# Appendix E

## Methodology for Assigning Probabilities of Flame Termination

The following guidelines may be used for assigning probabilities of flame termination in conjunction with the conduct of a fire safety analysis of a ship using the Ship Fire Safety Engineering Methodology (SFSEM). There are three ways a fire may terminate in a compartment:

1. The fire may self-terminate or extinguish **I**tself without any action on the part of the crew or without discharging a firefighting agent from any of the ship's fire extinguishing systems; this probability is referred to as the I-Value in the SFSEM.
2. The fire may be extinguished by the application of a firefighting agent from an installed or **A**utomated fire extinguishing system with no human intervention other than activation of the system; this probability is referred to as the A-Value in the SFSEM.
3. The fire may be extinguished by the **M**anual application of a firefighting agent from a portable fire extinguisher, semiportable fire extinguishing system, or hoseline; this probability is referred to as the M-Value in the SFSEM.

As noted in the Theoretical Basis of the SFSEM [1], I, A, & M-values are determined by assigning probabilities to various subfactors that together affect the overall calculation of the probability of flame termination. Detailed information concerning the construction and use of network diagrams for the calculations of probabilities of flame termination are provided in Appendix F: Network Diagrams of the Final Report of the Fire Safety Analysis of the 180' WLB Seagoing Buoy Tender. [2] Detailed information concerning the various conditions and parameters that influence each subfactor are provided in Appendix G: Fire Growth Factors of the same report. [2]

The following guidelines are used to establish the spreadsheets and document various key parameters that are taken into account during the assignment of probabilities at the subfactor level. Specific guidance for assigning probabilities at the subfactor level is provided in the three attachments to these general guidelines. **Note: These are guidelines only, the engineer must alter recommended values based on experience and sound engineering judgment taking into account conditions expected or observed in each compartment.**

1. Assign a Compartment Use Indicator (CUI) to all compartments in accordance with the guidelines provided in the SAFE User Manual (Appendix H). [3]
2. Enter the Plan IDs, CUI assignments, and Compartment Names as the first three columns in an Excel spreadsheet; sort on CUI and compartment name as the secondary sort.
3. Estimate FRI time in minutes for each CUI based on modeling/calculations and then adjust up or down according to existing conditions in each compartment. Appendix G: Fire Growth Factors of the Final Report of the Fire Safety Analysis of the 180' WLB Seagoing Buoy Tender [2] provides detailed information concerning the factors that affect FRI times. Insert FRI times in column 4 and note in the footer of the spreadsheet that FRI times are estimated.
4. Columns 5 and 6 are used to record the class of fire (A, B, or C) that is most likely to occur in the compartment and the estimated size of the fire (small, medium, or large) that will likely be encountered by the fire party as they arrive on scene. Fire size is relative to the size of the compartment. The following table provides guidance of what constitutes a small, medium, and large fire in terms of the percentage of deck area occupied in compartments of varying size.

| | **Small Fire** | **Medium Fire** | **Large Fire** |
|---|---|---|---|
| **Small Compt** | <50% of deck area | 50%<deck area<75% | >75% deck area |
| **Medium Compt** | <33% of deck area | 33%<deck area<66% | >66% deck area |
| **Large Compt** | <25% of deck area | 25%<deck area<50% | >50% deck area |

Some other factors that affect the judgment of fire size include FRI time, compartment geometry (ceiling height), fuel load, fuel type, fuel package distribution, ventilation, and fire scenario (spray fire, smoldering fire, flammable liquid pool fire etc.). The following table provides guidance of what constitutes a small, medium, and large fire in terms of these other factors.

| | **Small Fire** | **Medium Fire** | **Large Fire** |
|---|---|---|---|
| **FRI Time** | FRI Time > 10 minutes | 3 minutes < FRI Time < 10 minutes | FRI Time < 3 minutes |
| **Ceiling Height** | Ceiling ht >9 ft | 7 ft < ceiling ht < 9 ft | Ceiling ht < 7 ft |
| **Fuel Load** | Fuel load density < 2 psf cellulosics equivalent | 2 psf cellulosics equivalent < fuel load density < 4 psf cellulosics equivalent | Fuel load density > 4 psf cellulosics equivalent |
| **Fuel Type** | Primarily cellulosics | Cellulosics and plastics | Primarily plastics |
| **Fuel Package Distribution** | Most fuel packages separated greater than 1 meter apart | Most fuel packages separated by approximately 1 meter | Most fuel packages separated less than 1 meter apart |
| **Ventilation** | Little to no ventilation | Forced ventilation or open doors to interior compartments | Large openings to outside air (weather) |
| **Fire Scenario** | Smoldering fire | Pool fire | Spray fire |

5. Columns 7 and 8 are used to record the most probable ignition source and location in the compartment. For example, “Galley Stove” (column 7) and “bulkhead” (column 8). Typical ignition sources include lighting fixture, a specific electrical appliance, a specific motor or controller, a bunk, wastebasket, and rag bag, etc. Locations are usually limited to one of the following bulkhead, corner, center, overhead, and bilges.
6. Copy this spreadsheet such that three separate spreadsheets are established for I, A, and M-values. The ship’s name, the parameter to be calculated (I, A, or M-Value) and the date are recommended for inclusion in the header of each spreadsheet; the footer may include additional information such as estimated or calculated FRI times, baseline analysis, or analysis of a specific alternative etc.

**Attachment 1**
**Methodology for Assigning I-Values**

1. Set up columns 9 through 13 to calculate I|EB (probability the fire will self-terminate or extinguish itself before full room involvement occurs given that established burning has occurred in the compartment) based on three subfactors as described in this attachment. The factors and subfactors should be shown as column headings and formulas should be embedded in the spreadsheet in accordance with the Theoretical Basis of the SFSEM. [1] Probabilities should be expressed as a number between 0 and 1 (two decimal places). Notes at the bottom of this spreadsheet should define the subfactors and factors as well as the formulas for calculating the I-values.
2. Column 9, Subfactor: "Iebar" - Fire Grows to the Enclosure Point. Assign a probability that the fire will grow from EB to the enclosure point. This probability is dependent on many elements including:
    - Fuel type, quantity, and distribution of fuel packages
    - Bulk density of fuel and orientation of the fuel packages (i.e. vertical or horizontal)
    - Ignition temperature, location and deck area covered by ignition source
    - Boundary insulation
3. Column 10, Subfactor: "Icbar" - Fire Grows to the Ceiling Point. The probability that the fire will grow from the enclosure point to the ceiling point. This probability is dependent on many elements including:
    - Fuel type, quantity, and distribution of fuel packages
    - Height of the fuel packages
    - Boundary insulation and combustibility of bulkhead and ceiling linings
    - Height of overhead
    - Ventilation Factor (i.e. A*H^.5)

Detailed information concerning these factors is provided in Appendix G: Fire Growth Factors of the Final Report of the Fire Safety Analysis of the 180' WLB Seagoing Buoy Tender [2]

4. Column 11, Subfactor: "Irbar" - Fire Grows to the Room Point. The probability that the fire will grow from the ceiling point to the room point. This probability is dependent on many elements including:
    - Fuel type, quantity, and distribution of fuel packages.
    - Boundary insulation and combustibility of bulkhead and ceiling linings.
    - Compartment width/depth ratio.
    - Ventilation Factor (i.e. A*H^.5).
5. Column 12, Factor: "Ibar" - Probability that the fire will not self-terminate is calculated in accordance with the following formula: Ibar=Iebar*Icbar*Irbar.
6. Column 13, Factor: "I|EB" - Probability that the fire will self-terminate before full room involvement given that established burning has occurred, is calculated in accordance with the following formula: I|EB=1-Ibar.
7. The spreadsheet will now show calculated values for I|EB. These values should be reviewed by comparing I-values between various CUIs and I-values for compartments having identical CUIs. The values typically range from ".25" for spaces with short FRI times, high fuel loads, and significant probabilities of large fires to ".85" for Stairways, Passageways, and Sanitary Spaces with infinite FRI times, negligible fuel loads, and probabilities of small fires. If a set of I-values for a CUI or an individual compartment's I-value seems inconsistent with other I-values the engineer should revisit the values assigned to the three individual subfactors and

reassign more appropriate probabilities. This process should be repeated until the engineer is satisfied that the calculated I-values are reasonable and consistent.

**Attachment 2**
**Methodology for Assigning A-Values**

The compartments shown on this spreadsheet should be limited to those that have an automated fire extinguishing system. Typical automated systems include the following:

- $CO_2$ Total Flooding System (typically installed in Flammable Liquids Storeroom, Paint Lockers, Engine Rooms, and Auxiliary Machinery Spaces such as JP-5 Pump Rooms)
- AFFF Bilge Sprinkling Systems (typically installed in Engine Rooms, Auxiliary Machinery Spaces such as Steering Gear Rooms and Hydraulic Machinery Spaces)
- AFFF Sprinkling Systems (typically installed in Auxiliary Machinery Spaces such as Bow Thruster Machinery Rooms)
- Aqueous Potassium Carbonate (APC) Systems (typically installed in Galleys)
- Water Sprinkling Systems (typically installed in Cargo Holds)
- Halon/Halon Alternatives (e.g., FM 200) (typically installed in Engine Rooms)

1. Set up columns 9 through 25 to calculate A|EB (probability of an automated fire extinguishing system extinguishing the fire before full room involvement occurs given that established burning has occurred in the compartment) based on 12 subfactors as described in this attachment . The factors and subfactors should be shown as column headings and formulas should be embedded in the spreadsheet in accordance with the <u>Theoretical Basis of the SFSEM</u>. [1]. Probabilities should be expressed as a number between 0 and 1 (express probabilities to two decimal places). Notes should be included at the bottom of this spreadsheet that define the factors as well as the formulas for calculating the A-values.
2. <u>Column 9, Subfactor: “dan” - Detection of Fire</u>. Estimate the percentage of time around the clock that the compartment is monitored by an automatic detection device or by a human. Note the percentage of time a compartment is *monitored* is usually higher than the percentage of time it is *occupied*. Reasons for this include the ability to observe conditions in one compartment from another compartment through open doors or hatches. Normally, the “dan” factor will not vary significantly between in port and at sea conditions since compartments with automated systems typically include automatic detection systems. However, two sets of A-Values should be prepared (i.e. In Port and At Sea) if “dan” values vary between in port and at sea conditions. The following guidelines for assigning probabilities to the “dan” subfactor apply to compartments with automatic detection devices:
   - If a compartment has multiple automatic detectors in a single zone, assign “.99” (equivalent to a fully addressable system).
   - If a compartment has a single detector in a single zone, assign “.95” (equivalent to a fully addressable system).
   - If a compartment has multiple automatic detectors but the compartment is one of many in a single zone, assign “.90”.
   - If a compartment has a single detector but the compartment is one of many in a single zone, assign “.85”.
   - If the following conditions are noted: missing or inoperative detectors, dead batteries or faulty wiring, reports of numerous false alarms, etc. the assigned probabilities should be reduced in accordance with the perceived reliability of the system.

   The following guidelines for assigning probabilities to the “dan” subfactor apply to compartments without automatic detection devices:
   - If a compartment is normally occupied part of the day, assign a value that is calculated by dividing the total number of hours a week the compartment is occupied by 168 and

then increase this value to account for the possibility of observing fires from another compartment. This should result in values ranging from ".50" to ".80". This range is also applicable to compartments in view of a surveillance camera
- If a compartment is not normally occupied and is remotely located (i.e. out of the main stream of normal traffic) assign ".50" or less depending on its degree of remoteness. This range is also applicable to compartments not in view of a surveillance camera.

3. Column 10, Subfactor: "nan" - Notification of the Bridge. Assign a value that is equal to "dan" if the compartment has an automatic detection device. For compartments without an automatic detection device assign ".90".
4. Column 11, Subfactor: "san" - Sound the Alarm. It is assumed that if the Bridge receives the notification, the alarm will be sounded due to the military discipline and training that can be expected on Coast Guard cutters. However, there is a slight possibility of announcing the wrong location and there is a very remote probability that the PA system will be inoperative, thus a probability of ".95" is assigned.
5. Column 12, Factor: "An" - Notification is calculated in accordance with the following formula: An=dan*nan*san.
6. Column 13, Subfactor: "fap" - Secure the Fuel Supply. The primary concern here is the likelihood of securing the flammable liquid supply to potential spray fires. Main machinery Spaces (CUI=EM) on ships are normally equipped with remote fuel shut-off valves accessible from outside the compartment. Therefore assign ".80" to compartments with a CUI of "EM". "QA" and "QE" spaces may be subject to flammable liquid spray fires but are not generally equipped with remote shut-off valves. Therefore assign values of ".70" to ".90" depending on the presence of internal combustion engines or flammable liquid fuel lines in these spaces. Assign a value of "1.00" to all other spaces unless they have internal combustion engines or flammable liquid fuel lines in the compartment.
7. Column 14, Subfactor: "vap" - Secure the Ventilation. Forced ventilation is most likely installed in spaces with a CUI of "EM", "TU" and "K". Therefore ventilation in these spaces may not be secured with the certainty that it can in spaces without forced ventilation unless the automated suppression system automatically secures the ventilation system. Therefore in spaces with forced ventilation systems (e.g. CUI of "EM", "TU", or "K") assign a value of ".80" if the ventilation system is not automatically secured, assign a value of ".90" if the ventilation system is automatically secured. In all other spaces without forced ventilation assign a value of ".95".
8. Column 15, Subfactor: "pap" - Secure the Electrical Power. Due to the quantity of electrical motors and controllers installed in spaces with a CUI = "EM" or "EE" assign a value of ".80". Most other spaces have, as a minimum, electrical lighting and may have electrical equipment installed in addition to lighting. Therefore in all other spaces assign values ranging from ".80" to ".90".
9. Column 16, Factor: "Ap" - Preparation is calculated in accordance with the following formula: Ap=fap*vap*pap.
10. Column 17, Subfactor: "saa" - Alignment of Automated System. System alignment involves all the physical devices (e.g., electrical, mechanical, pneumatic, hydraulic) that must be properly configured for the system to work if activated. AFFF sprinkling systems primarily involves piping systems and valves, but the system also requires proper alignment of the AFFF proportioner and storage tank. $CO_2$ systems are less complex in that they usually include fewer valves and other components compared with AFFF sprinkling systems. APC systems for deep fat fryers and Galley stoves include even fewer valves and components. Therefore the following guidelines are provided for assigning probabilities to the "saa" subfactor:
    - AFFF Sprinkling: assign ".85"

- CO2 Total Flooding: assign ".90"
- Halon/Halon Alts: assign ".90"
- APC System: assign ".95"

11. <u>Column 18: Subfactor "aaa" - Agent Discharges from Nozzle</u>. This subfactor describes the probability that an agent will flow from its storage location to the nozzle and discharge into the protected space. This probability is influenced by a potential blockage in the piping system, sufficient pressure to move the agent through the piping system, and potential failure of the nozzles themselves. These systems are designed to be inherently reliable. Therefore the following guidelines are provided for assigning probabilities to the "aaa" subfactor:
    - AFFF Sprinkling: assign ".90"
    - CO2 Total Flooding: assign ".95"
    - Halon/Halon Alts: assign ".95"
    - APC System: assign ".99"
12. <u>Column 19: Subfactor "daa" - Agent Discharges on Fire</u>. The design, location, and aim of the nozzles affect the ability of the agent to discharge directly on the fire. In addition the presence of high piled storage may block the agent from reaching the fire. Therefore the following guidelines are provided for assigning probabilities to the "daa" subfactor:
    - AFFF bilge sprinkling: assign ".85"
    - AFFF overhead sprinkling: assign ".90"
    - CO2 Total Flooding: assign "1.00"
    - Halon/Halon Alts: assign "1.00"
    - APC System: assign "1.00"
    - Significant obstructions: assign ".80 or less" (does not apply to gaseous systems)
13. <u>Column 20, Factor: "Aa" - Agent Application</u> is calculated in accordance with the following formula: Aa=saa*aaa*daa.
14. <u>Column 21: Subfactor "qae" - Quantity of Agent Adequate</u>. There is an inexhaustible supply of sea water available on board ships. Therefore, assign a value of "1.00" for water sprinkling systems. Ships normally carry large quantities of AFFF concentrate, additional AFFF is also usually available from other ships that are called to assist in firefighting efforts. Therefore, assign a value of ".95" for AFFF sprinkling systems. $CO_2$ and Halon systems are normally designed to flood the protected space one time. Spare bottles must be used for a second discharge and it is quite unlikely that there is sufficient quantity of agent on board to flood the space more than twice. Therefore, assign a value of ".90" for $CO_2$ and Halon systems. APC systems are designed with adequate quantities of agent to extinguish up to large class B fires in deep fat fryers or Galley stoves. However, the agent may be exhausted before very large fires are fully extinguished. Therefore, assign a value of ".90" for APC systems
15. <u>Column 22: Subfactor "cae" - Concentration of Agent Adequate</u>. The spacing and design of the nozzles as well as the system discharge pressure influence the concentration of agent in APC systems as well as AFFF and water sprinkling systems. The size of the space, the quantity of agent discharged into the space and the leakage factors determine the concentration of agent in $CO_2$ and Halon total flooding systems. Therefore, the following guidelines are provided for assigning probabilities for the "cae" factor:
    - AFFF Sprinkling: assign "1.00"
    - CO2 Total Flooding: assign ".90"
    - Halon/Halon Alts: assign ".90"
    - APC System: assign "1.00"
16. <u>Column 23: Subfactor "bae" - Probability Blackout Occurs</u>. The probability of blackout primarily depends on three factors: quantity of agent (accounted for in column 21),

concentration of agent (accounted for in column 22), and the size of the fire (estimated in column 6). Therefore the following guidelines are provided to assign probabilities to the "bae" subfactor:

- In compartments where large-sized fires are expected, assign a value of ".90".
- In compartments where medium-sized fires are expected, assign a value of ".95".
- In compartments where small-sized fires are expected, assign a value of ".99".
- In multilevel engineering spaces, assign a value of ".85" or less.

17. Column 24: Factor "Ae" - Fire Extinguishment is calculated in accordance with the following formula: Ae=qae*cae*bae.
18. Column 25: Factor "A|EB" - The probability of Automated Fire Extinguishment before full room involvement given Established Burning has occurred, is calculated in accordance with the following formula: A|EB=An*Ap*Aa*Ae.
19. The spreadsheet will now show calculated values for A|EB. These values should be reviewed by comparing A-values for various compartments with the same automated fire extinguishing system. The values typically range from ".50" for AFFF bilge sprinkling systems to ".85" for APC systems to ".90" for $CO_2$ and Halon systems. Considerable variability has been noted in the probability of A|EB due to the range of probabilities assigned to the various subfactors for different compartments with the same automated system. In particular, the reliability of detection systems (subfactor "dan") varies greatly from ship to ship and compartment to compartment. If a set of A-values for a particular automated system or an individual compartment's A-value seems inconsistent with other A-values, the engineer should revisit the probabilities assigned to the 12 individual subfactors and reassign more appropriate values. This process should be repeated until the engineer is satisfied that the calculated A-values are reasonable and consistent.
20. After SAFE has been run on the baseline data set, actual FRI times will be part of the output results. It is extremely important that these calculated FRI times be compared to the estimated FRI times and updated in column 4. The engineer should revisit and change as necessary the assigned probabilities for affected subfactors and the size of the fire likely to be encountered by the fire party shown in column 6. The revised A|EB values should then be entered into SAFE as part of the baseline data set and the baseline results recalculated.

**Attachment 3**
**Methodology for Assigning M-Values**

1. Set up columns 9 through 25 to calculate M|EB (probability of manually extinguishing the fire before full room involvement occurs, given that established burning has occurred in the compartment) based on 12 subfactors as described in this attachment. The factors and subfactors should be shown as column headings and formulas should be embedded in the spreadsheet in accordance with the Theoretical Basis of the SFSEM. [1]. Probabilities should be expressed as a number between 0.00 and 1.00 (express probabilities to two decimal places). Notes should be included at the bottom of this spreadsheet that define the subfactors and factors as well as the formulas for calculating the M-values.
2. Column 9, Subfactor: "dmn" - Detection of Fire. Estimate the percentage of time around the clock that the compartment is monitored by an automatic detection device or by a human. Note: The percentage of time a compartment is *monitored* is usually higher than the percentage of time it is *occupied*. Reasons for this include the ability to observe conditions in one compartment from another compartment through open doors or hatches. Normally, the "dmn" factor will vary significantly between in-port and at-sea conditions, especially on ships with relatively few automatic detectors installed throughout the ship. Therefore, two sets of M-Values are normally prepared (i.e., In Port and At Sea). The following guidelines for assigning probabilities to the "dmn" factor apply to compartments with automatic detection devices:
    - If a compartment has multiple automatic detectors in a single zone, assign ".99" (equivalent to a fully addressable system)
    - If a compartment has a single detector in a single zone, assign ".95" (equivalent to a fully addressable system)
    - If a compartment has multiple automatic detectors but the compartment is one of many in a single zone, assign ".90"
    - If a compartment has a single detector but the compartment is one of many in a single zone, assign ".85"
    - If the following conditions are noted: missing or inoperative detectors, dead batteries or faulty wiring, or reports of numerous false alarms, etc. the assigned probabilities should be reduced in accordance with the perceived reliability of the system.

    The following guidelines for assigning probabilities to the "dmn" factor apply to compartments without automatic detection devices:
    - If a compartment is normally occupied part of the day, assign a value that is calculated by dividing the total number of hours a week the compartment is occupied by 168 and then increase this value to account for the possibility of observing fires from another compartment. This should result in values ranging from ".50" to ".80". This range is also applicable to compartments in view of a surveillance camera
    - If a compartment is not normally occupied and is remotely located (i.e. out of the main stream of normal traffic) assign ".50" or less depending on its degree of remoteness. This range is also applicable to compartments not in view of a surveillance camera.
    - On ships that have a reduced in port duty section, there is less monitoring of spaces due to a reduction in personnel on board. On these ships, in spaces that are not protected by an automatic detection device, reduce dmn by 0.2 from the number generated in accordance with the guidelines above.
3. Column 10, Subfactor: "nmn" - Notification of the Bridge. Assign a value that is equal to "dmn" if the compartment has an automatic detection device. For compartments without an

automatic detection device assign ".90". Assign a value of "1.00" to the Bridge (aka Pilothouse) for At Sea conditions.

4. Column 11, Subfactor: "smn" - Sound the Alarm. It is assumed that if the Bridge receives the notification, the alarm will be sounded due to the military discipline and training that can be expected on Coast Guard cutters. However, there is a slight possibility of announcing the wrong location and there is a very remote probability that the PA system will be inoperative, thus a probability of ".95" is assigned. Assign a value of "1.00" to the Bridge (aka Pilothouse).
5. Column 12, Factor: "Mn" - Notification is calculated in accordance with the following formula: Mn=dmn*nmn*smn.
6. Column 13, Factor: "fmp" - Secure the Fuel Supply. The primary concern here is the likelihood of securing the flammable liquid supply to potential spray fires. Main machinery Spaces (CUI=EM) on ships are normally equipped with remote fuel shut-off valves accessible from outside the compartment. Therefore assign ".80" to compartments with a CUI of "EM". "QA" and "QE" spaces may be subject to flammable liquid spray fires but are not generally equipped with remote shut-off valves. Therefore assign values of ".70" to ".90" depending on the presence of internal combustion engines or flammable liquid fuel lines in these spaces. Assign a value of "1.00" to all other spaces unless they have internal combustion engines or flammable liquid fuel lines in the compartment.
7. Column 14, Subfactor: "vmp" - Secure the Ventilation. Forced ventilation is most likely installed in spaces with a CUI of "EM", "TU" and "K". Therefore ventilation in these spaces may not be secured with the certainty that it can in spaces without forced ventilation. Therefore in spaces with a CUI of "EM", "TU" or "K" assign a value of ".80" unless a compartment is equipped with an automated suppression system that automatically secures the ventilation. In this event assign a value of ".90". In all other spaces without forced ventilation assign ".90". In absolutely airtight spaces (no forced or natural ventilation) such as Voids and Water Tanks (CUI = "V" and "W") assign a value of "1.00".
8. Column 15, Subfactor: "pmp" - Secure the Electrical Power. Due to the quantity of electrical motors and controllers installed in spaces with a CUI = "EM" or "EE" assign a value of ".80". Most other spaces have, as a minimum, electrical lighting and may have electrical equipment installed in addition to lighting. Therefore in all other spaces assign values ranging from ".80" to ".90". In spaces without any electrical power including lighting such as Voids and Water Tanks (CUI = "V" or "W") assign a value of "1.00".
9. Column 16, Factor: "Mp" - Preparation is calculated in accordance with the following formula: Mp=fmp*vmp*pmp.
10. Column 17, Subfactor: "sma" - Firefighters Respond to the Scene. On a ship, the firefighters do not have great distances to travel; however their ability to arrive on the scene prior to full room involvement conditions is proportional to the assumed FRI time (estimated in column 4). This factor is significantly different on ships that employ a rapid response team (RRT) concept. Response to the scene is also enhanced in compartments that are equipped with a fully addressable detection system. Therefore, the following guidelines are used to assign the probabilities to the "sma" subfactor:

| FRI Time (minutes) | sma (w/o RRT & w/o address. dets) | sma (w/ RRT & w/ address. dets.) | sma (w/ RRT & w/o address. dets.) |
|---|---|---|---|
| 1 | .10 | .50 | .20 |
| 2 | .30 | .60 | .40 |
| 3 | .50 | .70 | .60 |

| | | | |
|---|---|---|---|
| 4 | .70 | .80 | .75 |
| 5 | .90 | .90 | .90 |
| 6-9 | .95 | .99 | .99 |
| >10 | 1 | 1 | 1 |

11. Column 18: Subfactor "ama" - Firefighters Access Compartment. The ability to access a compartment on a ship is directly affected by the likelihood that the compartment is locked (and therefore the time to obtain a key or break down the door). Spaces such as storerooms, staterooms, ship store; weapons spaces such as the Armory; medical spaces such as the Dispensary and Sick Bay; and commissary spaces such as Dry Stores are quite likely to be locked. Therefore these spaces are assigned a value of ".90". Spaces such as Refrigerated Stores, Radio Room, and Combat Information Center are likely to be locked with high-security heavy-duty locks; therefore, these spaces are assigned a value of ".80". All other spaces are likely to be unlocked and are therefore assigned a value of "1.00".
12. Column 19: Subfactor "dma" - Agent Discharges on Fire. The following factors directly affect the ability of the firefighters to discharge an agent directly on the fire: size of the compartment, number of levels in the compartment, and amount of obstructions in the compartment. Therefore, the following guidelines are provided for assigning probabilities to the "dma" subfactor:
    - Large sized space, single level, no obstructions: assign ".85"
    - Medium sized space, single level, no obstructions: assign ".90"
    - Small sized space, single level, no obstructions: assign "1.00"
    - Multi-level compartments: assign ".80"
    - Significant obstructions: assign ".80"
13. Column 20, Factor: "Ma" - Agent Application is calculated in accordance with the following formula: Ma=sma*ama*dma.
14. Column 21: Subfactor "qme" - Quantity of Agent Adequate. The preferred agent for extinguishing Class A fires is water. There is an inexhaustible supply of sea water available on board ships. Therefore, in compartments where class A fires (shown in column 5) are expected, assign a value of "1.00". AFFF is the preferred agent for extinguishing Class B fires. Ships normally carry adequate quantities of AFFF concentrate, additional AFFF is also usually available from other ships that are called to assist in firefighting efforts. Therefore, in compartments where class B fires are expected, assign a value of ".95". $CO_2$ is the preferred agent for extinguishing class C fires. $CO_2$ portable extinguishers are normally located in close proximity to spaces with a class C fire threat, additional $CO_2$ extinguishers are also stored in the Repair Locker. Therefore, in compartments where class C fires (see column 5) are expected, assign a value of ".90".
15. Column 22: Subfactor "cme" - Concentration of Agent Adequate. The concentration of water for extinguishing class A fires is an important factor in building sprinkler systems. It is less of a factor in applying water from manually applied hose streams on ships. Therefore, in compartments where class A fires are expected, assign a value of "1.00". Fire suppression systems on ships are carefully designed to produce AFFF in the appropriate concentration of 6 percent. Therefore, in compartments where class B fires are expected, assign a value of ".95" to account for the possibility of a system malfunction in producing the correct concentration of agent. The concentration of $CO_2$ achieved with a portable extinguisher on a class C fire is a function of the size of the fire, the firefighting technique employed, and the quantity of extinguishers available. Therefore, in compartments where class C fires are expected, assign a value of ".90" to account for probable deficiencies in the applied concentration of $CO_2$.

16. Column 23: Subfactor “bme” - Probability Blackout Occurs. The probability of blackout primarily depends on three factors: quantity of agent (accounted for in column 19), concentration of agent (accounted for in column 20), and the size of the fire (estimated in column 6). The following guidelines are provided to assign probabilities to the “bme” subfactor for ships with normal duty section sizes:
    - In compartments where large-sized fires are expected, assign a value of “.65”.
    - In compartments where medium-sized fires are expected, assign a value of “.80”.
    - In compartments where small-sized fires are expected, assign a value of “.95”.

    On ships that have a reduced in-port duty section, rely on the local fire department and outside assistance from other ships that may be in port. This reduces the probability that blackout will occur compared with other ships. Therefore, the following guidelines are provided to assign probabilities to the bme subfactor for ships with reduced in port duty sections:
    - In compartments where large-sized fires are expected, assign a value of “.25”.
    - In compartments where medium-sized fires are expected, assign a value of “.50”.
    - In compartments where small-sized fires are expected, assign a value of “.90”.
17. Column 24: Factor “Me” - Fire Extinguishment is calculated in accordance with the following formula: Me=qme*cme*bme.
18. Column 25: Factor “M|EB” - The probability of Manual Fire Extinguishment before full room involvement given Established Burning has occurred is calculated in accordance with the following formula: M|EB=Mn*Mp*Ma*Me.
19. The spreadsheet will now show calculated values for M|EB. These values should be reviewed by comparing M-values for various CUIs and M-values for compartments within CUIs. The values typically range from “.05” for engineering spaces with short FRI times, high fuel loads, and significant probabilities of large class B spray fires to “.65” for Stairways, Passageways, and Sanitary Spaces with infinite FRI times, negligible fuel loads, and probabilities of small class A fires. If a set of M-values for a CUI or an individual compartment’s M-value seems inconsistent with other M-values, the engineer should revisit the probabilities assigned to the 12 individual factors and reassign more appropriate probabilities. This process should be repeated until the engineer is satisfied that the M-values are reasonable and consistent.
20. After SAFE has been run on the baseline data set, actual FRI times will be part of the output results. It is extremely important that these calculated FRI times be compared with the estimated FRI times and updated in column 4. The engineer should revisit and adjust as necessary the assigned probabilities for affected subfactors (primarily “sma” shown in column 17) and the size of the fire likely to be encountered by the fire party shown in column 6. The revised M|EB values should then be entered into SAFE as part of the baseline data set and the baseline results recalculated.

## References


1. Sprague, Chester M. & Dolph, Brian. Theoretical Basis of the Ship Fire Safety Engineering Methodology (Report No. CG-D-30-96, Final Report, September 1996).
2. Sprague, Chester M., White, Derek & Dolph, Brian. Fire Safety Analysis of the 180' WLB Seagoing Buoy Tender (Final Report, Pending Approval for Publication in the NTIS, July 1997).
3. Clouthier, Elizabeth, Rich, Doris & Romberg, Betty. Ship Applied Fire Engineering (SAFE) User Manual, Version 2.2, A Computer Model for the Implementation of The Ship Fire Safety Engineering Methodology (SFSEM) (Report No. CG-D-10-96, Final Report, March 1996).