The benefit of performance-based Fire Safety Engineering

Prescriptive versus performance-based design

The design of fire suppression systems for naval vessels can either be based on prescriptive regulations or be performance-based. Prescriptive regulations arise from experience as they are created from established practices and knowledge from more or less disastrous incidents. Many prescriptive regulations are based on either non-valid assumptions or on validations that have been lost. Frequently the origin and rationale for the regulation is not traceable and may have become obsolete due to the development of new methods, equipment and materials. Therefore it is often not possible to assure the applicability of the regulation. This can lead to installation of costly, poorly dimensioned and ineffective systems.

Prescriptive regulations have advantages. They are relatively simple to use, incorporate common experiences into standard protocols and are agreed upon as providing an adequate level of safety. From a liability point of view, prescriptive regulations free the design authority from responsibility, to some extent. A disadvantage of prescriptive regulations is that they have a tendency to favor existing technologies, making innovation and technological development more challenging.

The need and desire for innovation is an important reason behind the philosophy of 'goal-based ship constructions' that has been introduced in the IMO SOLAS code in 2002. As naval vessels are likely to have specific requirements for operability and threat management, performance based safety design is generally the only approach available.

A performance based design approach involves the establishment of agreed upon fire safety goals and objectives, deterministic and/or probabilistic analysis of fire scenarios and quantitative assessment of how alternative designs/systems meet the fire safety goals and objectives. To do so accepted engineering tools, experimental methods and performance criteria are used.

Performance based design of firefighting systems may require more work than would be required if prescriptive regulations were used. However, performance-based design has the potential to provide both a more cost effective system that is tailored to a particular vessel or to spaces on that vessel. From the perspective of naval firefighting applications, there is also the potential for enhanced operability, effectiveness and survivability of the vessel. Performance based fire regulations have been adopted in SOLAS and the Naval Ship Code (NSC).

Research organisations from Canada, The Netherlands and Sweden have applied the performance based approach to a number of firefighting issues for naval vessels in the joint project *New Fire Suppression Technologies on Board Naval Ships* (FiST). Parties involved are DRDC in Canada, TNO and Royal Netherlands Navy in The Netherlands and SP Fire Technology and FOI in Sweden.

Fire-fighting capability after battle damage

There are no prescriptive requirements regulating residual capacity of fixed fire-fighting systems after weapon induced damage. Such a requirement is an example of where a performance based approach is desirable. The results of our research illustrate what residual capacity might be achieved from a damaged system and can be used to select redundancy approaches to reach the required performance.

Test results indicate that a damaged low pressure water spray system (reduced number of nozzles and pressure reduced to 5 bar) still meets the performance criteria: the fire is quickly suppressed and the compartment temperature is reduced to below 60 °C within seconds.

Performance criteria are met when redundant water feed pipes each supply 50 % of the nozzles in a compartment and the system is fed by the ship's fire main.

Tests on a high pressure water mist system indicate that reducing the number of nozzles and operational pressure to 25 bar shows compliance with the performance criteria. The compartment temperature did not rise above 150 °C and was reduced to below 60 °C within a few minutes. In such conditions, flashover will not occur and the ship divisions will not lose integrity. Even at fire main pressure, the system kept the compartment temperature below 350 °C. This could prevent flashover and postpone or prevent fire breakthrough to adjacent spaces. When pump capacity is such that the operational pressure can be maintained at 25 bar, even in case of damage the fire can be controlled and be prevented from spreading.

Weapon storage protection

There are prescriptive requirements regarding water discharge densities to be applied in weapon storage spaces ranging up to 32 liters/m²/min. It would be beneficial to reduce discharge densities as the installation of systems for handling and storing large volumes of water can be challenging. A performance-based approach was again used to identify suitable protection systems for a defined design fire scenario.

The performance criteria were based on the assumption that 200 °C is the critical temperature for a fast heating phase and 150 °C for a slow but prolonged heating of a weapon. The criteria were a result of weapon cook-off tests performed at TNO in the past. The results showed that a system with a flow rate of 10 liters/m²/min met the performance criteria for our specific scenario. Prescriptive requirements in this case lead to an over-dimensioned and costly system.

Conclusion

At their best, prescriptive regulations can provide good quality fire safety design. At their worst, prescriptive regulations can result in expensive and poorly adapted systems for managing fire threats on naval vessels. Designers, researchers and regulatory bodies must challenge the prescriptive requirements and try to find better, safer solutions when this is financially and technically feasible.

In the FiST project we investigated performance criteria for cases where no regulations were prescribed, for example on damaged water mist systems. There have been suggestions for technical innovations, such as the use of bulkhead nozzles (rather than ceiling nozzles), more robust layout and local protection, residual capacity in the pump and the ability to connect water mist systems to the fire main. These innovations might have been inhibited by prescriptive regulations.

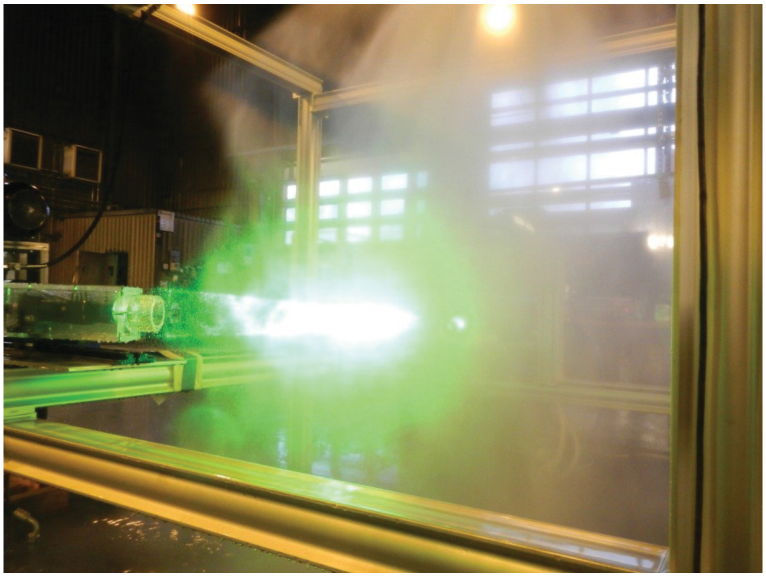
Furthermore, testing of prescriptive regulations for water spray systems for ammunition storage spaces indicated that these can lead to poorly designed systems. Poor design not only affects the system, but also influences ship construction. In the past designers have had to cope with the free surface effects of enormous water flows into magazine spaces during discharge of the system.

Canada was able to verify specific design options with respect to the use of NOVEC 1230. Knowledge on combining NOVEC with water mist will be implemented in future ship designs or mid-life upgrades. In Sweden the knowledge has been applied in design of fire fighting systems for submarine engine compartments. In the Netherlands the work from FiST will be input for selection and layout of water mist systems on new shipbuilding programs with high degree of automation. We are currently investigating opportunities to develop practical methods, rules of thumb and tools for ship designers to employ performance based approaches to fire suppression themselves.

Picture captions


Spray of a regular watermist nozzle in the back and sprays from fragment holes in the front.


Ordnance dummy during a fire test.


We measured the droplet size distribution as a function of system pressure. Pressure at the nozzle will be reduced in case of battle damage.