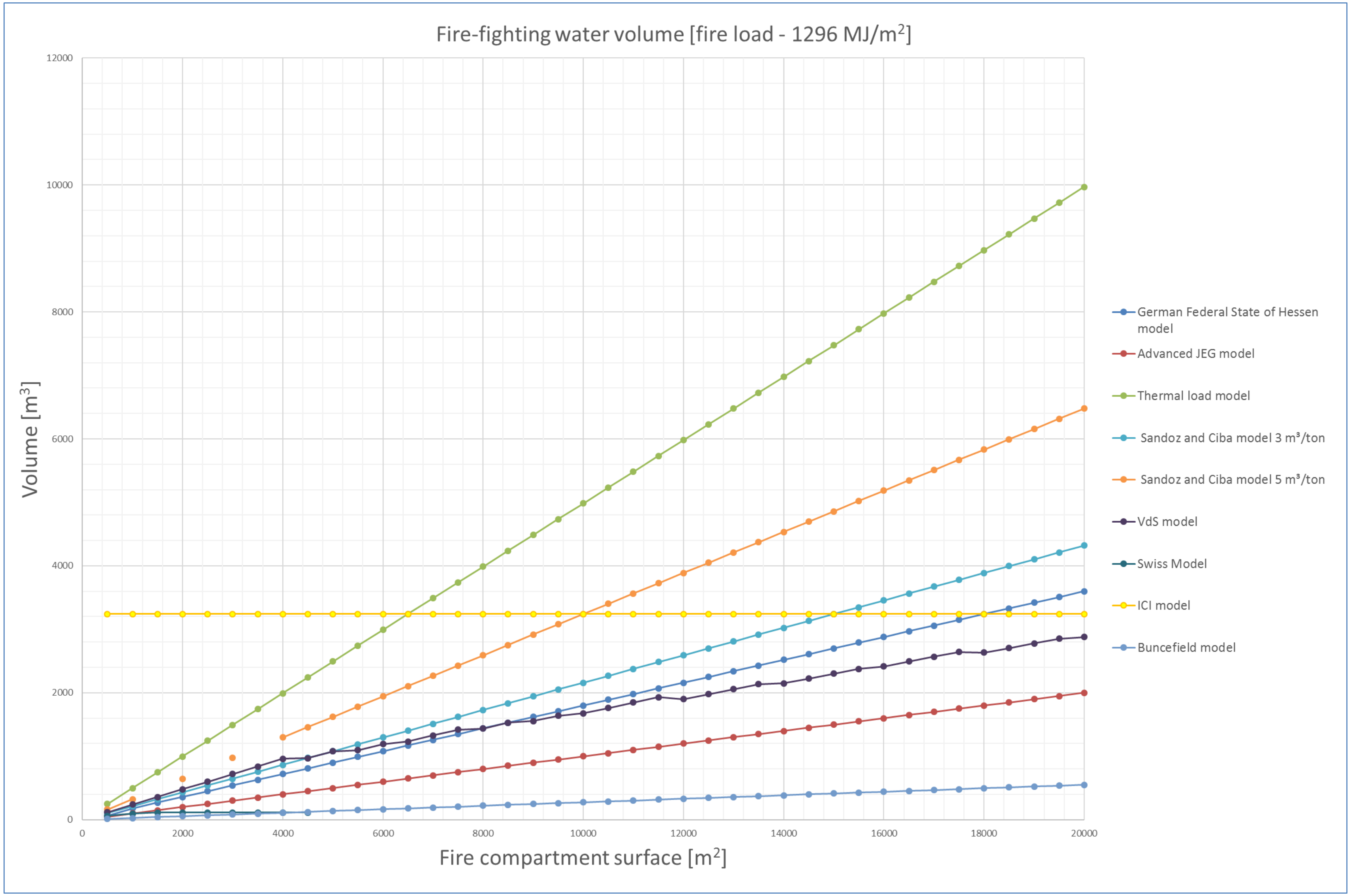


Figure II
Comparison of methodologies for determining firefighting water volume with a fire load of 1,296 MJ/m2



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