Contact person
Franz Evegren
Fire Technology
+46 10 516 50 88
Franz.Evegren@sp.se

Procedure outline of engineering analysis required by Regulation 17

Background

SOLAS chapter II-2 (part F) Regulation 17 (hereafter referred to as Regulation 17) states that fire safety design and arrangements may deviate from the prescriptive requirements set out in parts B, C, D, E or G, provided that the design and arrangements meet the fire safety objectives and functional requirements of the regulations. When fire safety design or arrangements deviate from the prescriptive requirements, an engineering analysis shall be carried out based on the guidelines in MSC/Circ.1002. These guidelines describe to use a deterministic performance-based approach based on fire safety engineering to verify that the fire safety of the novel design is at least equivalent to that stipulated in regulations, often referred to as the “equivalence principle”. Since there are no general explicit criteria for the required level of fire safety, the fire safety in the alternative design needs to be compared to that of a prescriptive design. Accordingly, the prescriptive design is used as a reference design, complying with the fire safety requirements in parts B, C, D, E and G of SOLAS 2009 chapter II-2. The documented level of fire safety of the alternative design is therefore not absolute, but relative to the implicit fire safety of a traditional design, which is likewise a product of the implicit fire safety level in prescriptive regulations. Accounting for uncertainties when comparing levels of fire safety, the engineering analysis based on MSC/Circ.1002 should demonstrate that the alternative design and arrangements with reasonable confidence has a fire safety equivalent to, or better than, that of a prescriptive design.

Summary

Briefly, the procedure outline of the engineering analysis outlined in MSC/Circ.1002 and required when laying claim to Regulation 17 can be described as follows:

- *A design team is formed*
  Together, the members of this design team shall have all necessary competences to perform the engineering analysis.
- *A preliminary analysis in qualitative terms is conducted*
  This analysis includes definitions of scope, development of design fire scenarios and development of trial alternative designs. The analysis is documented in a Preliminary Analysis Report which shall be submitted to the Administration for consideration before a quantitative analysis is initiated.
- *A quantitative analysis is conducted*
  This analysis includes a quantification of the design fire scenarios, development of performance criteria and an evaluation of the trial alternative designs.

The final documentation from the regulation 17 analysis shall demonstrate whether an equivalent safety level has been obtained for the alternative design.

Description of the analyses

Below follows a more detailed description of the analyses to be performed according to MSC/Circ.1002.

The general scope is often known before the engineering analysis according to MSC/Circ.1002 is initiated. If that is the case a design can be formed which shall have all the necessary competences to perform the analysis. When the needs for verification are more established throughout the process the design team may need to be reformed.

The preliminary analysis in qualitative terms

The general procedure of the preliminary analysis in qualitative terms to be performed by the design team commences by definitions of scope. The overall scope of the design changes is first outlined, followed by a description of the base design. When these have been defined follows an investigation of affected fire safety regulations, which is meant to clarify the needs for verification. The evaluations in this step of the process are qualitative and comprise the evaluation of prescriptive requirements and associated functional requirements required. The fire safety objectives and functional requirements may also be evaluated. All identified pros and cons regarding fire safety with the base design in relation to the prescriptive design are collected in a so called Procon List in order to keep track of all identified differences in fire safety. This list will be of significant value when forming fires scenarios.

Process of the preliminary analysis in qualitative terms.

The first step in the development of fire scenarios is to perform an identification of fire hazards. This is a systematic brainstorming session where the fire safety of each of the concerned spaces is thoroughly investigated to identify fire hazards. The process is carried out by the multidisciplinary design team selected for this specific design case and results in a tabulation of fire hazards. These are used to estimate fire risk indices of the affected spaces, to get an indication of the distribution of fire risks in the novel design, i.e. an enumeration of fire hazards.

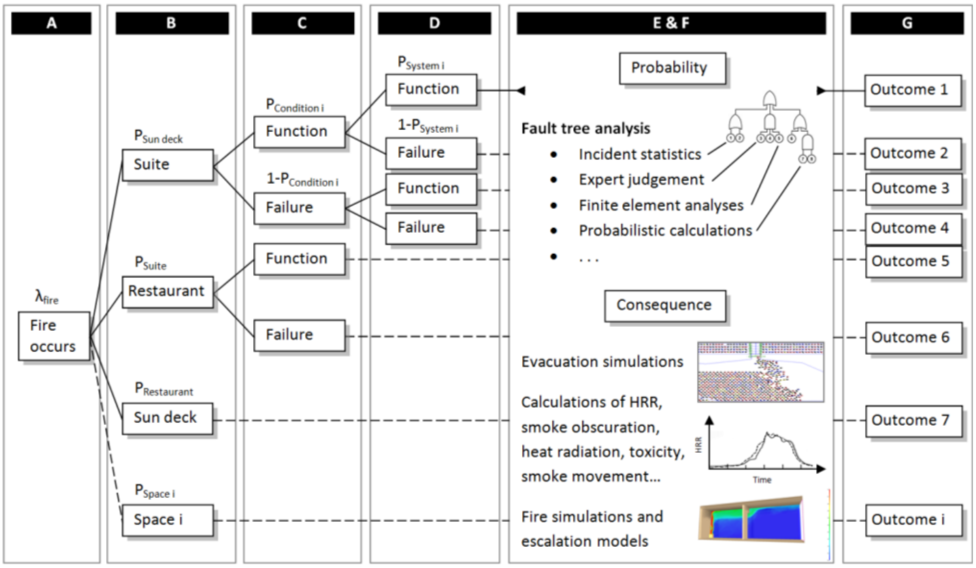
Differences in fire safety between the base design and a prescriptive design should hitherto also have been added and ranked in the Procon List. As many of those as possible are now to be included when selecting fire hazards to determine representative fires and failure modes, which will form fire scenarios.

A range of the largest and most probable enumerated fire hazards are thereafter determined. Throughout the selection process it will be kept in mind to primarily select fire hazards that represent differences in fire safety between the novel and the reference design. Characteristic fire load density, HRR, smoke production etc. Of the particular type of space and different failure modes (e.g. failure of sprinkler system, detection or closed door) are some of the fire hazards that will be selected to specify the fire scenarios. Significant differences in fire safety on the Procon list that have not been included in the representative fire scenarios will need special attention in the proceeding assessment.

Throughout the foregoing analyses, another list should have been managed. It consists of RCM's (risk control measures) that have been identified as possible to mitigate consequences or the occurrence of fire. The list is used as foundation for the development of trial alternative designs where RCM's are composed to make up different RCO's (risk control options). Applied to the base design suitable RCO's will be selected to make up the trial alternative designs which will be subject to evaluation through the fire scenarios in the quantitative analysis. The documentation of the above described process in a preliminary analysis report closes the preliminary analysis in qualitative terms. The preliminary analysis report is to be submitted to the Administration for consideration and needs to be approved before the quantitative analysis is initiated.

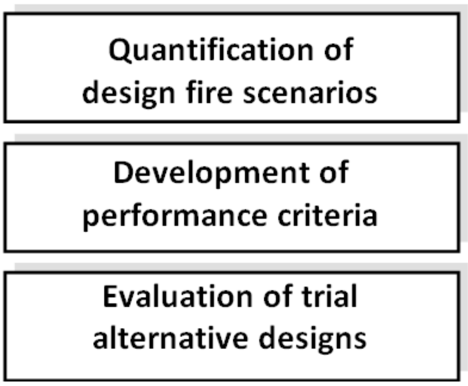
The quantitative analysis

The steps in the quantitative analysis are to a large degree integrated. The first goal is however to quantify the design fire scenarios. When the novel spaces, conditions and systems have been taken into account to make up specific scenarios, this is often done by calculating probability and consequence of each scenario (see figure). Since specific statistical data seldom exists, failure models are often necessary to estimate the probabilities. Fault tree analysis (FTA) is a popular method used to models failure possibilities for scenario events and to quantify failure probabilities. Some examples of inputs to an FTA are enumerated in section E in figure 7.6. These may, however, also provide sufficient information regarding the probabilities, and an FTA is in those cases unnecessary.



Description of the quantification of fire scenarios through an event tree.

The quantification of consequences takes many calculations into account. A starting point is to establish conservative but probable diagrams describing the heat release rate per time unit, depending on the available initial fuels, the fire load, ventilation conditions etc. In certain cases, fire tests and experiments may be necessary to properly predict the fire characteristics. In other cases it may be sufficient to model the fire through calculations and simulations. The approach thereafter is commonly to compare estimations of the conditions in the affected compartments with evacuation simulations. Parameters describing the conditions in compartments affected by smoke or fire are e.g. heat radiation, toxicity, smoke obscuration and the temperature and height of the smoke layer. Transient calculations of these parameters will settle when the conditions will be inhabitable. This time will be compared with the calculated time for escape (there are also some other factors necessary to take into account, such as the reaction time and the fact that many passengers tend to stay in their cabins when the alarm sounds). Comparing the analyses will settle a number of expected casualties, i.e. the consequences of the specific scenario. In other cases simpler analyses may be sufficient, only estimating the probability or time till a certain condition has occurred; e.g. fire or smoke spread to the adjacent compartment or a certain temperature in the smoke layer. The calculated results are summarized as the outcome of the scenario. Regardless of the calculation procedures utilized to estimate the results, a sensitivity analysis should be conducted to determine the effects from uncertainties and limitations in input parameters. Since several extensive evaluations are necessary for each considered scenario it is essential to select the range with care. Some will affect the result more than others and the labour of the analysis will to a large degree depend on the number of scenarios.



Process of the quantitative analysis.

The quantified outcomes above are now to be merged into risk measures. Performance criteria and safety margins are settled upon when it is clear what risk measures, or parameters for comparison, that will be used in the specific design case. This is generally done as soon as possible in the above process. Estimations from probabilistic risk analyses are commonly presented in the risk measures “individual risk” and “societal risk”. In risk management “individual risk” is normally defined as the probability for an individual, situated in a specific area for a year, to be exposed to inhabitable conditions from possible accidents scenarios. Being in a space for one year where the individual risk is 10^{-4} implies the probability to die is one in ten thousand. The individual risk is independent from the possible number of exposed people and reveals nothing on the extent of damage to society. “Societal risk” on the other hand, concerns the total risk to human life in the areas affected by the possible fire scenarios. If one million people are situated in an area for a year where the individual risk is 10^{-4}, then the societal risk is 100. Societal risk is typically expressed as the expected number of fatalities in a year of operation or illustrated in a FN diagram. What is notable concerning the expected number of fatalities is that it needs a fairly delimited context to make sense, which although is the case when comparing two similar designs.

As mentioned above, two analyses are required to evaluate the novel design and arrangements; one for the regulatory prescribed design and one for the trial alternative designs. The most advantageous risk control options, depending on cost-effectiveness regarding degree of improved safety, will determine which of the acceptable trial alternative designs will be selected as the final alternative design. The engineering analysis is to be thoroughly documented and turned in for consideration to the Administration which will settle upon whether the final alternative design accepted by the design team will be approved along with the performed analysis.

Yours sincerely,

SP Technical Research Institute of Sweden
Fire Technology - Fire Dynamics

Franz Evegren

Franz Evegren