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Memo Report

From: W. Mark Cummings, P.E.

To: Bill Hopkins; Archetype Architects

Subject: **Fire and Life Safety Evaluation of the Proposed Configuration of the Maine Wharf Museum in Portland, ME**

As requested, Fire Risk Management, Inc. (FRM) has performed an evaluation of the configuration for the museum that is planned as part of the renovation/construction activities for a newly renovated building located at the head (west end) of the Maine Wharf. This evaluation is intended to assess both the potential fire hazards that may exist within the museum spaces and the ability of its occupants to safely egress should a fire occur. The primary function of this evaluation is to assess whether or not it is feasible to allow the use of a new open stairway that is to be constructed as part of the museum's requirements near the east end of the facility and connects the 2nd and 3rd floor levels as part of the means of egress strategy for the Museum during a fire event. Specifically, this evaluation is being used to support a performance-based approach to life safety for the 2nd and 3rd floors of this building.

Background

An existing structure that is located on the Maine Wharf in Portland, ME is being completely renovated to accommodate new uses; including a restaurant and mercantile spaces on the 1st floor and, with the addition of two new stories, a museum that will occupy the 2nd and 3rd floor levels. With the inclusion of both the new restaurant on the 1st floor and the museum occupying the 2nd and 3rd floors, the building will mostly consist of Assembly occupancies; both Group A-2 (restaurant) and A-3 (museum). The existing structure would be classified as consisting of Type IIB construction. Although the building's structural components will continue to consist of Type II materials after the renovation, these structural components are to be protected by the application of fire rated materials, such that the building can then be classified as meeting the requirements for Type IIA construction. During discussions with the Architects, it was stated that they intend to classify the building as meeting at least a Type VA construction, since that too will still meet all requirements for this Assembly building, but will provide more flexibility in the selection of potential construction materials going forward.

Early in the planning and design development for the renovated building, the planned location for the exit stair enclosures was based on the requirements for the 1st floor restaurant, which was to maximize the area available for seating. To accomplish this, one stair enclosure was located near the west end of building and the 2nd stair enclosure was located at a point closer to the center portion of the building, albeit maintaining the requisite separation distance required by the codes, which allowed for a larger, undivided area at the east end of the facility to be used for restaurant seating. This planning occurred prior to knowledge of the desire to utilize the upper floors in supporting the new museum, which is also an Assembly occupancy that has greater restrictions on travel distances to the exits; including "common path of travel" restrictions.

Figure 1 is a general depiction of the proposed layout for the 2nd and 3rd floors of the Maine Wharf building to accommodate the Museum space requirements. As depicted in the figure,

there is a significant amount of assembly space that is to the east of the central stair tower. Also, the location of the open stairway in the southeast corner of the building is also shown.

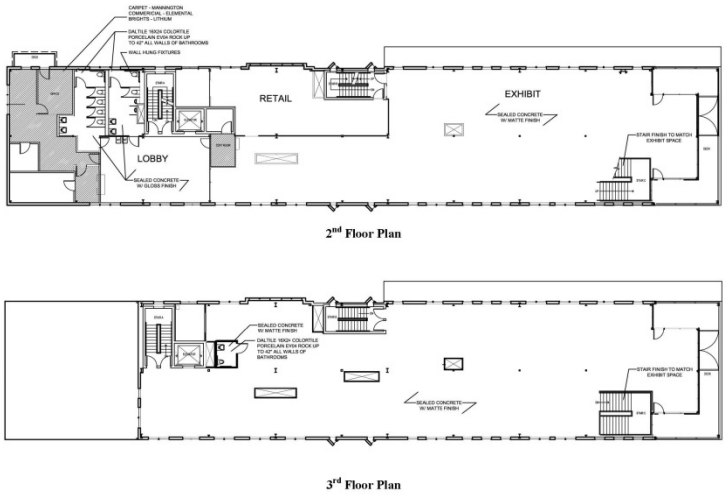

Figure 1 – Proposed Maine Wharf Museum Layout

In general, the overall construction plan for the building will meet the code requirements of both the building code (MUBEC) and the Life Safety Code®, NFPA 101, with two notable exceptions; the use of the open stairway connecting the 2nd and 3rd floor levels, and the common path of travel restrictions within the east end of the assembly areas on both floors. Per the requirements of NFPA 101, the open stairway would not be allowed to serve as part of the means of egress from either floor, even if it is designed to comply with all requirements for a "*convenience opening*"; as outlined in Section 8.6.8 of NFPA 101. Therefore, the travel distances from the east ends of the assembly areas on each floor will exceed the maximum allowed by the code for common path of travel; that distance a person must travel before having access to pathways to two separate exits. If the proposed stairway at the southeast corner of the building were enclosed by barriers having a 1-hour fire resistance rating, then this stair could be used as part of the means of egress and would allow both floor levels to comply with all egress travel distance restrictions. However, due to the manner in which the public is intended to "flow" when viewing the museum's various exhibits, enclosing this stairway represents a hardship for the museum's management and could jeopardize its decision to utilize this facility. As such, during a meeting with City and State officials, it was discussed that the use of a performance-based approach to life safety involving the use of this open stair would be acceptable if it is demonstrated that the risk to the life safety of the occupants would not be notably increased. Specifically, it must be demonstrated that all occupants will have sufficient time to egress during a fire event, prior to conditions deteriorating within the building that would prevent their safe egress.

Fire Hazards versus Egress Time

The primary prescriptive requirement outlined in NFPA 101 that is currently not being met by the originally proposed building configuration is the lack of a fire-rated enclosure for the stairway in the southeast corner of the building that connects the 2nd and 3rd floors. Even if used as part of the means of egress, this stairway would not be used as an exit enclosure, but simply as a means for exit access; similar to a corridor. Since the building is provided with sprinkler protection throughout and the maximum allowed total travel distance to an exit is not exceeded, if this stairway were treated as other means of egress access, it would not require any specific fire resistance rating. It is this fact, coupled with the relatively "open" nature of the assembly areas and the high ceiling heights on each floor level that form the basis for the potential opportunity to employ a performance-based approach for egress from the east end of the 2nd and 3rd floors.

The alternative life safety approach to having an enclosed stairway connecting the two floors is to demonstrate that safe egress from the east end of both floor levels can still be accomplished without the need for this stairway to be enclosed. This approach is validated by performing fire

hazards and egress analyses, which evaluate the time that may be available for safe egress during a fire event and compares this time to that which is needed for all occupants to safely egress reach an exit. If the former exceeds the later, then the building may be deemed as providing an adequate level of life safety.

To evaluate the impact of a fire on the environment within the museum areas, it is necessary that a "design fire" be developed that is considered representative of one that could occur in the area(s) under evaluation. The parameters of the design fire, such as heat release and smoke generation, along with the specific configuration of the building area(s) being evaluated are used as input to a computer fire model; in this instance, the Consolidated Fire and Smoke Transport (CFAST) model that was developed by the National Institute of Standards and Technology (NIST). This tool is used to evaluate the time it would take for the compartment (floor level) to become untenable when exposed to the effects of the design fire. The codes typically use the point at which it is predicted that the hot upper (smoke) layer descends to within six (6) feet of the floor as the metric for the point at which a compartment becomes untenable and safe egress is no longer possible. However, for this evaluation, two sets of metrics were initially used to assess the time at which safe egress is no longer deemed possible; one for each floor level:

1. For the 3rd floor level, the time for the smoke layer to reach 7 ft; which would generally be the time at which some would begin to enter a doorway if the upper portion of the stair was enclosed, and
2. For the 2nd floor level, the time for the smoke layer to descend below a smoke barrier/curtain/draft stop that is to be installed around the stair opening; installed below the 2nd floor ceiling.

Since the occupants of the 2nd floor must travel "upward" when using the stair for egress, once the smoke reaches a level that it could begin to "spill" into the stairway opening, it would then potentially subject occupants to travel through smoke. For that reason, the 2nd floor requirements for time to safe egress are different from those of the 3rd floor level.

To evaluate the time needed for occupants to safely egress the building, standard egress calculations provided in the Fire Protection Engineering Handbook[1] were used. These calculations are empirically-based, generated from data collected by researchers regarding the movement of people during a fire event. These calculations provide estimates for the time needed for all occupants to safely egress the areas under evaluation.

2nd Floor Assembly Area

As seen in Figure 1 above, the 2nd floor assembly space of the museum generally consists of one large, open space that will be populated by various exhibit cases, stands, and partitions on which some of the exhibits will be displayed. It is reported that the exhibits that are enclosed in glass cases, will be mounted on stands that are constructed of either metal or wood. The partitions that are to be installed will be constructed of wood and covered in a black cloth. Typically, plastic (PVC) panels are mounted on the partitions to display graphics or other types of signage. Figure 2 is representative of a typical floor

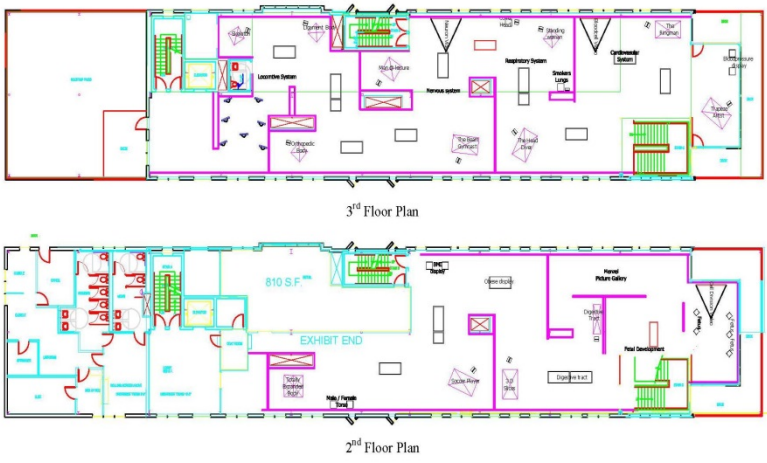

Figure 2 – Representative Museum Exhibition Floor Layout

[1] The SFPE Handbook of Fire Protection Engineering, 3rd Edition, Society of Fire Protection Engineers, Bethesda, MD., 2002

layout that would be expected for any given exhibition. As can be seen, the path of egress can become convoluted when transiting around the various partitions that may be added. Other than the electrical components used to provide lighting within the display cabinets or highlighting wall-mounted exhibits, there are very few potential sources of ignition.

It is likely that any plausible postulated fire scenario will involve the wood furnishings or possibly the PVC mounting boards that are used to display text and graphics. The fabric material that is used to cover the wood partitions consists of fire retardant material, tested to meet NFPA 701 requirements, but if subjected to sufficient energy, would be expected to support combustion. However, the overall mass of this material at any single location will be small and would not likely sustain a fire of any significant duration, but could act to provide a fire source to involve other materials, such as the wood or PVC. No other combustible materials exist in this area in any quantity that might support a fire of any size that might threaten the safety of the occupants. For this reason, the choice of the design fire used to evaluate the risk to life safety in this area of the church is based on a "fuel package" consisting of a solid wood structure. Using fire growth data obtained from fire research performed by the NIST, a design fire was developed to support the fire hazards analysis of the assembly areas, based on test data resulting from the burning of a standard (wood) wardrobe. These fire test data are considered representative of a fire involving wood products whereby vertical flame spread is possible; resulting in a faster growth rate. In this instance, the design fire achieves a maximum heat release rate of about 4.5 megawatts (MW) in less than three (3) minutes, which is considered to be plausible for the types and configurations of the combustible materials that will be present in the museum's exhibition area. Also, the heat of combustion (Δh_c) value for PVC is actually slightly less than that for wood (soft or hard), so the use of fire test data involving wood products continues to be realistic, if not conservative, for these materials as well. The primary difference in a fire involving plastics versus wood would be the actual byproducts of combustion; whereby plastics tend to produce/release more toxic chemicals. However, since the evaluation only considers any exposure to the smoke layer as being a "failure", the actual level of toxicity within the smoke layer is not relevant to the results of this evaluation.

For the hazards assessment of the museum floors, the design fire is estimated as occurring at a point near the eastern exit stair enclosure; thereby potentially isolating the greatest number of occupants from direct access to a stair enclosure and requiring that they use the open stair as their initial means of egress. Figure 3 depicts both the assumed fire location and the maximum travel distance that is used to support the analysis of egress from the 2nd floor level.

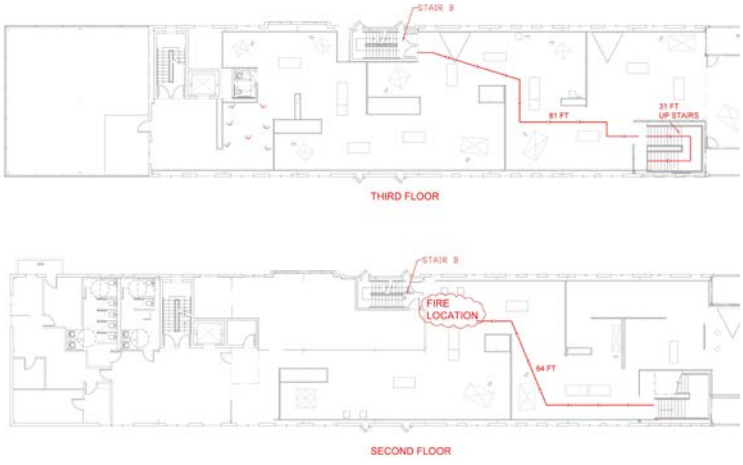

Figure 3 – 2nd Floor Egress Route

Discussions with the Museum's management indicated that the number of occupants that will be allowed within the exhibition area at any given time will be limited to prevent an "overloading" of the area and provide for a better "viewing environment" of the exhibits. However, since a specific number was not provided, the estimated occupant load used for this evaluation is based on the overall occupant load factor used during the code assessment for the overall building. Typically, occupant load factors provided in the Life Safety Code®, NFPA 101,

are used to develop occupant load estimates. However, NFPA does not provide an occupant load factor specific to museums; only for "concentrated" or "less concentrated" assembly spaces. The most recent edition of the International Building Code (IBC) does provide an occupant load factor that is specific to museums; 30 ft^2/person. Based on what has been described as the "typical" layout for the museum, the IBC value appears to be appropriate and was used when developing an overall maximum estimated occupant load for the building and its exit capacity requirements. Using this value, along with the area that is within the portion of the assembly space that is isolated from the exits by the fire, a maximum occupant load of 77 persons is estimated as being required to egress via the open stair during this fire scenario. When using the egress calculations/methods outlined in the SFPE Handbook, it is estimated that the last person will reach the top of the stairs within 90 seconds of fire notification. At that time, they are considered "isolated" from direct exposure to the smoke layer developing at the 2nd floor level. It is estimated that an additional 27 seconds would be needed for that same last individual to reach the 3rd floor exit; for a total egress time of 117 seconds.

During the initial fire evaluations it was assumed that the fire barrier installed below the 2nd floor ceiling to isolate the stair opening extended to a point within 7 ft. (2.1 m) of the 2nd floor level. When using the design fire scenario within the CFAST model, it is estimated that it would take more than 2 minutes (approx. 130 s) for the hot upper (smoke) layer to reach the point that is 7 feet above floor level and when it would then begin to "spill" into the stair opening. The building configuration used to support the model is a representation of the area (and volume) that would be available for smoke to collect within each of the two floors. That portion of the 2nd floor that is isolated from the assembly space by walls was not included in the model. Figure 4 provides a representation of the building configuration used by the model. As seen in Figure 4, the volume within the lower (2nd floor) is much smaller than that of the upper (3rd floor) level. This is due to much of the 2nd floor area being occupied by office, mercantile, and other areas that are separated from the assembly space. Also, there are two separate ceiling heights on the 3rd floor level, with the highest being that associated with the area below the "arched" roof. The ceiling height depicted in the model for the portion of the building that has the arched roof is a function of the "equivalent volume" for that portion of the ceiling area. The stairway is located in the southeast corner and is open to the 3rd floor above. Based on the drawings provided by Archetype at the outset of this evaluation, an enclosure is provided around the stairway at the 3rd floor level with an open doorway leading into the 3rd floor assembly space. Figure 5 is a depiction of the fire model results at 2 minutes; showing the depth of the hot upper layer at the 2nd floor level just prior to the smoke layer descending to the point that it enters the stairway opening.

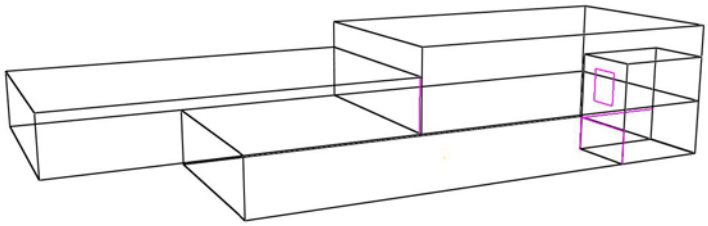

Figure 4 – CFAST Schematic of Museum floor Levels

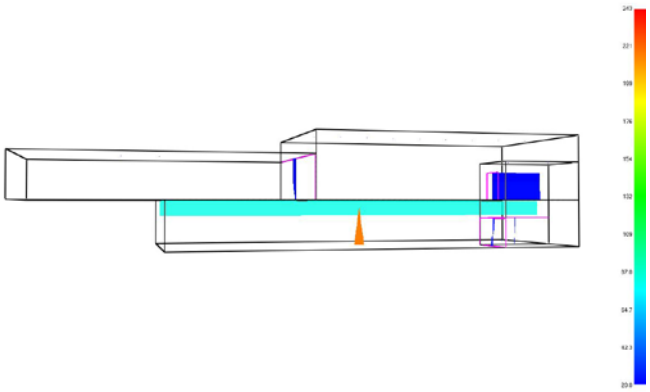

Figure 5 – CFAST Fire Simulation at 120 Seconds

3rd Floor Assembly Area

As outlined above, the height of the ceilings at the 3rd floor level are greater than that of the 2nd floor area. Additionally the total volume of the 3rd floor ceiling that is available for "smoke filling" is much greater than the 2nd floor; thereby providing a greater time before the hot smoke layer descends to a point that would prohibit safe egress from this floor. Figure 6 shows both the assumed fire location, which isolates the greatest number of occupants, and the route to be used by 3rd floor occupants that need to egress via the open stair to the exit located at the 2nd floor level. The occupant load estimated for the 3rd floor scenario is 76 persons. The egress analysis estimated that it would take approximately 91 seconds for all persons to exit the open stairway at the 2nd floor level and 118 seconds for the last person to reach the 2nd floor exit; values that are obviously similar to the 2nd floor fire scenario due to the similarities in floor configurations (egress routes) and occupant loads.

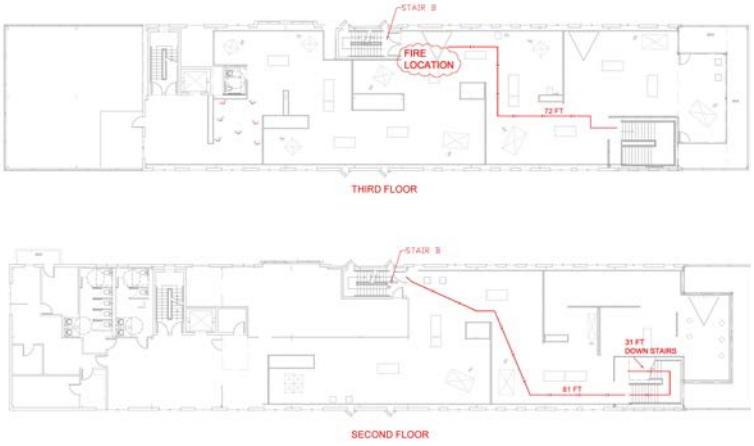

Figure 6 – 3rd Floor Egress Route

When applying the design fire to the 3rd floor egress scenario, the fire model estimates that it would take approximately 170 seconds for the smoke layer to reach a point 7 ft above the 3rd floor level; well after the time it is estimated that all occupants would left this floor level via the open stair. Figure 7 is a depiction of the fire model results, showing the smoke layer (using 3D depiction) prior to reaching the 7 foot level at which point it would have entered the 3rd floor stair enclosure doorway.

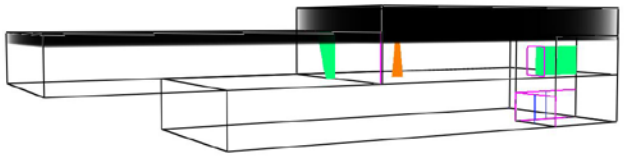

Figure 7 – CFAST Fire Simulation at 140 Seconds

Summary and Recommendations

The focus for this evaluation was to assess the ability to utilize an open stairway at the east end of the building that connects the 2nd and 3rd floors in support of safe egress during a fire event. The design fire that was used to support the fire modeling is believed to be relatively conservative, given the types and amounts of combustible materials (fuel loading) that will actually be present in the assembly areas of interest. Based on the results of the fire modeling, when compared to the estimated time that will be needed for all occupants within the assembly areas to safely egress, it appears that the use of the open stairway will not put occupants at undue risk.

The egress analyses indicate that the required safe egress time (RSET) from both floor levels is approximately 90 seconds. The fire model results indicate that the available safe egress time (ASET) is approximately 115 seconds for the 2nd floor assembly area and 140 seconds for the 3rd floor assembly area. These data are graphically presented in Figures 8 and 9 below. The RSET value for the 2nd floor assembly is based on having the smoke barrier/curtain/draft stop installed such that it extends downward below the 2nd floor ceiling to a height of 8 ft above the finished

floor level. At this depth, a margin of safety of approximately 25 seconds is provided to ensure that all occupants are at the 3rd floor level before smoke begins to move into the open stairway. Equally, the RSET value for the 3rd floor level is also based on the smoke layer reaching a height of 8 ft above floor level; a value 2 ft greater than what is typically used in an evaluation of this type to ensure occupant safety. Even at this level, a margin of safety of nearly 1 minute is provided for the ASET value; at 149 seconds.

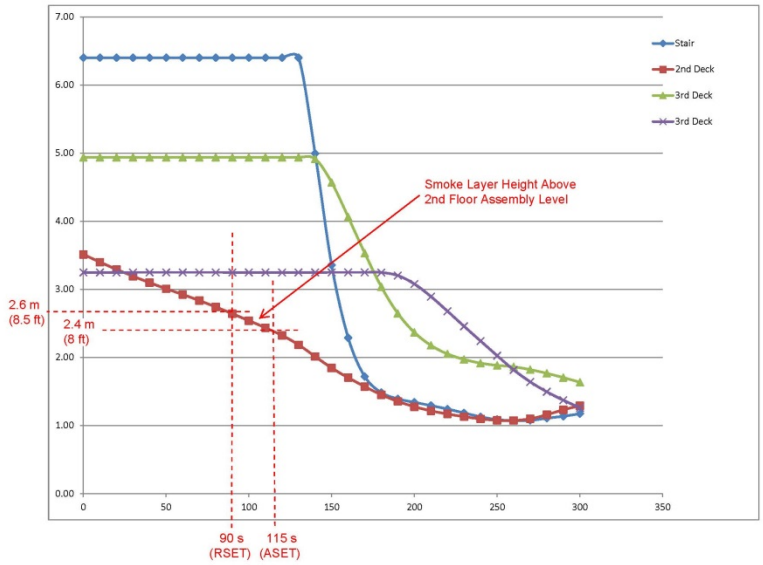

Figure 8 – 2nd Floor Fire Model Results

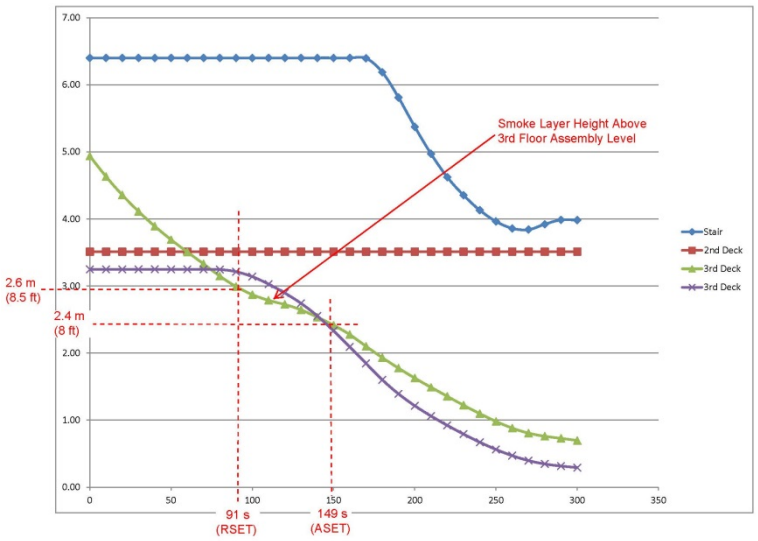

Figure 9 – 3rd Floor Fire Model Results

It is realized that the RSET value listed above is the time that it takes for occupants to safely exit the stairway on the alternate floor level and not the total time needed for all occupants to reach an exit, which is an additional 27 seconds. However, the reason for using the time to reach the alternate floor level as the RSET value is due to the fact that the time needed for the smoke level to then reach a level of 8 ft above the level of exit discharge is much longer. For example, as seen in Figure 8, the smoke layer would not reach a point 8 ft above the 3rd floor level until after

3 minutes had elapsed; and the smoke layer never descends below the 3rd floor level within the 5-minute duration of the fire simulation when the 2nd floor exit is used (Figure 9).

It should also be noted that these fire simulations do not take into account any impact on fire growth and/or duration that would be expected due to the operation of the installed fire sprinkler system. Using the design fire's heat release rate, while assuming an RTI value for standard 155°F sprinklers, the fire model estimated that a nearby sprinkler would operate within 80 s; a time slightly less than that needed for all (76 or 77) occupants to reach the alternate floor. As such, it would be expected that the available time to actually reach an exit would be even greater.

The portion of the assembly areas on each floor used to estimate the occupant load for this analysis represents roughly 50% of the overall exhibition area on each floor. Hence it would be anticipated that the maximum occupant load for each floor of the exhibition areas should be kept to no more than about 150 persons at any one time. It is realized that these exhibits will be viewed by the public on a "self-paced" basis, with some patrons taking more time to transit the entire exhibit (both floors) than others. Consideration should be given by the Museum's management to evaluate the average time it may take to view the entire exhibit and implement procedures to restrict the flow into the exhibit area to maintain occupant loading at or below this level at all times. This should provide additional assurance that should a fire event occur, all occupants will have sufficient time to safely egress.

Based on the review of the proposed building configuration, coupled with the smoke movement and egress analyses performed, the following recommendations are provided:

1. A smoke barrier/curtain/draft stop should be installed around the stair opening at the 2nd floor ceiling that extends to a minimum of 8 feet above the 2nd floor level. This barrier should be of non-combustible material.
2. Although used for this evaluation, based on drawings provided by Archetype Architects, the presence of the enclosure at the top of the stairway (3rd floor level) does not provide any benefit with regards to increased life safety. Unless there are other, non-fire or life safety related reasons for this enclosure, it could be removed from the building design without any impact on the level of life safety being provided.
3. Given that the premise for the egress analyses are based on early notification of occupants, it is recommended that additional smoke detection be provided within the assembly areas on both levels to ensure that early detection of a fire occurs and that occupants are quickly made aware of the hazard. Given the presence and height of the various temporary partitions that may be installed, visual indication for all occupants of a fire's presence could otherwise be delayed.

The assumptions used for both the fire and egress analyses were intended to provide results that are relatively conservative; representing conditions that are unlikely to occur. However, when making an evaluation of this type to support a more performance-based approach to a building's (or portion thereof) life safety is used, such conservatism is deemed appropriate. This is especially true when attempting account for the fact that this building will be used by people of all ages; from the very young to senior citizens, both of whom may require more time to egress than what is factored into the "standard" calculations.

If the above recommendations are implemented, it is believed that the Museum proposed for the Maine Wharf building can provide a more than adequate level of life safety, including the use of the open stair as part of the overall means of egress. If there are any questions regarding this evaluation, including any of the recommendations contained herein or if additional details are desired on any facet of the evaluation, please don't hesitate to contact me.

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Principal Engineer