

NFPA 160

Standard for Flame Effects Before an Audience

2001 Edition



NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 160

Standard for

Flame Effects Before an Audience

2001 Edition

This edition of NFPA 160, *Standard for Flame Effects Before an Audience*, was prepared by the Technical Committee on Special Effects and acted on by the National Fire Protection Association, Inc., at its November Meeting held November 12–15, 2000, in Orlando, FL. It was issued by the Standards Council on January 13, 2001, with an effective date of February 9, 2001, and supersedes all previous editions.

This edition of NFPA 160 was approved as an American National Standard on February 9, 2001.

Origin and Development of NFPA 160

NFPA 160, *Standard for Flame Effects Before an Audience*, was developed by the Technical Committee on Special Effects, which was established in 1994, in response to a recognized need for a document to provide guidance to public safety officials, designers, and operators of flame effects. The purpose of this standard is to provide requirements for reasonable protection for viewing audiences and performers of flame effects.

For the 2001 edition, the Committee completed a partial revision of the standard. Revisions included amendments to standardized definitions, harmonization with the pyrotechnics special effects document, and editorial changes according to the *Manual of Style*.

Technical Committee on Special Effects

Henry W. Renfrew, Chair
Compliance and Response Mgmt., CT [SE]

Edgar C. Buckingham, Secretary
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Jose R. Colon, Connecticut Dept. of Public Safety, CT [E]
Rep. Int'l Fire Marshals Assoc.
John A. Conkling, American Pyrotechnics Assoc., MD [M]
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Stephen E. Daily, Anheuser-Busch Cos., MO [U]
Randall W. A. Davidson, Risk Int'l & Assoc., CA [SE]
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R. Scott Schaffner, RADCO, CA [RT]
Larry Schoeneman, Interesting Products, IL [SE]
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Tylor A. Wymer, Walt Disney World Entertainment, FL [U]
William J. Young, Plant Systems Inc., OH [M]
Rep. Nat'l Propane Gas Assn.

Alternates

Damon H. Andrew, Busch Entertainment Corp., MO [U]
(Alt. to S. E. Daily)
Gary R. Barnes, Universal Studios, FL [U]
(Alt. to J. G. Fuller)
Daniel Birket, Birket Engineering, Inc., FL [M]
(Alt. to G. A. Birket)
Douglas B. Dreager, D K Dreager Design Studio Inc., CA [M]
(Alt. to E. C. Buckingham)
Richard Gregson, Unreel Effects Inc., Canada [M]
(Alt. to J. W. Cammaert)
Bonnie J. Kosanke, Journal of Pyrotechnics, Inc., CO [SE]
(Alt. to K. L. Kosanke)
Larry J. McCune, U.S. Bureau of Alcohol, Tobacco & Firearms, DC [E]
(Alt. to D. S. Shatzer)
Robert B. Nicholson, III, Eastern Propane Corp., NJ [M]
(Alt. to W. J. Young)

Guy R. Colonna, NFPA Staff Liaison

G. Clark Parkhurst, Jr., Bristol, CT [IM]
(Alt. to R. C. Huggins)
David J. Pier, MP Assoc., Inc., CA [M]
(Alt. to T. Morris)
Karl G. Ruling, Entertainment Services & Technology Assn., NY [SE]
(Alt. to L. Schoeneman)
Patrick Seeley, Harris Production Services, NV [U]
(Alt. to J. Harris)
Lawrence Weinman, Luna Tech, Inc., AL [M]
(Alt. to T. DeWille)
Michael L. Zieman, RADCO, CA [RT]
(Alt. to R. S. Schaffner)
Anthony C. Mirabella, Connecticut Natural Gas Corp., CT [M]
Rep. American Gas Assoc.
(Voting Alternate)

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the controlled use of flame, pyrotechnics, or other means of special effects for entertainment, exhibition, demonstration, or simulation before a proximate audience; and the design, fabrication, installation, testing, control, operation, and maintenance of user equipment, fuel storage, and sources for special effects before a proximate audience.

This Committee does not have responsibility for documents on hazards other than those involving a proximate audience and the life safety considerations of the audience.

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

Information on referenced publications can be found in Appendix C.

Chapter 1 General

1.1* Scope. This standard shall provide requirements for the protection of property, operators, performers, support personnel, and the viewing audiences where flame effects are used indoors or outdoors. The purpose of this standard shall be to provide minimum requirements to the operators and manufacturers for the safe operation of flame effects.

1.1.1* This standard shall apply to flame effects for entertainment, exhibition, demonstration, or simulation before an audience, including their design, fabrication, installation, testing, control, operation, and maintenance.

1.1.2 This standard shall apply to the following:

- (1) Use of indoor and outdoor flame effects before an audience (*see 1.4.8, Flame Effect*)
- (2) Design, fabrication, installation, testing, control, operation, and maintenance of equipment, materials, procedures, and systems used to produce flame effects
- (3) Rehearsal, videotaping, audiotaping, or filming of any television, radio, or movie production if such production is before an audience and includes the use of flame effects
- (4) Rehearsal of any production incorporating flame effects before an audience

1.1.3 This standard shall not apply to the following:

- (1) Flame effects produced solely by pyrotechnic special effects devices
- (2)* Use of pyrotechnic special effects
- (3)* Storage of flammable solids, liquids, and gases
- (4) Manufacture, off-site storage, and transportation of materials and equipment used to produce flame effects
- (5) Use of flame effects in fire training

Exception: Where there is an audience that is not part of the training, this standard shall apply.

- (6)* Manufacture, transportation, storage, sale, or use of model or high-power rocket motors
- (7) Traditional nontheatrical public display of flames such as the following:
 - a. Use of lighted candles in restaurants or religious services
 - b. Fireplaces in areas open to the public
 - c. Restaurant cooking visible to the patrons

- d. Listed Group II flame effects
- (8) Use of consumer fireworks by the public
- (9) Use of motor vehicles in races or sanctioned competitive sporting events

1.2 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard. Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency. The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.3 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.4 Definitions.

1.4.1 Accumulator. A container or piping that holds a predetermined volume of fuel that is ready for use in a flame effect.

1.4.2 Accumulator Charge Valve. A valve used to control the flow of fuel into an accumulator.

1.4.3* Approved. Acceptable to the authority having jurisdiction.

1.4.4* Authority Having Jurisdiction. The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

1.4.5 Direct Ignition. An automatic or manual ignition system that ignites fuel without a pilot.

1.4.6 Effect Valve. The last fuel shutoff valve before the flame effect burner.

1.4.7 Fail-Safe. A state or an attribute of a system such that every single point failure in the system results in all controlling parts of the system with the ability to do harm to humans, animals, or equipment being disconnected from all sources of power and stored energy at the primary disconnect point.

1.4.8 Flame Effect. The combustion of flammable solids, liquids, or gases to produce thermal, physical, visual, or audible phenomena before an audience.

1.4.9 Flame Effect Assistant. A person who works under the supervision of the flame effect operator.

1.4.10 Flame Effect Burner. A burner designed to produce specific sizes and configurations of flames for flame effects.

1.4.11 Flame Effect Operator. The single person with overall responsibility for flame effect operations and safety.

1.4.12* Flame Effect Systems, Classifications.

1.4.12.1 Group I Flame Effect. An attended, manually controlled flame effect.

1.4.12.2 Group II Flame Effect. An individual or group flame effect designed for unattended operation that is temporarily or permanently installed outside any structure.

1.4.12.3 Group III Flame Effect. An attended, temporarily installed flame effect for a specific production with limited operation and fixed time for removal.

1.4.12.4 Group IV Flame Effect. A large individual or group flame effect that is permanently installed inside or outside any structure designed for unattended operation without a main show supervisory control system.

1.4.12.5 Group V Flame Effect. A large individual or group flame effect that is temporarily or permanently installed inside or outside any structure and is designed for intermittent or continuous operation under the supervision of a main show control system but without full-time supervision by a technician.

1.4.12.6 Group VI Flame Effect. A large individual or group flame effect that is temporarily or permanently installed inside or outside any structure and is designed for intermittent operation under the supervision of a main show control system and a technical director, with cast members in close proximity to the effect at the time of operation.

1.4.12.7 Group VII Flame Effect. An individual flame effect that can be temporarily or permanently installed inside or outside any structure that, due to its unique operating requirements, does not fit into any other classification.

1.4.13 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

1.4.14* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets identified standards or has been tested and found suitable for a specified purpose.

1.4.15* Primary Safety Control. A control with a sensor that is directly responsive to the ignition device attributes necessary for the safe operation of the effect.

1.4.16 Proof-of-Closure Valve. A safety shutoff valve equipped with an interlock switch that is actuated only when the valve is fully closed.

1.4.17 Proven Pilot. A pilot flame supervised by a primary safety control.

1.4.18* Safety Shutdown (Lockout). The safe shutdown of the flame effect in the event of the actuation of any flame effect primary safety control or limit switch.

1.4.19 Safety Shutoff Valve. A listed, fast-closing valve that automatically and completely shuts off the fuel supply in response to a normal or safety shutdown.

1.4.20 Shall. Indicates a mandatory requirement.

1.4.21 Supervisory Cock. A listed, manually actuated valve with two double-pole, double-throw switches that prove the valve position.

1.4.22 Vent Valve. A listed, normally open, power-closed valve, normally located between the two safety shutoff valves.

Chapter 2 Storage of Flame Effect Materials and Devices

2.1* General. All flame effect materials and devices not connected for use shall be stored in accordance with applicable codes and standards and any state and local regulations.

2.2 Holding Areas. All flammable flame effect materials and loaded devices that have been removed from storage areas in anticipation of use shall be stored in a holding area acceptable to the authority having jurisdiction.

2.2.1 The maximum quantity of flammable flame effect materials and loaded devices stored in a holding area shall be that quantity used in one day.

Exception: Quantities in excess of those used in one day shall be permitted to be stored in holding areas with the approval of the authority having jurisdiction.

2.2.2 Flammable flame effect materials and loaded devices in holding areas shall be secured or supervised continuously by an attendant trained in emergency response procedures.

Chapter 3 Approval Requirements

3.1 Approval Requirements. The use of all flame effect materials or devices shall be approved.

3.2 Flame Effect Plan. A plan for the use of flame effects shall be approved by the authority having jurisdiction.

3.2.1 After a plan has been approved, the plan shall be maintained to be readily available at the site for inspection.

3.2.2* If any addition or modification of flame effects to that described in the approved plan is made, that addition or modification shall be approved by the authority having jurisdiction.

3.3* Content of Plans.

3.3.1 The plan for the use of flame effects shall be submitted in writing or other form acceptable to the authority having jurisdiction. The plan shall include the following:

- (1) The name of the person, group, or organization responsible for the production
- (2) The dates and times of the production
- (3) The location of the production
- (4) The design criteria in Appendix B
- (5) The flame effect classification
- (6) A site plan showing the following:
 - a. A narrative description of the flame effect
 - b. The location of flame effect devices to be fired and their controls and control sequence
 - c. The area affected by the flame effect device
 - d. The location of the audience
 - e. The fuels used and their estimated consumption
 - f. Air for combustion and ventilation for indoor effects
 - g. Flammable materials piping
 - h. Storage and holding areas and their capacities

- i. Supplemental fire protection features
- j. Emergency response procedures
- k. Means of egress
- (7) A current material safety data sheet (MSDS) for the materials (fuels) consumed in the flame effect
- (8) Documentation that the combustible materials used for construction of the flame effects have been rendered flame retardant
- (9) The name of the effect operator

3.3.2 Operating instructions shall be available to the authority having jurisdiction when flame effects are in use.

3.4 Flame Effect Demonstration. When required, a walk-through and a representative demonstration of the flame effects shall be provided to the authority having jurisdiction before flame effects are approved. The demonstration shall be scheduled with sufficient time to allow resetting of the flame effects prior to the arrival of the audience.

3.5 Interruption of Fire Protection and Life Safety Systems During Flame Effect Demonstrations and Operations. Fire protection and life safety systems shall not be permitted to be interrupted during the operation of flame effects.

Exception No. 1: Portions of fire protection and life safety systems shall be permitted to be interrupted during the operation of temporary indoor flame effects when the following conditions are met:

- (a) Approval of the authority having jurisdiction is received.
 - (b) Approval of the owner or owner's agent is received.
 - (c)* An approved fire watch capable of directing the operation of all fire protection and life safety systems installed in the building is present.
- Exception No. 2: Fire protection and life safety systems shall be permitted to be interrupted during the operation of permanently installed indoor flame effects only for initial acceptance of the system.*

Chapter 4 Documentation of Flame Effects

4.1 General. All flame effect devices and materials shall have drawings, manuals, or written descriptions to describe the type of item and performance specification of the flame effect created. This documentation shall be on site and available to the authority having jurisdiction.

4.2 Operating Procedures. All flame effects shall have written operating instructions including startup, show operations, normal shutdown procedures, and emergency shutdown procedures. Operating instructions shall be readily available to the operator.

Chapter 5 Use of Flame Effects

5.1* Testing and Evaluation. Flame effects shall be tested to verify that they operate in accordance with their designs. Flame effects shall be evaluated to verify that operators, performers, and the audience are not exposed to a hazardous situation when the flame effects are activated as designed or anticipated.

5.2 Housekeeping. The premises where flame effect devices are installed or fired shall be maintained in a neat and orderly condition.

5.3 Site Inspection. The flame effect operator shall inspect all areas of the site where flame effect materials and devices are ignited before startup and after shutdown.

5.4 Smoking. Smoking shall be prohibited in the area where fuels used in flame effects are present.

Exception: Smoking by performers as part of the performance shall be permitted where approved by the authority having jurisdiction.

5.5 Rehearsal and Pre-Show Operations. The flame effect operator shall advise all performers and support personnel that they are exposed to a potentially hazardous situation when performing or otherwise carrying out their responsibilities in the vicinity of a flame effect. Performers and support personnel familiar and experienced with the flame effects being used shall be permitted to be in the area of a flame effect, but only voluntarily and in the performance of their duties.

5.6 Show Operations. Show operations shall be in accordance with the plan approved by the authority having jurisdiction.

5.7 Post-Show Operations. Post-show operations shall be in accordance with the plan approved by the authority having jurisdiction.

5.7.1 Fire and life safety systems that have been interrupted shall be restored immediately after completion of the flame effect.

5.7.2 When restoration of fire and life safety systems is necessary, it shall be conducted by a person trained in the operation of all aspects of the systems.

5.8 Maintenance. Flame effect systems shall be maintained to design specifications.

5.9 Emergency Operations. Emergency operations shall be in accordance with the plan approved by the authority having jurisdiction.

5.10 Protective Clothing. The flame effect performers, operators, and assistants shall be protected by clothing or other means suitable for their exposure to flame effects. Protective clothing requiring fire resistance shall be tested and demonstrated to be flame retardant, and documentation shall be furnished to the authority having jurisdiction upon request.

5.11 Security.

5.11.1 A means shall be provided to render installed flame effect systems inoperative when not in use.

5.11.2 Portable flame effects shall be stored and secured when not in use.

Chapter 6 Flame Effect Operator

6.1* Operator Qualifications. The operator of any flame effect shall understand and be familiar with the operating manual or instructions. The operator shall demonstrate competency by experience and training or by holding a license acceptable to the authority having jurisdiction.

6.2 Operator Responsibilities. The flame effect operator shall be responsible for storage, setup, operations, and tear-down of all flame effect materials, devices, equipment, systems, and supervision of assistants.

6.3 Substance Abuse and Safety. No person shall use or handle flame effect materials or devices under the influence of the following:

- (1) Intoxicating beverages
- (2) Narcotics or controlled substances
- (3) Prescription drugs or nonprescription drugs that can impair judgment

6.4* Minimum Age. All flame effect operators shall be at least 21 years of age.

Chapter 7 System Components, Flame Effect Control Systems, and Design

7.1 General Requirements for Flame Effect Control System Design.

7.1.1 All flame effect control systems shall be designed and installed to prevent accidental firing and unintentional release of fuel.

7.1.2 All flame effect control systems shall be designed to implement the following functions:

- (1) Emergency stop capability

- (2) Fuel management
- (3) Controlled enabling of flame effect
- (4) Controlled arming of flame effect
- (5) Controlled and repeatable firing of flame effect

The flame effect plan submitted for approval to the authority having jurisdiction shall indicate the means of providing for these requirements.

7.1.3 Flame effect control system components shall be listed.

Exception: Where listed devices are not available, approved devices shall be permitted.

7.1.4 Location and Accessibility of Control Systems. Control system components and protective devices, including sensors, valves, and switches, shall be located so that they are protected against physical damage and tampering, and so they can be serviced and maintained.

7.2* Specific Requirements for Flame Effect Control System Design and Operation, by Group. Control systems for each flame effect group shall be in accordance with Table 7.2.

Table 7.2 Group Control Functions Required

Flame Effect Group	Control Type	Minimum Control Requirements
I	Manual controls	1. No automatic controls shall be required.
II	Automatic controls	1. Ignition supervision shall be provided.
III	Automatic controls	2. Automatic shutoff shall follow failure.
		1. Manual operation of the effect valve shall be permitted.
		2. If the operator cannot confirm the pilot or direct ignition source for the flame special effect, a primary safety control shall be installed.
		3. Two fuel shutoff valves shall be provided, installed in series, one of which will be a safety shutoff valve.
IV	Automatic controls	1. Primary limit device(s) shall be installed as required.
		2. A fuel supervisory station shall be installed with fuel pressure limit switches to control the supervisory station valves.
		3. Each flame effect burner shall be equipped with a primary safety control and an effect valve.
		4. A flame effect safety control system that is capable of safely operating the entire flame effect consistently for repeated cycles shall be used.
V	Automatic controls	1. The requirements for Group IV shall apply.
		2. A flame effect safety control system that is capable of safely operating the entire flame effect consistently that is sequenced by the main control system shall be used. The flame effect safety control system shall maintain all of its internal safety features, with the interface between the flame effect control system and the main show control system limited to those commands and status indicators that cannot alter or override the flame supervisory system control logic.
VI	Automatic controls	1. The requirements for Group V shall apply.
		2. Where cast members are in close proximity to the flame effect, the flame effect shall be under the active control of a main show control system and a fail-safe positive manual enable.
VII	Manual or automatic controls	1. Controls shall be as recommended by the designer and acceptable to the authority having jurisdiction.

7.3 Implementation of the Required Control Functions.

7.3.1* Emergency Stop. Flame effects shall not be operated without either an approved plan or a supervisory control system for the emergency stop and complete shutdown of the flame effect and any interrelated safety-critical system.

Interrelated safety-critical system and flame effect control system safety considerations shall extend to safety-critical effects, allied equipment and other proximate equipment to avoid additional or contributory hazards. Where such hazards exist, the effects safety controller shall have a direct validated means of confirming the status or other information from the other systems before the safety-critical effect is enabled or triggered.

7.3.1.1 Manually controlled flame effects (Group I and manually controlled Group VII) shall have a plan for the emergency stop and complete shutdown of the operation of the effects through one or more of the following:

- (1) Manual fuel shutoff valve(s)
- (2) Manual turn-off of control power
- (3) Fire containment devices
- (4) Other devices acceptable to the authority having jurisdiction

7.3.1.2 Automatically controlled flame effects (Group II through Group VI and automatically controlled Group VII) shall have provisions for the emergency stop and complete shutdown of the operation of the effects installed according to the following criteria:

- (1) The flame effect control system shall not be capable of operation unless the emergency stop is reset.
- (2) The actuation of the emergency stop shall bring the flame effect control system to a safe state.
- (3) The emergency stop shall be designed so that it must be reset manually.
- (4) The emergency stop shall actuate both manually and automatically upon the detection of an unsafe condition, including power failure.
- (5) The emergency stop shall be fail-safe.
- (6)* The emergency stop shall be automatically actuated when a monitored condition exceeds a preset limit of operation.

7.3.1.3 Manually operated emergency stop control stations shall be clearly identified and placed in accessible locations, and they shall be designed to maintain the actuated state until manually reset. Operation of a manual emergency stop station shall actuate the emergency stop.

7.3.2 Fuel Management.

7.3.2.1 The fuel supply for the operation of the flame effect shall be only available during operation.

7.3.2.2 Fuels not provided through a central distribution system, and that are supplied to the flame effect shall be limited to that amount necessary for operation.

7.3.2.3 Fuels delivered through a central distribution system shall be in accordance with the following:

(a) A manual fuel shutoff valve shall be installed in an accessible location at the point of delivery and upstream of any other flame effect control system components, which, when closed, will shut off all fuel supplied to the flame effect control system. Where the point of delivery is outside a building con-

taining the flame effect control system, the valve shall be located outside of the building.

(b) Where low fuel pressure could cause the flame effect control system to malfunction, devices to provide low-pressure supervision shall be installed. Where high fuel pressure could cause the flame system to malfunction, devices to provide high-fuel-pressure supervision shall be installed.

(c)* A supervisor station shall be installed downstream of the manual fuel shutoff valve. This station shuts all fuel supplied to the flame effect control system when closed. When opened during the enable process, this station shall be held open by a maintained signal from the flame effect control system.

The supervisor station shall be provided with a means to test the seat-tightness of the valve at the operating pressure.

7.3.2.4 Effect Valve. Each flame effect shall be provided with an automatic fuel shutoff valve (the effect valve), installed upstream of the burner. This valve shall shut all fuel to the burner when closed. It shall be opened only at the time of firing the flame effect and shall be held open by a maintained signal from the flame effect control system. This valve shall automatically close on loss of the hold-open signal.

7.3.2.5* Systems Using Fuel Accumulator. Fuel accumulators used in flame effect control systems shall meet the following requirements:

(a) Accumulator tanks shall be designed, manufactured, and certified as unfired pressure vessels.

(b) The volume of fuel stored in an accumulator tank shall be no more than what is required to produce the desired flame effect.

(c) Each accumulator shall have a manual fuel shutoff valve at the connection to the inlet of the tank. When closed, this valve shall shut off all fuel supplied to the accumulator tank.

(d) An accumulator charge valve shall be installed at the connection to the inlet of the tank. This valve is opened to charge the accumulator. The accumulator shall be charged as close to the time of the actual arming and firing of the effect as is practical.

(e) The outlet of the accumulator shall be piped to the effect valve.

(f) Each accumulator installation shall permit the venting of fuel.

(g) The mixing of air or any other oxidizing media with fuel in an accumulator tank shall be prohibited.

7.3.3* Controlled Enabling of Flame Effect Control System. All flame effect control systems shall be manually or automatically enabled according to a prescribed sequence of operations outlined in the plan, which prepares the flame effect for subsequent arming and firing.

7.3.3.1 A flame effect safety controller shall be used to automatically sequence the enable process, monitor areas of restricted access, and allow, trigger, and request safety-critical action. Flame effect control system safety considerations shall extend to other safety-critical effects, allied equipment, and other proximate equipment to avoid additional or contributory hazards. In such circumstances, the effect safety controller shall have a direct validated means of confirming the status or other information from the other systems before the safety-critical effect is enabled or triggered.

7.3.3.2* The enable process shall begin with the activation of the control power to the flame effect control system.

7.3.3.3 Fuel Supply and Auxiliary Services. Following the activation of the control power, the fuel supply and auxiliary services necessary to the operation of the flame effect control system (compressed air supply, oxidizers, additives, etc.) shall be permitted to be turned on. Positive confirmation through the use of an interlock or other device of the fuel supply and each auxiliary service shall be made prior to the continuation of the enable process.

7.3.3.4* Interlocks. Interlocks shall be provided in the control system to monitor changes of condition and to automatically implement control system responses to the change of state. Safety interlocks shall be fail-safe.

7.3.4 Controlled Arming of Effect. All flame effects shall be manually or automatically armed prior to any attempt to fire. The arming of the effect shall be manually or automatically monitored and confirmed until the effect is fired.

7.3.4.1 Manual Confirmation of Arming (Group I and Manually Controlled Group VII). The flame effect shall be confirmed as armed when the means of ignition can be clearly and directly seen by the person who is actually firing the flame effect for the entire time that the effect is enabled. When the means of ignition cannot be clearly and directly seen by the person who is actually firing the flame effect for the entire time that the effect is enabled, the confirmation of the arming of that effect shall be done automatically.

7.3.4.2* Automatic Confirmation of Arming (Group II through Group VI and Automatically Controlled Group VII). The flame effect shall be confirmed as armed when a sensor(s) has detected the presence of the means of ignition necessary for the correct operation of the effect through the monitoring of a characteristic unique to the means of ignition.

7.3.4.3 Control sensors and devices used to verify the arming of flame effects shall monitor the operating characteristics of the effect. They shall be designed to operate reliably for the environment in which the effect operates.

7.3.4.4 Where cast members or moving set pieces are present in the hazard area immediately before or after the arming and firing of the flame effect, a positive manual enable shall be required during arming and firing.

7.3.4.5 It shall not be possible for an ignition detection device to report the presence of an ignition device or pilot, due to false sensing of ignition devices, pilots, or flame effects other than that ignition device or pilot intended to be sensed by the ignition detection device. It also shall not be possible for an ignition detection device to report the presence of an ignition device or pilot due to false sensing of other non-fire-related devices normally present in the local environment including, but not limited to, spark effects, ultraviolet light sources, or effects that generate heat without flame.

7.3.5* Firing of Flame Effects. Flame effects shall only be fired after they have been confirmed as armed following the completion of the enable and arming process and confirmation that the hazard area is clear. If the arming confirmation is lost during the firing process or the hazard area becomes unsafe, the firing of the effect shall be immediately terminated and the effect secured until the problem has been corrected.

7.3.5.1* Monitoring of the Hazard Area Surrounding the Flame Effect. That area surrounding each flame effect that is made hazardous by the operation of the effect shall be monitored and confirmed clear and ready for firing, or access to

the area shall be supervised by automatic means, or the area shall be made inaccessible, prior to any attempt to fire the effect. Other parameters critical to the safety of the flame effect shall also be monitored or supervised.

7.3.5.2* Supervision of the Hazard Area Surrounding the Flame Effect. The accessible hazard area shall be under the direct observation of the person who is actually firing the flame effect for the entire time that the effect is enabled and fired. Where the hazard area cannot be seen by the person who is actually firing the flame effect for the entire time that the effect is enabled, an alternative means of monitoring the area shall be permitted to be used, with the approval of the authority having jurisdiction.

If all areas of safety concern cannot be seen by a single human operator, as many enable buttons shall be used as are necessary to ensure complete safety. Such buttons shall be monitored separately and verified for proper operation by the flame effect control system.

7.3.5.3 Firing. The design of the flame effect control system shall prevent the firing of any flame effect except on the deliberate positive action of a qualified operator or the verification by the automatic control system of correct enabling and arming of the effect.

(a) *Manual Firing of Flame Effects.* It shall be the responsibility of the qualified operator to verify the correct enabling and arming and the safety of the hazard area prior to the manual firing of the effect.

(b) *Automatic Firing of Flame Effects.* The operating power for firing any flame effect shall originate from the flame effect control system and only be supplied under the supervision of all limits, interlocks, and ignition-monitoring devices present for the safe and reliable operation of the flame effect. All effect valves shall be permitted to be opened only by a maintained firing signal from the flame effect control system and shall automatically close on loss of signal.

7.3.6 Post-Operation Securing. Immediately following the firing of any flame effect, the enable and arming signals shall be removed, all fuel and auxiliary services shall be secured without going through the above-specified sequence of operation, and a visual inspection of all effect hazard areas shall be completed prior to confirmation that the flame effect control system is secure.

Chapter 8 System Installation and Testing

8.1 General. Flame effects shall be tested to verify that they operate in accordance with the design. Documentation of the testing shall be provided by the manufacturer or fabricator.

8.2 Pressure Testing. Flame effect piping systems shall be pressure tested in accordance with the code under which they were fabricated.

8.3 Leak Testing.

8.3.1 The complete piping system with all accessories in place shall be leak tested at the system operating pressure.

8.3.2 System pressures shall be recorded together with the temperature and atmospheric pressure. Test duration shall be not less than $\frac{1}{2}$ hour for each 500 ft³ (14 m³) of pipe volume or fraction thereof. When testing a system having a volume less than 10 ft³ (0.28 m³), the test duration shall be permitted to

be reduced to 10 minutes. For piping systems having a volume of more than 24,000 ft³ (680 m³), the duration of the test shall not be required to exceed 24 hours.

Exception: Leak testing of reassembled flame effect control systems designed to be separated into subassemblies shall be permitted to be tested at system operating pressure with leak detection using a noncorrosive leak detecting solution, or other means acceptable to the authority having jurisdiction, at the reconnected joints.

8.4 Temperatures of Components.

8.4.1 Temperatures of components that are used in the fabrication of a flame effect control system shall not exceed the rated temperature limits of the component during sustained operation of the flame effect.

8.4.2 Temperatures of components subject to the heat of the flame effect shall be determined while the flame effect is being operated at its maximum design cycle rate during the acceptance test required by Section 8.1. The temperatures shall be observed until a maximum or stable reading has been attained. The temperatures attained shall not exceed the rated temperature for the components.

8.4.3 Temperatures of Surroundings. Temperatures of combustible materials subject to the heat of the flame effect shall not exceed 117°F (47.2°C) above the ambient temperature after equilibrium temperatures are attained. The temperatures shall be observed until a maximum or stable reading has been attained.

Chapter 9 Fire Protection Provisions

9.1 General. The wide range in size, arrangement, and location of flame effects covered by this standard shall preclude the inclusion of detailed fire protection provisions that are applicable to all flame effects. The provisions of this chapter shall be subject to verification or modification through analysis of local conditions.

9.2 Fire Hazards Analysis.

9.2.1* A fire analysis shall be conducted on flame effects. This analysis shall be coordinated with the building owner, flame effect operator, and the authority having jurisdiction.

Exception: Where waived by the authority having jurisdiction.

9.2.2* Where the fire hazards analysis determines a need for fixed or supplemental fire protection equipment or standby fire safety personnel, such equipment or personnel shall be provided.

9.3 Standby Fire Safety Personnel Requirements.

9.3.1 Where required, standby fire safety personnel shall be positioned in accordance with the fire safety analysis along with operational supplemental equipment.

9.3.2 Standby fire safety personnel shall have a working knowledge of the supplemental fixed or portable fire-fighting equipment used in the area of the flame effects.

9.3.3 Standby fire safety personnel shall have a means of communication or of transmitting an alarm during the operation of flame effects.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1 This document details how to control the use of flame effects. The issue of permitting or prohibiting the use of open flames before an audience is in the scope of a code, such as NFPA 101®, *Life Safety Code*®. The *Life Safety Code* has traditionally prohibited open flames within assembly occupancies.

A.1.1.1 The circumstances of each show or attraction can be unique and can require individual evaluation when determining the need for protective systems. Factors such as the experience and qualifications of the operations and maintenance personnel, clearance distance between show elements and nonparticipants, visual conditions, and magnitude of the potential hazards are to be weighed in the development and presentation of the production.

A.1.1.3(2) For information on the use of pyrotechnic special effects before an audience, see NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*.

A.1.1.3(3) For information on the storage of flammable and combustible liquids, see NFPA 30, *Flammable and Combustible Liquids Code*.

For information on the storage of flammable gases, see NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*, and NFPA 58, *Liquefied Petroleum Gas Code*.

A.1.1.3(6) For information on the manufacture, transportation, or storage of model or high-power rocket motors, see NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

For information on the sale or use of model or high-power rocket motors, see NFPA 1122, *Code for Model Rocketry*, and NFPA 1127, *Code for High Power Rocketry*.

A.1.4.3 Approved. NFPA does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.1.4.4 Authority Having Jurisdiction. The phrase “authority having jurisdiction” is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property

owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.1.4.12 Examples of flame effects are as follows:

- (1) *Group I.* Hand-held burning torches, cigarette lighters, candles, matches, and lighting paper in an ashtray.
- (2) *Group II.* Unattended torches, burning urns, and small fires.
- (3) *Group III.* Effects used by traveling shows and concerts and effects used for limited-duration special events, such as the Olympics.
- (4) *Group IV.* A burning cabin or bonfire and large single or multiple flaming brazier entrance features used to create a “theme” atmosphere. A stand-alone-type flame effect control system without any significant control supervision by a main show control system is used.
- (5) *Group V.* A simulated building or vehicle explosion that is part of a larger theme-type attraction. The flame effect control system is totally dedicated to the operation of the flame effect elements. The flame effect control system maintains all its internal safety features, with the interface between the flame effect control system and the main show control system limited to those commands and status indicators that cannot alter or override the flame supervisory system control logic.
- (6) *Group VI.* A live-action stunt show that is part of a larger theme-type attraction. The flame effect control system is totally dedicated to the operation of the flame effect elements. The flame effect control system maintains all its internal safety features, with the interface between the flame effect control system and the main show control system limited to those commands and status indicators that cannot alter or override the flame supervisory system control logic.
- (7) *Group VII.* A fire created as part of an illusion used to make an item or individual disappear.

(See Table A.1.4.12 for a list of features included in each flame effect group.)

Table A.1.4.12 Features Included in Flame Effect Groups

Features	Flame Effect Groups						
	I	II	III	IV	V	VI	VII
Outside	X	X	X	X	X	X	X
Inside	X		X	X	X	X	X
Temporary installation	X	X	X		X	X	X
Permanent installation		X		X	X	X	X
Attended	X		X			X	X
Unattended		X		X	X		X
Visual flame verification	X		X				X
Automatic flame supervision		X		X	X	X	X
Manual fuel controls	X						X
Automatic fuel controls		X	X	X	X	X	X
Main show control					X	X	
Proximate cast						X	X

Note: A blank space means that the feature cannot be in the group. An X means that it is a feature of the group.

A.1.4.14 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.1.4.15 Primary Safety Control. In the event of ignition failure or loss of flame, the control causes a safety shutdown.

A.1.4.18 Safety Shutdown (Lockout). The flame effect can be restarted only after a manual reset following correction of the abnormal condition.

A.2.1 The following NFPA standards cover storage of flame effect materials:

NFPA 30, *Flammable and Combustible Liquids Code*

NFPA 54, *National Fuel Gas Code*

NFPA 55, *Standard for the Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders*

NFPA 58, *Liquefied Petroleum Gas Code*

NFPA 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*

NFPA 101®, *Life Safety Code®*

NFPA 430, *Code for the Storage of Liquid and Solid Oxidizers*

NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*

A.3.2.2 There is an inherent danger in the modification of flame effects once the initial commissioning activities are complete. A protective control system could provide protection against events and safety concerns that are not recognized or fully understood by other than the original designers of the system. For others to attempt modifications to a protective system invites the inadvertent elimination of subtle but important safety features of a system.

A.3.3 Measures for control of inadvertent liquefied or gaseous fuel releases, additive system releases, portable component releases, or fire should be coordinated with local emergency-handling agencies, such as fire and police departments.

Information on those hazards not commonly covered in the training programs of emergency-handling agencies should be provided upon request to emergency responders.

The safety of emergency personnel should be considered in the plan.

A.3.5 Exception No.1(c). A fire watch is a qualified person or persons in attendance during all times when fixed fire protection systems are intentionally taken out of operation and should be acceptable to the authority having jurisdiction. The fire watch should be familiar with the operation of all fire and life safety systems in the building and be able to notify emergency responders.

A.5.1 An audience should be located so that the incident thermal radiation received does not exceed that calculated by the following equation:

$$t = \left(\frac{35}{q} \right)^{1.33}$$

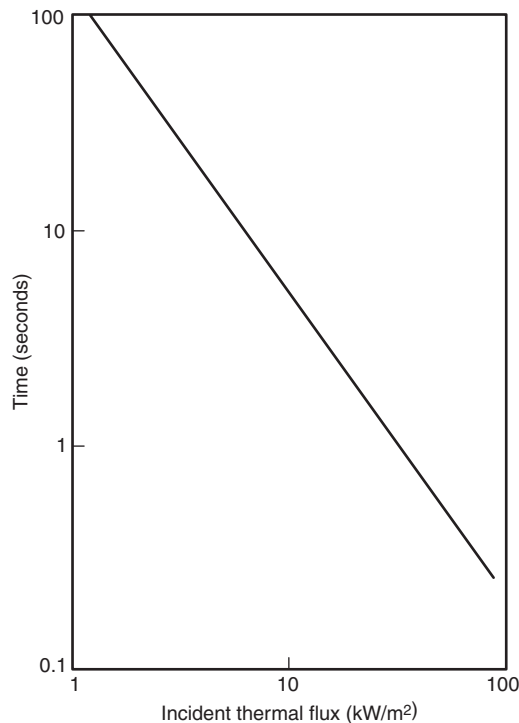
where:

t = time in seconds

q = incident thermal flux in kW/m²

The value of q can also be taken from Figure A.5.1.

FIGURE A.5.1 Time required for pain due to exposure to thermal radiation.



When applying the preceding equation to an effect with a duration of 4 seconds or less, the time used in calculating the maximum acceptable level of incident thermal flux should correspond to the root mean square (RMS) value of the peak incident thermal flux.

The incident radiation should not cause the surface temperature of the exposed skin of a member of the audience to exceed 44°C (111°F). Incident radiation can be measured with a radiometer. Skin temperature can be measured with an infrared surface thermometer or other equivalent means.

Calibrated tinder techniques can be used for measurement of continuous effects.

A.6.1 There is no substitute for a diligent, capable, well-trained operations and maintenance staff; therefore, operators of equipment involved in safety-critical processes or effects are the primary safety and control element and should have a full understanding of the system including the possible dangers and the required responses.

A.6.4 The flame effect operator is defined as the person who has overall responsibility for the flame effect. Attendants and assistants can be less than 21 years of age.

A.7.2 In Table 7.2, Group VI, positive manual enable, is sometimes known as “Man in the Loop.”

A.7.3.1 Enabling the safety-critical effect could require coordination of the emergency stop systems of independent subsystems developed by separate vendors or contractors. This requirement applies only when an emergency stop button is pressed. Generally, conditions internal or local to a single subsystem (other than pressing an emergency stop button) that cause an automatic safety shutdown of one subsystem need not cause a shutdown of other subsystems. After a safety shutdown resulting from a pressed emergency stop button, and

after the offending button has been reset, individual subsystems can be brought out of the shutdown condition, as long as no emergency stop button remains pressed.

A.7.3.1.2(6) Examples of monitored conditions are as follows:

- (1) Loss of purge airflow to electrical enclosures in classified areas
- (2) Loss or impairment of required ventilation systems
- (3) Detection of flammable gas
- (4) Loss of “proof of vacancy” in areas that present a serious hazard to personnel
- (5) Loss of proof of the safe state of any valve or other protective device that is required to maintain the protective nature of the system
- (6) Detection of a person in an unsafe area
- (7) Detection of unsafe environmental conditions
- (8) Detection of equipment in an unsafe state, condition, or position
- (9) Wind or other weather conditions that create unsafe conditions
- (10) System errors that should be addressed or acknowledged prior to a restart of the system

A.7.3.2.3(c) As shown in Figure A.7.3.2.3(c), an example supervisor station can include the following.

(a) Two safety valves in series, each with proof of closure, should be provided in the gas line to the main burners. An automatic vent valve should be provided between the two valves.

(b) Where the automatic vent valve is prohibited by the authority having jurisdiction, two safety shutoff valves in series, each with a proof of closure switch, supervised by a listed automatic valve proving system should be provided in the gas line to the burners. Valve proving should be performed either after every burner shutdown or prior to every burner light-off.

(c) Where flame effect fuel piping systems are subdivided into zones, each zone shall be separated from other zones by a zone station. A zone station should consist of a manual fuel shutoff valve at the point of connection to the fuel supply piping and upstream of any other station components, and an automatic zone valve. The zone station shuts all fuel to or from the flame effect zone when closed. When opened during the enable process, this station should be held open by a maintained signal from the flame effect control system.

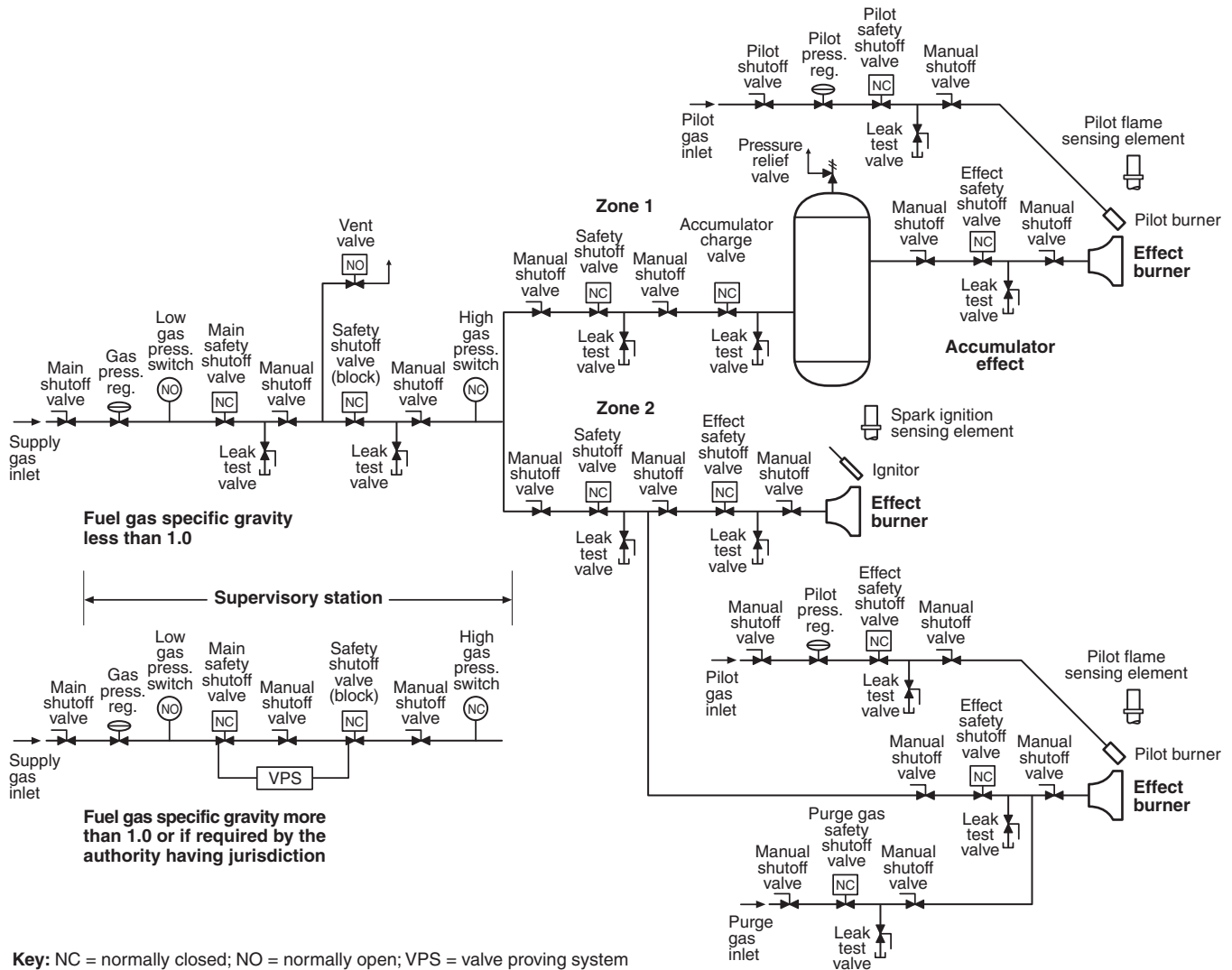
The zone valve should automatically close in the event of the loss of the hold-open signal. The zone valve should only be opened as close to the time of the actual arming and firing of the flame effects as is practical. The zone valve should be provided with a means to test the seat-tightness of the valve at operating pressure.

A.7.3.2.5 The operating characteristics of some flame effects require that fuel be released at a rate greater than can be delivered by the fuel supply. To do so requires that quantities of fuel be temporarily accumulated at the location of the effect.

A.7.3.3 Some of the operating parameters that can be enabled or monitored during the enabling of the flame effect control system include the following:

- (1) Control power
- (2) Main fuel supply
- (3) Safety interlocks
- (4) Ventilation airflow interlock (where used)
- (5) Support services (compressed air, hydraulic pressure, etc.)
- (6) Other parameters as required by the authority having jurisdiction

FIGURE A.7.3.2.3(c) Example of various flame effect control and piping components.



A.7.3.3.2 Guidelines for Flame Effect Enabling. Where required for operation and maintenance, control systems can have separate sources of control power to allow operation in distinct modes; for example, they can have one source for automatic (normal) operation and a second for limited operation of the flame effects for the purpose of maintenance and testing. Where multiple sources of control power are available, the design of the flame effect control system should meet the following minimum criteria:

- One mode of operation should be “off,” which should remove all control power from the flame effect control system.
- System operation should be such that the selection of one mode of operation disables all other modes of operation. It should not be possible to change from one mode of operation to another without turning all control power off. The flame effect control system should operate safely during the transition from one mode to any other mode of operation.
- All control power, regardless of source and mode of operation, should be interrupted by actuation of the emergency stop system. Loss of control power should bring the flame effect system to a safe state.

(d) When a main show control system is used, the status of the control power (mode of operation) should be automatically sent to the show control system at all times. Where a main show control system is used, and the mode of operation is in any mode other than that of normal automatic operation, or “off,” the sending of any command from the show control system to the flame effect control system should automatically actuate the emergency stop system and bring the flame effect system to a safe state.

Circumstances for consideration include the following:

- Particular position, mode, or state for the proper operation of a safety-critical system.

Example: A fire-breathing dragon that needs to be in a particular position before fire is initiated.

Similarly, other set pieces might have to be out of the area of the fire before fire is initiated.

Example: A fire on a set that is on a lift that is not to be initiated until the lift is confirmed to be in the fully raised position.

- Effects on vision or hearing that could prevent the safe operation of systems or the related procedures or operations.

Example: A fog or other atmospheric effects system that could obscure egress routes or interfere with monitoring an effect fire or with taking corrective action in case of an incident.

(c) Conditions that can be confused with conditions or events of the safety-critical system.

Example: Other effect systems that create the appearance of fire, smoke, or heat.

Personal computers, single-board controllers, and other systems with control capability but that are not routinely used in protective applications should not be used as life safety controllers. Only effect safety controllers should be used to prevent any safety-critical action. Non-effect safety controllers should not be used to allow, trigger, or request safety-critical action unless the signals of these non-effect safety controllers are intercepted and qualified by an effect safety controller that has responsibility for allowing safety-critical actions. Personal computers and single-board controllers can be used in related applications such as the display, logging, and trending of process variables, environmental conditions, status, faults, and other information.

Show controllers, including stage, lighting, pyrotechnics, animation, automation, and audio controllers that are used to control overall show timing relationships or that provide synchronization with audio, lighting, and unrelated effects, should be permitted to provide timing information to a flame effect safety controller but should not directly control safety-critical processes. The flame effect safety protective controller then should use this information, and other safety-related information, to control safety-critical effects.

The flame effect control system that is responsible for control of safety-critical effects should not provide control of general show timing or of non-safety-critical effects, except as follows.

(a) Timing internal to a single effect, such as to create phases or subeffects, should be permitted to be programmed into the flame effect control system.

(b) The protective flame effect control system should be permitted to provide control of a limited number of small non-safety-critical effects with limited and simple timing needs. In such cases, there should be a division of the safety-critical and non-safety-critical functions of the system.

The purpose of this requirement is to prevent equipment that is being used for protective control purposes from being utilized for general show control purposes when doing so would partially obscure the protective control purpose of the system, distracting the designers and operators from devoting attention to the safety-critical aspects of the system, which are of primary concern.

A.7.3.3.4 Examples of interlocks that can be included in the flame effect control systems are as follows:

- (1) Wind speed and direction
- (2) Critical temperatures
- (3) Opacity instrumentation
- (4) Purge airflow and/or damper positions
- (5) Combustion airflow
- (6) Position indicator switches for animated figures and sets
- (7) Cast position confirmation switches
- (8) Audience position/ride vehicle position indicators
- (9) Others as required by the operation of the show

A.7.3.4.2 Some of the sensors that are currently in use for monitoring these characteristics are as follows:

- (1) Ultraviolet flame detector in combination with a listed primary safety control
- (2) Infrared flame detector in combination with a listed primary safety control
- (3) Flame rod in combination with a listed primary safety control
- (4) Thermocouple temperature sensor in combination with a listed primary safety control or as part of a listed automatic valve assembly
- (5) Other devices directly sensitive to the characteristics of the means of ignition and acceptable to the authority having jurisdiction

A.7.3.5 The firing of the flame effect is normally achieved through the release of the fuel into ambient air where the mixture is ignited by an ignition device. Normally, this is achieved by the opening of a manual or electrically actuated fuel release valve. Other methods of fuel release are acceptable on the approval of the local authority. Examples of firing methods for flame effects are as follows:

- (1) Manual firing by cast member or technician
- (2) Firing by a timer and/or programmable logic controller (PLC)
- (3) Firing by a PLC with positive manual enable

A.7.3.5.1 Supervision. Certain venues can have areas, both visible to and out of sight of the technical director, in which a person who is present in the area during the firing of the effects might be exposed to the possibility of injury. These areas should be supervised by an intrusion monitor and alarm system during all times when the effects are enabled.

A.7.3.5.2 Alternate Means of Monitoring and Supervising the Hazard Area. Certain venues can have areas, both visible to and out of sight of the technical director, where during the enable process one of the following can occur:

- (1) Cast members can be present immediately before or after the firing of the effect.
- (2) Members of the audience might enter the area during the firing of the effect.
- (3) Moving set pieces can affect the safe operation of the effect.

A positive manual enable of the flame effect control system should be maintained by a qualified operator with a clear view of the operating area of the effect during the entire process of the enabling, arming, and firing of the effect.

Where the technical director does not have a clear view of the hazard area, additional positive manual enable devices should be installed and operated by qualified operators who are in such a position that they have a clear view of the area. Cast members who can be present immediately before the arming and firing of the effect should have additional positive manual enable devices that have to be actuated before the flame effect can be fired.

These positive manual enable devices should have the following characteristics.

(a) The positive manual enable device should consist of a momentary contact push button switch that will close a normally open isolated contact when depressed, thereby sending a confirming signal to show control.

(b) These enable operators should be located in positions such that the technician or cast member can view the effects area and/or confirm that they are safely out of harm's way.