Case Studies in Fire Safety 2 (2014) 9–15

Contents lists available at ScienceDirect

Case Studies in Fire Safety

journal homepage: www.elsevier.com/locate/csfs

Assessment of fire protection systems in proscenium theaters

Jaewook Kwon *

Ove Arup & Partners PC, New York, United States

ARTICLE INFO

Article history:
Received 29 October 2013
Received in revised form 30 June 2014
Accepted 1 July 2014
Available online 22 July 2014

Keywords:
Fire safety
Theater
CFD
Active fire protection systems

ABSTRACT

Stage fire protection measures, details differing from one region to another, have been established, codified and enforced throughout the world and have changed little over the past 100 years. Technological advancements in both stagecraft and fire protection systems have led to a need in the theater community to study the current state of theater fire protection requirements. The objective of the study was to assess the level of protection afforded by stage active fire protection measures, as prescribed by the International Building Code (IBC) (2009), NFPA 80 Standard for Fire Doors and Other Opening Protectives (2007) and as implemented in current design practice, in the event of a fire in the stagehouse of a proscenium theater. The study presented herein assesses the effectiveness of each of the fire protection systems required by building codes for proscenium type theaters. The egress study is not part of this study and thus not specifically carried out.

Computational fluid dynamics (CFD) has been utilized to examine fire conditions and to assess the effectiveness of the fire protection systems provided within a stage. The input data including representative theater dimensions, fuel loads, and fire scenarios have been determined by a survey of theater design professionals.

Introduction

Stage fire protection measures, details differing from one region to another, have been established, codified and enforced throughout the world and have changed little over the past 100 years. Technological advancements in both stagecraft and fire protection systems have led to a need in the theater community to study the current state of theater fire protection requirements. The objective of the study was to assess the level of protection afforded by stage active fire protection measures, as prescribed by the International Building Code (IBC) [1], NFPA 80 *Standard for Fire Doors and Other Opening Protectives* [2] and as implemented in current design practice, in the event of a fire in the stagehouse of a proscenium theater. This study consists of two parts. Part I identified (1) the magnitude of fire necessary to activate the automatic fire protection systems including rate-of-rise heat detectors, sprinklers, fire curtain, and roof vents and (2) the activation order of the fire protection systems, which was published through the Fire Protection Research Foundation (FPRF) [3]. Part II presented herein assesses the effectiveness of each of the fire protection systems required by building codes for proscenium type theaters. It is noted that although an egress analysis is not part of this study, it could be part of a fire engineering analysis for any new theater design in order to compare Available Safety Egress Time (ASET) to Required Safety Egress Time (RSET).

Computational fluid dynamics (CFD) has been utilized to examine fire conditions and to assess the effectiveness of the fire protection systems provided within a stage. The input data including representative theater dimensions, fuel loads, and fire scenarios have been determined by a survey of theater design professionals.

* Address: 77 Water St., NY 10005, United States. Tel.: +1 212 896 3263.
E-mail address: jaewook.kwon@arup.com

http://dx.doi.org/10.1016/j.csfs.2014.07.001
2214-398X/

The Fire Research Division at the National Institute of Standards and Technology (NIST) has been developing the CFD model, Fire Dynamic Simulator (FDS) [4] that has been optimized for use in simulating the effects of fire. FDS solves numerically a form of the Navier–Stokes equations for low speed, thermally driven flows. FDS V5.2.4 was utilized for this study.

Prescriptive code requirements

The following highlights the requirements in the International Building Code with regard to stage protection and stage ventilation as it is of primary concern to this study. The IBC is the most frequently referenced source for local municipality building codes in the U.S.

Proscenium wall opening protection

The requirements with regard to proscenium wall openings for stages with a height greater than 15.24 m are as follows:

- A fire curtain or water curtain is to be provided to contain smoke/fire within the stage. The fire curtain is required to be designed and installed to prevent a glow from a fire being visible to the audience.
- The curtain is required to be activated by rate-of-rise heat detectors operating at a temperature rise of 9–11 °C per minute and by manual operation.
- The curtain is to close the proscenium opening completely within 30 s from the operation of the release mechanism.
- Smoke developed rating for a fire curtain is to be 25 or less in accordance with ASTM E84 [5].
- No smoke and fire is to be spread through the curtain for 30 min tested in accordance with ASTM E119 [6].

Sprinklers

Sprinklers are required to be provided under a roof and a gridiron. If catwalks and galleries over the stage are more than 1.2 m in width, the sprinklers must be provided under all catwalks and galleries over the stage. It is noted that these requirements are not required for the stages in which the stage area is 93 m^2 or less, the stage height is 15.24 m or less, and curtains, scenery, or other combustible hangings are not retractable vertically.

Stage ventilation

The requirements with regard to stage ventilation for stages greater than 15.24 m in height or larger in area than 93 m^2 are as follows:

Natural means of exhaust

- Two or more roof vents are required to be provided;
- Aggregate clear area of the openings is to be no less than 5% of the stage area;
- Vents are required to be located near the center and above the highest part of the stage area;
- The vents are to be activated by heat-activated devices and by manual means.

Or,

Mechanical means of exhaust

- A mechanical exhaust system is to be activated by the operation of sprinkler system protecting the stage and manual means that are readily accessible to the fire department.
- A smoke layer must be maintained at greater than 1.83 m above the highest level of the seating or maintained above the top of the proscenium opening.

Fire modeling input

Geometry

It was decided that the models would need to be representative of theaters being built today, with currently mandated code requirements as the goal was to look at the performance of modern, current fire protection systems. For quality and relevant data, the assistance was provided from both American Society of Theater Consultants (ESTA) members and the theater consulting community through an online survey which gathered dimensional criteria for three theater models – small, medium and large – which is summarized in the table below. Thirty five responses were returned, the results compiled and averaged, and the data turned into plans and sections. Based on these, the geometry of the CFD models was built.