Report of the Committee on
Motor Vehicle and Highway Fire Protection

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[1]

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of this document.

Committee Scope: This Committee shall have primary responsibility for documents on motor vehicle fire prevention and protection measures to reduce loss of life and property damage in the operation and maintenance (repair) of such vehicles (except as specified herein); fire prevention and protection recommendations for motor freight terminals; protection for tunnels, air right structures and bridges; and to recommend protection facilities on limited-access highways. Included as motor vehicles are trucks, buses, taxicabs, limousines, and passenger cars; excluded are the design, fire protection, and operational procedures for fire apparatus, mobile homes and travel trailers, tank vehicles of all kinds for handling flammable and combustible liquids and liquefied petroleum gases, and vehicles transporting explosives and other hazardous chemicals. The construction and protection of garages is handled by the NFPA Committee on Garages.

The Report of the Technical Committee on Motor Vehicle and Highway Fire Protection is presented for adoption in 3 parts.

Part I of this Report has been submitted to letter ballot of the Technical Committee on Motor Vehicle and Highway Fire Protection, which consists of 11 voting members and is reporting in 2 Segments.

Segment No. 1 consists of Proposal 502-1 (Log #CP1) on Chapter 4.

On Segment No. 1, 9 voted affirmatively, and 2 ballots were not returned (Messrs. Friloux and Harrison.)

Segment No. 2 consists of the balance of Proposal 502-1 (Log #CP1).

On Segment No. 2, 9 voted affirmatively, and 2 ballots were not returned (Messrs. Friloux and Harrison.)


Part II of this Report has been submitted to letter ballot of the Technical Committee on Motor Vehicle and Highway Fire Protection, which consists of 11 voting members; of whom 8 voted affirmatively, 1 negatively after circulation of any negative votes (Mr. Wilson) and 2 ballots were not returned (Messrs. Friloux and Harrison.)

Mr. Wilson voted negatively stating:
“ Intrastate operation of vehicles in the 10,001 to 25,999 weight categories may not be regulated by Department of Transportation Regulations.”


Part III of this Report has been submitted to letter ballot of the Technical Committee on Motor Vehicle and Highway Fire Protection, which consists of 11 voting members; of whom 9 voted affirmatively, and 2 ballots were not returned (Messrs. Friloux and Harrison.)

The document when adopted will be retitled as NFPA 502, Standard for Highway Tunnels, Bridges, and Other Limited Access Highways.
PART I
502-1 - (Entire Document): Accept
SUBMITTER: Technical Committee on Motor Vehicle and Highway Fire Protection

The Committee further proposes to change the Recommended Practice to a standard and to revise the title of the document to Standard for Highway Tunnels, Bridges, and Other Limited Access Highways. The draft is shown at the end of this report.

SUBSTANTIATION: The development of this 1998 edition was accomplished by a Task Group appointed by the Chairman of the Technical Committee on Motor Vehicles and Highway Fire Protection in October 1993.

The initial efforts of the Task Group were to revise the 1992 edition of NFPA 502 to incorporate a totally revised chapter on tunnels and make other revisions and changes to correlate the new material in tunnel and air right structure requirements with existing chapters in the document.

The reworking of the document as related to tunnels and air right structures was to bring it up to current technology and practices. This resulted in the 1996 edition of NFPA 502.

The Task Group then began the second phase of their original plan to elevate the Recommended Practice to a Standard. The Task Group reviewed and completely revised all chapters of the document, with special emphasis on incorporating the lessons learned following completion of the full-scale fire ventilation test program at the Memorial Tunnel in West Virginia. Specifically to the Memorial Tunnel Fire Ventilation Test Program, changes were made to the chapter entitled "Ventilation During Fire Emergencies". The title of the standard was also changed to more accurately reflect the contents and to properly identify the major focus of the standard.

This Task Group effort was conducted by the following individuals:

Arthur G. Bendelius, Task Group Chair, Parsons Brinckerhoff, NY
Dennis J. Becker, Richard D. Kimball Co., Inc., MA
Anthony S. Caert, U.S. Federal Highway Administration, DC
William G. Connell, Bechtel/Parsons Brinckerhoff, MA
William A. Eppich, Protectowire Co., MA
Joseph A. Gonzalez, Parsons Brinckerhoff, MA
John P. Kenney, Boston Fire Department, MA
Sergiu Lucchian, Massachusetts Highway Department, MA
Colin F. Macedo, Sverdrup, WA.

Significant technical input was provided to the Task Group by:

David Hackman, John Mills, and James P. Michelini.

COMMITTEE ACTION: Accept.
1-5.3 Application of this standard to facility alterations and fire protection system upgrades shall be determined by the authority having jurisdiction.

1-5.4 That portion of this standard that covers emergency procedures shall apply to both new and existing facilities.

1-6 Safeguards During Construction. During the course of construction or alteration of any facility addressed in this standard, the provisions of NFPA 241, Standard for Safeguarding Construction, Alteration, and Demolition Operations, shall apply.

1-7 Units.

1-7.1 Metric units of measure in this standard are in accordance with the modernized metric system known as the International System of Units (SI). The liter unit, which is outside of but recognized by SI, is commonly used in the international fire protection industry. The appropriate units and conversion factors are listed in Table A-1-7.1.

1-7.2 If a value for measurement as provided in this standard is followed by an equivalent value in other units, the first stated value shall be regarded as the recommendation. A given equivalent value might be an approximation.

18 Definitions.

Agency. The organization legally established and authorized to operate a facility.

Air Right Structure. A structure that is built over the roadway using the roadway's air rights. [See Figure 1-8(a).]

Alteration. A modification, replacement, or other physical change to an existing facility.

Alternate Central Supervising Station. A prearranged location that is equipped, or that can quickly be equipped, to function as the central supervising station in the event the central supervising station is inoperative, untenable, or inaccessible for any reason.

Alternative Fuels. Motor vehicle fuels other than gasoline and diesel.

Ancillary Facility(ies). The structure(s) usually used to house or contain operating, maintenance, or support equipment and functions.

Approved.* Acceptable to the authority having jurisdiction.

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

Backlayering. The movement of smoke and hot gases contrary to the direction of the ventilation airflow. [See Figure 1-8(b).]

Bridge. A structure spanning and providing a highway across an obstacle such as a waterway, railroad, or another highway.

Building. Any structure used or intended for supporting or sheltering any use or occupancy. The term building shall be construed as if followed by the words "or portions thereof."

Central Supervising Station. The dedicated operations center where the agency controls and coordinates the facility operations and from which communication is maintained with supervisory and operating personnel of the agency and with participating agencies where required.

Combustible. Capable of undergoing combustion.

Command Post. The location for controlling and coordinating emergency operations, designated as such by the person in command during an emergency.

Communications. Radio, telephone, and messenger services throughout the facility and particularly at the central supervising station and command post.

Control Valve. A valve used to control the water supply system of a standpipe system.

Critical Velocity. The minimum steady-state velocity of the ventilating airflow moving toward the fire, within a tunnel, that is necessary to prevent backlayering.
Depressed Highway. An uncovered, below-grade highway or "boat section" where walls rise to the grade surface. Usually emergency response access is limited. Note: (Photo of a depressed highway will be included in the Report on Comments.)

Design Fire. The fire heat release rate, in megawatts, designated in conjunction with the authority having jurisdiction as the design fire size.

Dry Standpipe. A standpipe system designed to contain water only while the system is being utilized.

Dynamic Vehicle Envelope. As used in this standard, the space within the tunnel roadway allocated for the maximum vehicle movement.

Elevated Highway. A highway that is constructed on a structure that is above the surface but does not cross over an obstacle as a bridge does.

Emergency Response Plan. A plan developed by the agency with the cooperation of all participating agencies detailing specific actions to be performed by all those who are to respond during an emergency.

Engineering Analysis. An analysis that evaluates all the various factors that affect the fire safety of the facility or component. A written report of the analysis shall be submitted to the agency authority indicating the fire protection method(s) recommended that will provide a level of fire safety commensurate with this standard.

Facility. As used in this standard, this includes limited access highways, road tunnels, bridges, and elevated highways.

Fire Apparatus. A vehicle used for fire suppression or support by a fire department, fire brigade, or other agency responsible for fire protection.

Fire Department Connection. A connection through which the fire department can pump water into the standpipe system.

Fire Emergency. The existence of, or threat of, fire or the development of smoke or flames, or any combination thereof, that calls for immediate action to correct or alleviate the condition or situation.

Highway. As used in this standard, any paved facility on which motor vehicles travel.

Hose Connection. A combination of equipment provided for connection of a hose to the standpipe system that includes a hose valve with a threaded outlet.

Hose Valve. The valve to an individual hose connection.

Incident Commander. See Person-in-Command.

Labeled. Equipment or materials to which have 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.

Length of Tunnel. The length measured from face of portal to face of portal using the centerline alignment along the tunnel roadway.

Limited Access Highway. A highway where preference is given to through traffic by providing access connections using only selected public roads and by prohibiting crossings at grade and direct private driveways.

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.

Motorist. A motor vehicle occupant, including the driver and passenger(s).


Noncombustible Material. A material, that in the form in which it is used and under the conditions anticipated, does not aid combustion or add appreciable heat to an ambient fire.

Materials, where tested in accordance with ASTM E 136, Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C, and conforming to the criteria contained therein, are to be considered as noncombustible.

Participating Agency. A public, quasi-public, or private agency that has agreed to cooperate with and assist the agency during an emergency.

Person-in-Command. A person designated by the agency or a responsible fire or police representative on the scene of an emergency who is fully responsible at the command post. See also Incident Commander.

Point of Safety.* An enclosed fire exit that leads to a public way or safe location outside the structure, or an at-grade point beyond any enclosing structure, or another area that affords adequate protection for motorists.

Portable Fire Extinguisher. A portable device carried on or wheels and operated by hand containing an extinguishing agent that can be expelled under pressure for the purpose of suppressing or extinguishing a fire.

Powersubstation. An arrangement of electrical equipment that does not generate electricity but receives and converts or transforms generated energy to usable electric energy.

Queue. A line of stored vehicles.

Replace-in-Kind. To furnish with new parts or equipment, as applied to equipment and facilities, of the same type but not necessarily of identical design.

Road Tunnel. An enclosed roadway for motor vehicle traffic with vehicle access limited to portals.

Roadway. As used in this standard, the volume of space above the pavement surface through which motor vehicles travel.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Structures. Includes, but is not limited to, buildings, bridges, and underground installations.


1-9.1 The following factors shall be evaluated when considering the fire protection and fire life safety for the facilities covered by this standard:

(a) Protection of life
(b) Restricted vehicle access and egress
(c) Fire emergencies ranging from minor incidents to major catastrophes
(d) Fire emergencies occurring at one or more locations
(c) Fire emergencies occurring in remote locations at a long distance from emergency response facilities
(f) Exposure of structure to elevated temperatures
(g) Traffic congestion and control during emergencies
(h) Built-in fire protection features such as the following:
  1. Fire alarm systems
  2. Standpipe systems
  3. Sprinkler systems
  4. Ventilation systems
  (i) Protection of facility components
  (j) Evacuation and rescue requirements
  (k) Emergency response time
  (l) Separate emergency vehicle access points
(m) Emergency communications to appropriate agencies
(n) Protection of vehicles and property being transported
(o) Facility location such as the following:
  1. Urban
  2. Rural
(p) Physical dimensions

1-9.2 Limited Access Highways.

1-9.2.1 Limited access highways can include other facilities covered by this standard.

1-9.2.2 Fire protection for limited access highways shall comply with the requirements of Chapter 2.

1-9.3 Bridges and Elevated Highways.

1-9.3.1 Critical structural members shall be protected where necessary from collision and high-temperature exposure that could result in dangerous weakening or complete collapse of the bridge or elevated highway.

1-9.3.2 Elements of bridges and elevated highways frequently pass directly over residential, commercial, or industrial areas. Fire on these facilities (structure) could result in serious exposure to occupancies beneath and in close proximity to the bridge or elevated highway.

1-9.3.3 Fires within occupancies beneath and in close proximity to these facilities can also have a serious impact on the structural integrity of a bridge or elevated highway.

1-9.3.4 Fire protection for bridges and elevated highways shall comply with the requirements of Chapter 3.

1-9.4 Depressed Highways.

1-9.4.1 The majority of depressed highways are associated with road tunnels as connecting sections or open approaches.

1-9.4.2 The installation of standpipe systems and/or fire extinguishers shall be considered for use on depressed highways where physical factors permit or impede access to water supply and/or fire apparatus.

1-9.4.3 Additional requirements for fire protection of depressed highways are described in Chapter 4.

1-9.5 Road Tunnels.

1-9.5.1 The inability of smoke and heated gases from a fire emergency to readily disperse can seriously impede emergency response operations.

1-9.5.2 Fire protection for road tunnels shall comply with the requirements of Chapter 4.

1-9.6 Roadway Beneath Air Right Structures.

1-9.6.1 The limits that an air right structure imposes on the accessibility and function of the roadway beneath the structure under emergency conditions shall be assessed.

1-9.6.2 Where a building is constructed using the air rights over a roadway, the facility begins to resemble a road tunnel from the fire protection standpoint.

1-9.6.3 Where an air right structure is fully enclosed on both sides of the roadway, it shall be treated, from a fire protection standpoint, as a road tunnel and shall comply with the requirements of Chapter 4.

1-9.6.4 Where the air right structure is not fully enclosed, the decision whether to treat it as a road tunnel shall be made by the authority having jurisdiction after sufficient engineering analysis.

1-9.6.5 Smoke dispersion during a fire emergency will be similar to that of a road tunnel.

1-9.6.6 Fire protection for structures built over roadways are not covered by this standard except for the separation between the air right structure and the roadway beneath the air right structure. However, fire protection and fire life safety problems will be complicated by limited access, by traffic congestion, and by any fire situation on the roadway below or adjacent to the building.

1-9.6.7 Fire protection for the roadway beneath air right structures shall comply with the requirements of Chapter 5.

Chapter 2 Limited Access Highways

2-1 General. This chapter provides fire protection requirements for limited access highways.

2-2 Emergency Communications. Emergency communications, where required by the authority having jurisdiction, shall be provided by the installation of outdoor-type telephone boxes, coded alarm telegraph stations, radio transmitters, or other suitable devices. Such devices shall meet the following requirements:

(a) Be made conspicuous by means of indicating lights or other suitable markers
(b) Be identified by a readily visible number plate or other appropriate device
(c) Be posted with suitable instructions for use by motorists
(d) Be located, wherever possible, so that motorists can park their vehicles clear of the traveled lanes

2-3 Signage. Mile markers or other readily available location reference markers shall be installed along the highway to allow motorists to provide authorities with reasonably accurate locations for accident or emergency areas.

2-4 Fire Apparatus.

2-4.1 Guidelines regarding suitable fire apparatus for limited access highways can be found in Appendix I.

2-4.2 Arrangements for the response of nearby fire companies and emergency squads shall be made a part of the emergency response planning process (see Chapter 9). Where practical, means of access that allows the entrance of outside aid companies to the facility shall be provided, and procedures for utilizing such access shall be included in the emergency response plan. Appropriate precautions shall be taken at these points of entry to alert and control traffic to allow safe entrance by emergency equipment.

2-5 Ancillary Facilities. All related ancillary facilities that support the operation of limited access highways shall be protected as required by all applicable NFPA standards and local building codes and shall not be covered under this standard.

2-6 Emergency Response Planning.

2-6.1 It is important that a designated authority carry out a complete and coordinated program of fire protection that includes written pre-planned response and standard operating procedures.

2-6.2 Emergency traffic control procedures shall be established to regulate traffic during an emergency.

2-6.3 Emergency procedures and the development of an emergency response plan are addressed in Chapter 9.
Chapter 3  Bridges and Elevated Highways

3-1 General. This chapter provides fire protection requirements for bridges and elevated highways.

3-2 Emergency Communications.

3-2.1 Emergency communications, when required by the authority having jurisdiction, shall be provided by the installation of outdoor-type telephone boxes, coded alarm telegraph stations, radio transmitters, or other suitable devices. Such devices shall meet the following requirements:
(a) Be made conspicuous by means of indicating lights or other suitable markers.
(b) Be identified by a readily visible number plate or other appropriate device.
(c) Be posted with suitable instructions for use by motorists.
(d) Be located, where possible, so that motorists can park their vehicles clear of the traveled lanes.

3-3 Signage. Signs or mile markers shall be installed along the bridge to allow motorists to provide authorities with reasonably accurate location information.

3-4 Traffic Control. A traffic control procedure shall be established so that vehicles will either stop or proceed with caution. It is essential that traffic does not block or otherwise interfere with the response of emergency and fire equipment.

3-5 Fire Apparatus. Guidelines regarding suitable fire apparatus for bridges and elevated highways can be found in Appendix A.

3-6 Standpipe and Water Supply. Where the length or width of the bridge is such that hose lines of more than 40 ft (12 m) cannot be provided from a municipal supply, a standpipe system, in accordance with Chapter 6, shall be provided. In certain instances, it might be desirable for duplicate systems to be installed on each side of the roadway and to be cross-connected. Where freezing conditions prevail, systems shall be of the dry type.

3-7 Drainage. On bridges and elevated highways, consideration shall be given to drainage systems to channel and collect spilled hazardous or flammable liquids to areas that cannot cause additional hazards. Expansion joints shall be designed to prevent spilling to the area below.

3-8* Ancillary Facilities. All related ancillary facilities that support the operation of bridges and elevated highways shall be protected as required by all applicable NFPA standards and local building codes and shall not be covered under this standard.

3-9 Control of Hazardous Materials. Control of hazardous materials is addressed in Chapter 10.

3-10 Emergency Response Planning.

3-10.1 A designated authority shall carry out a complete and coordinated program of fire protection that shall include preplanned emergency response procedures to be contained in an emergency response plan.

3-10.2 Emergency procedures and the development of an emergency response plan shall comply with the requirements of Chapter 9.

Chapter 4  Road Tunnels

4-1 General. This chapter provides fire protection and fire life safety requirements for road tunnels. It also covers requirements, where appropriate, for the fire protection and fire life safety of depressed highways.

4-2 Road Tunnel Length. For the purpose of this standard, tunnel length shall dictate the minimum fire protection requirements, as follows:
(a) Where the tunnel length is 300 ft (90 m) or less the provisions of this standard do not apply.
(b) Where the tunnel length exceeds 300 ft (90 m), a standpipe system shall be installed in accordance with the requirements of Chapter 6. The remaining requirements of this chapter do not apply to tunnels exceeding 300 ft (90 m), except Section 4-5 shall apply.
(c) Where the tunnel length exceeds 800 ft (240 m), whereby the maximum distance from any point within the tunnel to an area of safety exceeds 400 ft (120 m), all provisions of this standard shall apply.

4-3 Fire Detection.

4-3.1 At least two means to detect, identify, and locate a fire in a tunnel, including one manual, shall be provided.

4-3.1.1* Manual double-action fire alarm pull stations mounted in weatherproof boxes shall be installed at intervals of not more than 300 ft (90 m) and at all cross passages and means of egress from the tunnel. The stations shall be accessible to both the public and tunnel personnel. The location of the pull stations shall be made conspicuous. The alarm shall indicate the location of the pull station at the monitoring station.

4-3.1.2 Closed-circuit television systems (CCTV) and/or traffic flow indication devices shall be permitted to identify fires in tunnels with 24-hr, full-time central supervision. Ancillary spaces within the tunnel (pump stations, utility rooms, cross passages, ventilation structures) and other areas not normally covered by such devices shall be supervised by automatic fire alarm systems.

4-3.1.3 Automatic fire detection systems shall be installed in tunnels where 24-hr, full-time operating personnel are not provided. The systems shall be in compliance with NFPA 72, National Fire Alarm Code.

Exception No. 1: Signals for the purpose of evacuation and relocation of occupants shall not be required.

Exception No. 2: System shall be for fire detection only.

4-3.1.3.1 Automatic fire detection systems shall be capable of identifying the location of the fire within 50 ft (15 m). The initiating device shall have a light that remains on until the device is reset.

4-3.1.3.2 Automatic fire detection within the tunnel shall be zoned to correspond with the tunnel ventilation zones where appropriate.

4-3.2 Fire Alarm Control Panel. An approved fire alarm control panel (FACP) shall be provided in accordance with NFPA 72, National Fire Alarm Code.

4-4* Communications. Communications systems are described in Appendix A.

4-5 Traffic Control.

4-5.1 Road tunnel length exceeding 300 ft (90 m) shall be equipped with the means to stop approaching traffic from entering the tunnel following activation of a fire alarm within the tunnel. Return to normal operation shall occur as determined by the authority having jurisdiction.

4-5.2 Road tunnels longer than 800 ft (240 m) shall be provided with means to stop traffic from entering the direct approaches to the tunnel, to control traffic within the tunnel, and to clear traffic downstream of the fire site following activation of a fire alarm within the tunnel.

(a) Direct approaches to the tunnel shall be closed following activation of a fire alarm within the tunnel. This shall be accomplished in such a manner that responding emergency vehicles are not impeded in transit to the fire site.

(b) Traffic within the tunnel approaching (upstream of) the fire site shall be stopped prior to the fire site until it is safe to proceed as determined by the incident commander.

(c) Means shall be provided downstream of the fire site to expedite the flow of vehicles from the tunnel such that no traffic shall be queued downstream of the fire site.
(d) Return to normal operation shall occur as determined by the incident commander.

4-6 Fire Apparatus. Guidelines regarding suitable fire apparatus for road tunnels can be found in Appendix I.

4-7 Standpipe and Water Supply. Standpipe and water supply systems in road tunnels shall comply with the requirements of Chapter 6.

48 Portable Fire Extinguishers. Portable fire extinguishers, each with a minimum 20-lb (9-kg) capacity, multipurpose agent, shall be located along the roadway in well-marked, easily accessible wall cabinets at intervals of not more than 300 ft (90 m). Portable fire extinguishers shall be in accordance with NFPA 10, Standard for Portable Fire Extinguishers.

Portable fire extinguishers, each having a rating of 2A:20:BC, shall be located along the roadway in well-marked, easily accessible wall cabinets at intervals of not more than 300 ft (90 m). To facilitate safe use by motorists, the maximum weight of each such extinguisher shall be 20 lb (9 kg). Portable fire extinguishers shall be in accordance with NFPA 10, Standard for Portable Fire Extinguishers.

4-9 Ventilation During Fire Emergencies. Tunnel ventilation systems to be employed during fire emergencies shall comply with the requirements of Chapter 7.

4-10 Tunnel Drainage System.

4-10.1 A drainage system shall be provided in tunnels to collect, store, and/or discharge effluent from the tunnel. In addition to water discharged from the fire protection system and liquids from incidental spills, this effluent can include water from tunnel cleaning operations and water from incidental sewage.

4-10.2 The drainage collection system shall be designed such that spills of hazardous or flammable liquids cannot propagate along the length of the tunnel.

4-10.3 Components of the drainage collection system, including the main drain lines, shall be non-flammable (i.e., steel, ductile iron, or concrete). Polyvinyl chloride (PVC), fiberglass pipe, or other combustible material shall not be permitted.

4-10.4 The collection system shall drain to a storage tank or transfer pumping station of sufficient capacity to receive, as a minimum, the simultaneous rate of flow from two fire hoses without causing flooding on the roadway.

4-10.5 Storage tanks and pump stations shall be classified for hazardous locations in accordance with NFPA 70, National Electrical Code®. All motors, starters, level controllers, and system controls shall be specified to conform to the intrinsic requirements of the hazard classification.

4-10.6 Storage tanks and pump stations shall be monitored for hydrocarbons. Detection of hydrocarbons in the tunnel drainage effluent shall initiate both a local and remote alarm.

4-11 Ancillary Facilities. All related ancillary facilities that support the operation of road tunnels shall be protected as required by all applicable NFPA standards and local building codes and shall not be covered under this standard.

4-12 Alternative Fuels. For information relating to the potential impact of alternative fuels on fire emergencies in road tunnels, see Appendix F.

4-13 Control of Hazardous Materials. Control of hazardous materials shall comply with the requirements of Chapter 10.

4-14 Emergency Response Planning.

4-14.1 A designated authority shall carry out a complete and coordinated program of fire protection that shall include pre-planned response and standard operating procedures in the form of an emergency response plan.

4-14.2 Emergency response planning, including development of emergency response plans, shall comply with the requirements of Chapter 9.
Chapter 6 Standpipe and Water Supply

6-1 Standpipe Systems.

6-1.1 Standpipe systems for road tunnels, bridges, depressed highways, elevated highways, roadways beneath air right structures, and limited access highways shall be designed and installed as Class 1 systems in accordance with NFPA 14, Standard for the Installation of Standpipe and Hose Systems.

Exception: Maximum and minimum residual pressures at the hose connections shall be as described in 6-2.1 and 6-2.2.

6-1.2 Standpipe systems shall be either wet or dry, depending upon climatic conditions, till times, or the requirements of the authority having jurisdiction, or any combination thereof.

6-1.3 Where wet standpipe systems are required in areas subject to freezing conditions, the water shall be heated and circulated, and all piping and fittings exposed to such conditions shall be heat-traced and insulated.

6-1.4 Wet standpipe systems shall be provided with suitable interconnection and bypass valve arrangements to allow isolation and repair of any segment without impairment to the operation of the remainder of the system.

6-1.5 Dry standpipe systems shall be designed such that the delivery time of water to any hose connection on the system is less than 10 minutes. Dry standpipe systems shall have provisions for complete draining after use. Combination air relief/vacuum valves shall be installed at each high point on the system.

6-1.6 Dry standpipes shall be installed in a manner that provides accessibility for inspection and repair and shall be protected from damage by moving vehicles.

6-2 Design Capacity.

6-2.1 Standpipe systems shall be designed to provide a minimum water supply of 250 gpm (16 L/sec) at a minimum residual pressure of 65 psi (450 kPa) at the most remote hose connection with a minimum of two hose connections flowing for a total flow of 500 gpm (32 L/sec) at 100 psi (690 kPa).

6-2.2 Maximum residual pressure at any hose connection shall be limited to 100 psi (690 kPa) by means of an approved pressure regulating device.

6-3 Water Supply.

6-3.1 Wet standpipe systems (automatic or semiautomatic) shall be connected to an approved water supply capable of supplying the system demand for a minimum of 1 hour.

6-3.2 Dry standpipe systems shall have an approved water supply capable of supplying the system demand for a minimum of 1 hour and accessible to a fire department pumper within 100 ft (30 m) of each fire department connection.

6-3.3 Acceptable water supplies include the following:

(a) Municipal or privately owned waterworks systems having adequate pressure and flow rate and a level of integrity acceptable to the authority having jurisdiction

(b) Automatic or manually controlled fire pumps connected to an approved water source

(c) Pressure-type or gravity-type storage tanks installed in accordance with NFPA 22, Standard for Water Tanks for Private Fire Protection

6-4 Fire Department Connections.

6-4.1 Fire department connections shall be of the threaded two-way or three-way type or shall consist of one 4-in. (101.6-mm) quick-connect coupling located at ground surface level and accessible to a fire department pumper.

6-4.2 Each standpipe zone shall have a minimum of two fire department connections located remotely from each other.

6-4.3 Fire department connections shall be protected from vehicular damage by means of boiroids or other suitable barriers.

6-4.4 Wherever possible, fire department connection locations shall be coordinated with emergency access and/or response locations.

6-5 Hose Connections.

6-5.1 Hose connections shall be spaced so that no location on the protected roadway is more than 150 ft (45 m) from the hose connection. Hose connection spacing shall not exceed 275 ft (85 m). Hose connections shall be located so that they are conspicuous and convenient yet reasonably protected from damage by errant vehicles or vandals.

6-5.2 Hose connections shall have 2 1/2-in. (63.5-mm) external threads in conformance with NFPA 903, Standard for Fire Hose Connections, and the authority having jurisdiction. Hose connections shall be equipped with caps to protect hose threads.

6-6 Fire Pumps. Fire pumps shall be supplied as necessary and installed in accordance with NFPA 20, Standard for the Installation of Centrifugal Fire Pumps.

6-7 Identification Signage.

6-7.1 Identification signage for standpipe systems and components shall be developed with input from the authority having jurisdiction. Identification signage shall, as a minimum, identify the limits and location of each fire department connection.

6-7.2 Identification signage shall be conspicuous and affixed to, or immediately adjacent to, ground surface level fire department connections and each roadway hose connection.

Chapter 7 Tunnel Ventilation During Fire Emergencies

7-1 General. Tunnel ventilation systems installed in road tunnels are an important element of the fire protection systems. Ventilation systems are installed in road tunnels to maintain, within the tunnel roadway, an acceptable level of traffic-generated pollutants. These systems and the tunnel operating procedures shall be developed to maximize utilization of the road tunnel ventilation system for the removal and control of smoke and heated gases resulting from fire emergencies within the tunnel.

7-1.1 In the circumstance where a ventilation system is not installed in a road tunnel for normal operations to maintain air quality within the tunnel, a ventilation system designed for smoke removal and/or control shall be required as defined in Chapter 4.

7-1.2 The ventilation operational procedures shall be designed to assist in the evacuation and/or rescue of motorists from the tunnel.

7-2 Normal Ventilation. The ventilation systems designed to control the contaminant levels within road tunnels (normal operations) can be configured several ways, employing either central fans or local fans. A description of the various ventilation configurations considered for normal operations is contained in Appendix H.

7-3 Smoke Control. Operation of the ventilation system provides a means for controlling smoke. Smoke control can be achieved by either capturing and removing the smoke through air ducts or by pushing it through the tunnel and out a portal. The approach used will depend on the type of ventilation system selected and on the mode of traffic operation and the surrounding environment. In all cases, the desired goal shall be to provide an evacuation path for motorists exiting from the tunnel and to facilitate firefighting operations.

7-3.1 In tunnels with bidirectional traffic where motorists could be on both sides of the fire site, the following shall be considered:
(a) Smoke stratification shall not be disturbed

(b) Longitudinal air velocity shall be kept at low magnitudes

(c) Smoke extraction through ceiling openings or openings high along the tunnel wall(s) is effective

7.3.2 In tunnels with unidirectional traffic where motorists would most likely be upstream of the fire site, the following issues shall be considered:

(a) Considerations with a longitudinal system are as follows:

1. Prevent backlayering by producing a longitudinal velocity greater than the critical velocity in the direction of traffic flow.

2. Avoid disrupting the smoke layer by initially not operating jet fans located near the fire site. Operate fans furthest away first.

(b) Considerations with a transverse or reversible semi-transverse systems are as follows:

1. Maximize the exhaust rate in the ventilation zone containing the fire and minimize the amount of outside air introduced by a transverse system.

2. Create a longitudinal airflow in the direction of traffic flow by operating upstream ventilation zone(s) in maximum supply and downstream ventilation zone(s) in maximum exhaust.

7-4 Memorial Tunnel Fire Ventilation Test Program. The Memorial Tunnel Fire Ventilation Test Program (MTFVTP), a full-scale test program, was conducted under the auspices of the United States Federal Highway Administration (FHWA), the Massachusetts Highway Department (MHD), and the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) to evaluate the effectiveness of various tunnel ventilation systems and ventilation airflow rates to control the smoke from a fire. The results of this program has had an impact on the design criteria for road tunnel emergency ventilation. Information available from the MTFVTP has been employed in the development of this standard. (A description of the MTFVTP and its results is contained in Appendix G.)

7-5 Design Objectives. The design objectives of the emergency ventilation system shall be to control and/or extract smoke and heated gases as follows:

(a) To provide a stream of noncontaminated air in a path of egress away from a fire (see Appendix B).

(b) To produce longitudinal airflow rates to prevent backlayering of smoke in a path of egress away from a fire (see Appendix C).

7.6 Criteria.

7.6.1 The design fire size [heat release rate produced by a vehicle(s)] shall be used to design the emergency ventilation system. The selection of the design fire size (heat release rate) shall consider the types of vehicles expected to use the tunnel. Representative fire heat release rates corresponding to the various vehicle types are provided for guidance in Table 7-6.1.

7.6.2 The design fire size selected has an effect on the magnitude of the critical air velocity necessary to prevent backlayering. A method for calculating the critical velocity is described in Appendix C.

7.7 Fans.

7.7.1 Tunnel ventilation fans that are to be utilized during fire emergencies, their motors, and all related components that would be exposed to the ventilation airflow shall be designed to remain operational for a minimum of 1 hour in an airstream temperature of 482°F (250°C).

7.7.2 Tunnel ventilation fans, such as jet fans, which could be directly exposed to a fire within the tunnel roadway, shall be considered expendable in the likelihood that the fan or group of fans closest to the fire site will be rendered inoperable by the fire. Accordingly, the design of such ventilation systems for use in a fire emergency shall incorporate fan redundancy.

7.7.3 Tunnel ventilation fans that are to be utilized in a fire emergency shall be capable of achieving full rotational speed from standstill within 25 seconds. Reversible fans shall be capable of completing full rotational reversal within 25 seconds.

7.7.4 Discharge/outlet openings for emergency fans shall be positioned a sufficient distance from supply air intake openings to prevent recirculation. If this is not possible due to site constraints air intake openings then shall be protected by other approved means or devices to prevent smoke from re-entering the system.

7-8 Dampers.

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Table 7-6.1 Fire Data for Typical Vehicles

<table>
<thead>
<tr>
<th>Cause of Fire</th>
<th>Equivalent Size of Gasoline Pool ft³ (m³)</th>
<th>Fire Heat Release Rate MW</th>
<th>Smoke Generation Rate cfm (m³/s)</th>
<th>Maximum Temperature °F (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>22 (2)</td>
<td>5</td>
<td>42 (20)</td>
<td>750 (400)</td>
</tr>
<tr>
<td>Bus/Truck</td>
<td>86 (8)</td>
<td>20</td>
<td>127 (60)</td>
<td>1290 (700)</td>
</tr>
<tr>
<td>Gasoline Tanker</td>
<td>323-1076 (30-100)</td>
<td>100</td>
<td>212-424 (100-200)</td>
<td>1830 (1,000)</td>
</tr>
</tbody>
</table>

2. Temperature 50 ft (10 m) downwind of the fire with the minimum air velocity necessary to prevent backlayering
7.8.1 All dampers that will be exposed to the exhaust air stream from the roadway fire shall be designed to remain fully operational in an air stream temperature 482°F (250°C) for at least 1 hour.

7.8.2 All moving and other critical components of the damper shall be designed to allow for expansion and contraction through the maximum anticipated temperature range.

7.8.3 For multibladed dampers, unless the application warrants a special type of bearing or it is impossible to locate the bearings out of the air stream such as with single point extraction dampers, the bearings shall be located out of the air stream. The actuators and bearings shall be isolated from the heated airstream to the greatest extent possible.

7.8.4 All other dampers designed for use during a fire emergency shall be equipped with power actuators capable of being manually or automatically controlled.

7.9 Sound Attenuators.

7.9.1 Sound attenuators that are located in the hot air stream from the roadway, such as those used in semi-transverse exhaust systems and fully transverse exhaust ducts, shall be capable of withstanding an air stream temperature of 482°F (250°C) for 1 hour without any obstruction of the airflow path. All the components of the attenuator shall remain structurally intact and in place after the above 1 hour of operation.

7.9.2 The sound absorbing fill material used in the baffles shall be noncombustible, non-toxic, and stable at the temperatures indicated in 7-9.1.

7.10 Controls.

7.10.1 Where both the local and remote controls provide the capability to operate the fans in an emergency mode, local control shall be capable of overriding remote control.

7.10.2 Control devices including motor starters, motor drives, and motor disconnects shall be isolated from the fan air stream to the greatest extent practical.

Chapter 8 Electrical Systems

8.1 General.

8.1.1 The electrical systems shall support life safety, fire emergency operations, and normal operations.

8.1.2 The electrical systems shall maintain ventilation, illumination, communications, drainage, and water supply and identify areas of refuge, exits, and exit routes and provide remote annunciation/alarm under all operating and emergency modes associated with the facility.

8.2 Wiring. All wiring materials and installation shall conform to NFPA 70, National Electrical Code, as modified in this standard.

8.3 Materials.

8.3.1 Materials manufactured for use as conduits, raceways, ducts, cabinets, and equipment enclosures and their surface finish materials, as installed, shall be capable of being subjected to temperatures up to 600°F (316°C) for 1 hour and not support combustion under the same temperature condition.

8.3.2 The electrical systems shall not utilize, within the confined spaces of limited access highways, materials that produce toxic by-products during electric circuit failure or when subjected to an external fire. PVC conduit and vinyl insulated/jacketed conductors or cables and exposed PVC conduit and PVC-coated metal conduit shall not be used in tunnels, ducts, plenums, or other enclosed spaces.

8.3.3 All insulations shall conform to NFPA 70, National Electrical Code, and shall be of the moisture and heat-resistant types with temperature ratings corresponding to the conditions of application.

8.3.4 All conductors shall be completely enclosed in armor sheaths, conduits, or enclosed raceways, boxes, and cabinets. Conductors in a raceway shall be permitted to be embedded in concrete or run in protected electrical duct banks, but they shall not be installed in an exposed manner or surface mounted in air plenums that could carry air at the elevated temperatures accompanying fire emergency conditions.

8.4 Power Source. The power source for all systems shall be of a capacity and configuration commensurate with the purpose of the system. The following systems shall be provided with reliable power for a fire emergency:

(a) Lighting
(b) Means of egress and areas of refuge lighting
(c) Exit signs
(d) Communications
(e) Tunnel drainage and fire pump(s)
(f) Ventilation during a fire emergency

The primary and secondary sources shall be wired to system equipment so that a single event or fire will have a minimum effect on the operation of the overall system.

8.5 Reliability.

8.5.1 The primary source of electric service shall be from the local electric utility.

8.5.2 A separate service shall be permitted to be the secondary source; provided it can be demonstrated that a single event within the utility system cannot affect both the primary and secondary source.

8.6 Lighting.

8.6.1 Tunnel lighting illumination levels during fire emergencies shall not be less than 0.2 fc [0.22 lux (minimum average)], throughout personnel egress paths within the roadway.

8.6.2 Lighting shall be provided to highlight special features (such as fire pull stations, extinguishers, and telephones) and special feature instructional signage.

Chapter 9 Emergency Response Planning

9.1 General. The agency that is responsible for the safe and efficient operation of the facility shall anticipate and plan for emergencies that could involve the system. Participating agencies shall be invited to assist with the preparation of the emergency response plan.

9.2 Emergencies. The following typical incidents shall be considered during the development of facility emergency response plans:

(a) Fire or a smoke condition in one or more vehicles or in the facility
(b) Fire or a smoke condition adjoining or adjacent to the facility
(c) Collision involving one or more vehicles
(d) Loss of electric power resulting in loss of illumination, ventilation, or other life safety systems
(e) Rescue/evacuation of motorists under adverse conditions;
(f) Disabled vehicles
(g) Flooding of travel way or evacuation route
(h) Seepage and spillage of petroleum products; flammable, toxic, or irritating vapors; and hazardous materials
(i) Multiple casualty incidents
93 Emergency Response Plan.

93.1 The emergency response plan shall include, as a minimum, the following:

(a) Name of plan
(b) Name of responsible agency
(c) Names of responsible individuals
(d) Dates adopted, reviewed, and revised
(e) Policy, purpose, scope, and definitions
(f) Participating agencies, top officials, and signatures of executives signing for each agency
(g) Safety during emergency operations
(h) Purpose and operation of central supervising station and alternate central supervising station
(i) Purpose and operation of command post and auxiliary command post
(j) Communications (i.e., radio, telephone, and messenger service) available at central supervising station and command post; also, efficient operation of these facilities
(k) Fire detection, fire protection, and fire extinguishing equipment; access/egress and ventilation facilities available; as well as details of the type, amount, location, and method of ventilation
(l) Procedures for fire emergencies, including a list of the various types of fire emergencies, the agency in command, and the procedures to follow
(m) Maps and plans of the roadway system and of all surface and connecting streets
(n) Any additional information and data that the participating agencies desire to have in the plan

93.2 A sample emergency response plan outline is provided in Appendix E.

94 Participating Agencies. Participating agencies that might be needed to coordinate and assist, depending on the nature of an emergency, include in the following:

(a) Ambulance service
(b) Building department
(c) Fire department (brigade)
(d) Medical service
(e) Police department
(f) Public works (e.g., bridges, streets, sewers)
(g) Sanitation department
(h) Utility companies (e.g., gas, electricity, telephone, steam)
(i) Water supply
(j) Local transportation companies
(k) Private industry having available heavy construction equipment
(l) Land management agencies
(m) Towing companies
(n) Highway departments (e.g., departments of transportation)
(o) Coast Guard
(p) Military

The participating agencies and names will vary depending upon the governmental structure and laws of the community.

95 Central Supervising Station. If the facility has a central supervising station (CSS) for the operation and supervision of the facility, 9-5.1 through 9-5.7 shall apply.

95.1 The CSS shall be staffed by trained and qualified personnel and shall be provided with the essential apparatus and equipment to communicate with, supervise, and coordinate all personnel.

95.2 The CSS shall provide the capability to communicate rapidly with participating agencies. Participating agencies such as fire, police, ambulance, and medical service shall have direct telephone lines or designated telephone numbers used for emergencies involving the facility.

95.3 Equipment shall be available and used for recording radio and telephone communications and CCTV transmissions during an emergency.

95.4 CSS personnel shall be thoroughly familiar with the emergency procedure plan and trained to employ it effectively.

95.5 An alternate site(s) that can function efficiently during an emergency in the event the CSS is out of service for any reason shall be selected and equipped, or equipment shall be readily available.

95.6 The CSS shall be located in an area separated from other occupancies by construction having a 2-hr fire resistance rating. The area shall be used for the CSS and similar activities and shall not be jeopardized by adjoining or adjacent occupancies.

95.7 The CSS shall be protected by fire detection, protection, and extinguishing equipment to provide early detection and extinguishment of any fire in the CSS.

96 Liaison.

96.1 An up-to-date list of all liaison personnel from participating agencies shall be maintained by the operating agency and shall be part of the emergency procedure plan.

96.2 The list shall include the full name, title, agency, business telephone number(s), and home telephone number of the primary liaison as well as an alternate.

96.3 The list shall be reviewed at least once every three months to verify the ability to contact the liaison without delay.

97 Command Post.

97.1 During an emergency where it is necessary to invoke the emergency procedure plan, a command post shall be established by the person in command for the supervision and coordination of all personnel, equipment, and resources at the scene of the emergency.

97.2 The emergency procedure plan shall delineate clearly the authority or participating agency that is in command and responsible for supervision, correction, or alleviation of the emergency.

97.3 The command post shall be located at a site convenient for responding personnel, easily identifiable, and suitable for supervising, coordinating, and communicating with participating agencies.
9.7.4 Each participating agency shall assign a liaison to the command post.

9.7.5 Effective use shall be made of radio, telephone, and messenger service to communicate with participating agencies.

9.7.6 The command post shall be readily identified and visible at all times.

9.8 Auxiliary Command Post.

9.8.1 Where necessary, the incident commander shall establish an auxiliary command post.

9.8.2 When necessary, a participating agency (not in command) shall establish an auxiliary command post to assist with the supervision and coordination of its personnel and equipment.

9.9 Training, Exercises, Drills, and Critiques.

9.9.1 Operating agency and participating agency personnel shall be trained to function efficiently during an emergency. They shall be thoroughly familiar with all aspects of the emergency procedure plan.

9.9.2 To optimize the emergency response plan, comprehensive training programs are necessary for all personnel and agencies expected to participate in any emergencies. Such a program shall involve competent supervisory staff experienced in fire fighting, life safety techniques, and hazardous materials emergencies.

9.9.3 Contacts should be made with roadside businesses and responsible persons living along limited access highways to elicit their cooperation in the reporting of fires and other emergencies. The objective of such contacts shall be to establish a positive system for the reporting of emergencies. Those who agree to participate in the system are to be provided with specific information on the procedures for reporting and a means for determining and reporting the location of the emergency as precisely as possible.

9.9.4 Exercises and drills shall be conducted at least twice per year to prepare the operating agency and participating personnel for emergencies. Critiques shall be held after the exercises, drills, and actual emergencies.

9.10 Records. Written records and telephone, radio, and CCTV recordings shall be kept at the CSS, and written records shall be kept at the command post and auxiliary command posts during fire emergencies, exercises, and drills.

Chapter 10 Control of Hazardous Materials

10.1 General. The facility operating agency shall adopt rules and regulations applicable to the transportation of hazardous materials. A program shall be maintained for enforcing these regulations. In developing such regulations, consideration shall be given to the following:

(a) The availability of a suitable alternative route(s) meeting federal requirements as prescribed in Title 49, Department of Transportation, Code of Federal Regulations, 177.825, "Routing and Training Requirements for Class 7 (Radioactive) Materials," and Title 49, Department of Transportation, Code of Federal Regulations, Part 397, Subpart C, "Routing of Non-Radioactive Hazardous Materials"

(b) Title 49, Department of Transportation, Code of Federal Regulations, Subtitle B, Parts 100 to 199

(c) The fire and accident experience of other similar facilities

(d) Past fire and accident experience on the facility and adjacent roads, or, in the case of a new facility, the past fire and accident experience on roads in the area

(e) Anticipated traffic volumes in peak and off-peak periods

(f) The need for inspection of vehicles and cargo and the availability of a safe place to conduct inspections with a minimum of traffic interference

(g) The need and desirability of escort service with due consideration of the extent to which it could disrupt the orderly flow of traffic and create additional hazards

(h) A plan developed by an operating agency in a dense urban area, as referenced in Hazardous Material Transportation Regulations at Tunnel and Bridge Facilities. This might not be suitable for all such facilities

Chapter 11 Referenced Publications

11.1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix J.

11.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.


11.1.2 Other Publications.

11.1.2.1 ASTM Publications. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.


11.1.2.2 MUTCD. Manual on Uniform Traffic Control Devices for Streets and Highways.

11.1.2.3 PIARC Publication. World Road Association (formerly Permanent International Association of Road Congresses), La Grande Arche, Parol Nord, Nivelles, 92055 Paris La Defense, Cedex 04.

"Road Tunnels, Report of the Committee," XXth World Road Congress, Montreal, Canada, 3-9 September 1995.

"Road Tunnels, Report of the Committee," XXth World Road Congress, Montreal, Canada, 3-9 September 1995.


Title 49, Department of Transportation, Code of Federal Regulations, 177.825, "Routing and Training Requirements for Class 7 (Radioactive) Materials."


Title 49, Department of Transportation, Code of Federal Regulations, Subtitle B, Parts 100 to 199.
Appendix A Explanatory Material

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only. The following notes, bearing the same number as the text of this document to which they apply, contain useful explanatory material.

A-1-4 Character of Fire Protection. (Text for this section will be included in the Report on Comments.)

A-1-7.1 SI units have been converted by multiplying the value by the conversion factor and rounding the result to the appropriate number of significant digits. (See Table A-1-7.1.) See ASTM E380, Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System), and ANSI/IEEE 268, American National Standard for Metric Practice.

A-1-8 Approved. The National Fire Protection Association 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-1-8 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-1-8 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-1-8 Point of Safety. The egress population to be served should be determined by engineering analysis.

A-2-5 Protection of related ancillary facilities such as service areas, rest areas, toll booths/plazas, pump stations/substations, and buildings used for administration, law enforcement, and maintenance presents problems that are not basically different from the fire protection problems of all such buildings. However, special consideration should be given to the fact that, or adjacent to, limited access highways, such buildings might be located in isolated areas. (See NFPA 30, Flammable and Combustible Liquids Code, and NFPA 30A, Automotive and Marine Service Station Code, for service stations.)

A-3-5 See A-2-5.

A-4-4 Radio communication systems, such as highway advisory radio (HAR) and AM/FM commercial station overrides, can be provided for the motorist as communications routes for all facilities and can provide identification of the emergency and actions the motorist shall take. All messaging systems should be capable of real time composition and selection by the emergency response authority and should not be of the recorded type. Areas of refuge or assembly, if available, should be provided with reliable two-way voice communication to the emergency response authority.

A-4-8 Consideration should be given to incorporating removal detection of an extinguisher into the alarm system.

A-4-11 See A-2-5.

A-6-1.1 Text for this section will be included in the Report on Comments.

A-7-1.1 Text for this section will be included in the Report on Comments.

A-7-7 Text for this section will be included in the Report on Comments.

A-8-4 It is expected that the operations of all systems within the vicinity of a fire will fail. This requirement is intended to limit the area of such failure.

<table>
<thead>
<tr>
<th>Table A-1-7.1 Conversion Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>units</td>
</tr>
<tr>
<td>1 inch</td>
</tr>
<tr>
<td>1 foot</td>
</tr>
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<td>1 square foot</td>
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<tr>
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<tr>
<td>1 cubic foot per minute</td>
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<td>1 gallon per minute</td>
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<tr>
<td>1 pound</td>
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<tr>
<td>1 degree Rankine</td>
</tr>
<tr>
<td>1 Btu per pound degree R</td>
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<tr>
<td>1 Btu per pound degree R</td>
</tr>
</tbody>
</table>

NFPA 502 — A98 ROP
Appendix B Temperature and Velocity Criteria

This appendix is not part of the requirements of this NFPA document but is included for informational purposes only.

B-1 General.

B-1.1 In this appendix, criteria for the protection of the motorist, employee, and fire fighter during emergency situations are provided with regard to air temperature and velocity.

B-1.2 To a large extent, the quantitative aspects of the criteria for emergency situations is arbitrary because there are no universally accepted tolerance limits pertaining to air temperature and velocity. In fact, tolerance limits vary with age, health, weight, sex, and acclimatization.

B-2 Air Temperature Criteria.

B-2.1 Motorists should not be exposed to maximum air temperatures exceeding 140°F (60°C) during emergencies. It is anticipated that the 140°F (60°C) air temperature will place a physiological burden on a few motorists, but the exposure also is anticipated to be brief and to produce no lasting harmful effects.

B-2.2 Studies of the severity of tunnel fires with respect to human environmental criteria demonstrate that the air temperature in the absence of toxic smoke is a limiting criterion for human survival.

B-3 Air Velocity Criteria.

B-3.1 The purpose of ventilation equipment in a tunnel emergency is to sweep out heated air and to remove smoke caused by any fire. In essentially all emergency cases, protection of the motorists and employees is enhanced by prompt activation of emergency ventilation procedures as planned in advance.

B-3.2 When ventilation air is needed in evacuation routes, it might be necessary to expose motorists to high air velocities. The only upper limit to the ventilation air velocity becomes great enough to create a hazard to persons walking in that airstream. According to descriptions of the effects of various air velocities given in the Beaufort scale, motorists under emergency conditions can tolerate as much as 2200 ft/min (11 m/s).

B-3.3 The minimum air velocity within the tunnel section experiencing the fire emergency should be sufficient to mitigate backlayering of the smoke (i.e., a flow of smoke in the upper cross section of the tunnel that is opposite in direction to the forced ventilation air).

B-3.4 Increasing the airflow rate in the tunnel decreases the airborne concentration of potentially harmful chemical compounds (referred to hereinafter by the general term "smoke"). The decrease in concentration is beneficial to those exposed to the compounds. However, a situation could arise in which the smoke source is completely removed and poses no threat of exposure to motorists, and actuating any fans would draw the smoke to the evacuation routes. Under these conditions, the fans should not be activated until it is safe to do so. To make decisions under these circumstances, a rapid and thorough communication system is needed so that the responsible personnel can make judgments based on information available that are consistent with established emergency policies.

B-3.5 The effectiveness of an emergency ventilation system in providing a sufficient quantity of noncontaminated air and in minimizing the hazard of smoke backlayering in an evacuation pathway is a function of the fire load. The fire load in a tunnel results from the burning rate of a vehicle(s), which, in turn, is a function of the combustible load in Btu of the vehicle.

Appendix C Critical Velocity Calculations

This appendix is not part of the requirements of this NFPA document but is included for informational purposes only.

C-1. The simultaneous solution of equations C-1 and C-2, by iteration, determines the critical velocity. The critical velocity is the minimum steady-state velocity of the ventilation air moving toward the fire that is necessary to prevent backlayering, as shown in the following equations:

\[ V_c = \left( \frac{g HQ}{r cp AT_f} \right)^{1/3} \]  
\[ T_f = \left( \frac{Q}{\rho c p A_c} \right) + T \]

where:

- \( A \) = area perpendicular to the flow \([\text{ft}^2 (\text{m}^2)]\)
- \( C_p \) = specific heat of air \([\text{Btu/\text{lb R} (kJ/kg K)}]\)
- \( g \) = acceleration caused by gravity \([\text{ft/\text{sec-sec} (m/s-s)}]\)
- \( H \) = height of the duct or tunnel at the fire site \([\text{ft (m)}]\)
- \( K_I \) = 0.606
- \( K_g \) = grade factor (see Figure C-1)
- \( Q \) = heat the fire is adding directly to the air at the fire site \([\text{Btu/sec (MW)}]\)
- \( T \) = temperature of the approach air \([\text{degrees R (K)}]\)
- \( T_f \) = average temperature of the fire site gases \([\text{degrees R (K)}]\)
- \( V_c \) = critical velocity \([\text{ft/min (m/s)}]\)
- \( \rho \) = average density of the approach (upstream) air \([\text{lb/ft}^3 (\text{kg/m}^3)]\)
Appendix D Fire Sprinklers in Road Tunnels

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

D-1 General. This appendix provides design considerations for fire sprinklers in road tunnels.

D-1.1 Currently, the use of and effectiveness of fire sprinklers in vehicular roadway tunnels is not universally accepted. Although it is acknowledged that sprinklers are highly regarded by fire protection professionals and fire departments in certain types of structures, there is much evidence to suggest that sprinklers are not only ineffective in controlling a fuel fire but can actually contribute to the spread or severity of the fire. Furthermore, it is felt that vehicular tunnel conditions cannot exploit sprinkler system strengths and could turn most of their advantages into disadvantages.

D-1.2 The major concerns expressed by tunnel authorities regarding fire sprinkler use and effectiveness include the following:

(a) Typical fires usually occur under vehicles or inside passenger or engine compartments designed to be waterproof from above; therefore, overhead sprinklers would have no extinguishing effect.

(b) A thin water spray on a very hot fire, if any delay occurs between ignition and sprinkler activation, will produce large quantities of superheated steam without materially suppressing the fire. This steam has the potential to be more damaging than smoke.

(c) Tunnels are very long and narrow, often sloped laterally and longitudinally, vigorously ventilated, and never subdivided, so heat normally will not be localized over a fire.

(d) Because of stratification of the hot gases plume along the tunnel ceiling, a number of the activated sprinklers would not, in all probability, be located over the fire. A large number of the activated sprinklers would be located away from the fire scene, producing a cooling effect that would tend to draw this stratified layer of smoke down toward the roadway level.

(e) Even a light spray from sprinklers would catch motorists unaware and would be in excess of that which windshield wipers could clear (even if they were on), possibly causing the roadway to become dangerously slippery.

(f) Water squirting from the ceiling of a subaqueous tunnel could suggest tunnel failure and induce panic in motorists.

(g) The use of sprinklers could cause the delamination of the smoke layer and induce turbulence and mixing of the air and smoke, thus threatening the safety of persons in the tunnel.

(h) Testing of a fire sprinkler system on a periodic basis to determine its state of readiness is impractical and costly.

D-1.3 Because of the concerns detailed in D-1.2, the use of sprinklers in road tunnels generally is not recommended. However, the following three recently commissioned U.S. road tunnels have been equipped with sprinkler systems: the Central Artery North Area (CANA) Route 1 tunnel in Boston, MA, and the I-90 First Hill Mercer Island and Mt. Baker Ridge tunnels in Seattle, WA. The decision to provide sprinklers in these tunnels was motivated solely by the fact that these tunnels will be operated to allow the unescorted passage of vehicles carrying/hauling hazardous cargo.

D-2 Application. The installation of sprinkler systems should be considered applicable only where the passage of hazardous cargo is considered. However, even in these cases, the tunnel operator and the local fire department or authority having jurisdiction should consider the advantages and disadvantages of such systems as they apply to a particular tunnel installation.

D-3 Extinguishing Agent. AFFF (aqueous film-forming foam) systems should be considered for in-tunnel sprinkler systems in lieu of water-only systems. Water-only sprinkler systems pose significant concerns where applied to roadway tunnels. The high water demand rate needs to be available from the local supply, and in-tunnel drainage piping, storage, and pumping systems all become much larger. Additionally, after deluge, the possibility of vapor explosion is dangerously increased. The strong cooling effect of a water-only system reduces the ability of the smoke to stratify at the ceiling, where it can be contained more easily by the tunnel ventilation system, and instead causes the smoke to spread over the cross section of the incident area.
D-4 Sprinkler System. To help ensure against accidental discharge, the sprinkler system should be designed as a manually activated deluge system. The sprinkler system piping should be arranged using interval zoning so that the discharge can be focused on the area of incident without necessitating discharge for the entire length of the tunnel. Each zone should be equipped with its own proportioning valve set to control the appropriate water/foam mixture percentage. Sprinkler heads should provide an open deluge and be spaced so that coverage extends to roadway shoulders and, if applicable, maintenance/patrol walkways. The system should be designed with enough water and foam capacity to allow operation of at least two zones adjacent to the incident zone if the fire occurs in a "border" area. Zone length should be based on activation time as determined by the authorities having jurisdiction. Piping should be designed to allow drainage through heads after flow is stopped.

D-5 System Control. It can be assumed that a full-time, attended control room is available for any tunnel facility in which safe passage necessitates the need for sprinkler system protection. Therefore, consideration should be given to human interaction in the sprinkler system control and activation design to ensure against false alarm and accidental discharge. Any automatic mode of operation should include a discharge delay to allow incident verification and assessment of in-tunnel conditions by trained operators.

D.5.1 An integrated graphic display of the sprinkler system zones, fire detection system zones, tunnel ventilation system limits, and emergency access and egress locations should be provided at the control room to allow tunnel operators and responding emergency personnel to make initial response decisions.

Appendix E Emergency Response Plan Outline

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

E-1 Outline. The following outline is for a typical emergency response plan.

1 General
1.1 Purpose
1.2 Background
2 Emergency response plan
2.1 General
2.2 Elements of the plan
2.2.1 Central supervising station (CSS)
2.2.2 Alternate CSS
2.2.3 Incident/activity identification systems
2.2.4 Emergency command posts
2.5 Operational considerations
2.4 Types of incidents
2.5 Possible locations of incidents
2.6 Incidents on approach roadways
2.7 Incidents within tunnel or facility
3 Coordination with other responsible agencies
3.1 Fire-fighting operational procedures
3.2 Traffic management
3.5 Medical evacuation plan
3.4 Emergency alert notification plan

Appendix F Alternative Fuels

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

F-1 General. Most vehicles currently in the United States traffic population are powered by either spark-ignited (gasoline) or compression-ignited engines (diesel). Vehicles that use alternative fuels such as compressed natural gas (CNG), liquefied petroleum gas (LPG), and liquefied natural gas (LNG) are being introduced into the vehicle population, but their percentage of the population is still too low for their characteristics to be a significant influence in the design of road tunnel ventilation with regard to vehicle emissions. However, growing concerns regarding the safety of some of these vehicles operating within road tunnels might soon affect the fire-related life safety design aspects of highway tunnels. For the requirements of road tunnel ventilation during fire emergencies see Chapter 7.

It is evident that there will be continued growth in the use of vehicles powered by alternative fuels (i.e., fuels other than gasoline or diesel). Of these potential alternative fuels, LPG currently is the most widely used, although the use of both CNG and LNG are growing. The American Gas Association estimates that by the year 2000, approximately 50 percent of the 16 million fleet vehicles in the United States will be powered by alternative fuels such as CNG. Under the Energy Policy Act of 1992 and the Clean Air Act Amendment of 1990, the following are considered potential alternative fuels:

(a) Methanol
(b) Hydrogen
(c) Ethanol
(d) Coal-derived liquids
(e) Propane
(f) Biological materials
(g) Natural gas
(h) Reformed gasoline
(i) Electricity
(j) "Clean" diesel

The alternative fuels considered most viable in the near future are CNG, LPG, LNG, and methanol.

F-2 Compressed Natural Gas. CNG has some excellent physical and chemical properties that make it clearly a safer automotive fuel than gasoline or LPG, provided well-designed carrier systems and operational procedures are followed. Although CNG has a relatively high flammability limit, its flammability range is relatively narrow compared to the ranges for other fuels.

In air at ambient conditions, a CNG volume of at least 5 percent is necessary to support continuous flame propagation, compared to about 2 percent for LPG and 1 percent for gasoline vapor. Thus, considerable fuel leakage is necessary in order to produce the mixture combushtable. Moreover, fires involving combustible mixtures of CNG are relatively easy to contain and extinguish.

Since natural gas is lighter than air, in the event of a leak, it normally dissipates harmlessly into the atmosphere instead of pooling. However, in a tunnel environment, this can lead to pockets of gas collecting in the overhead structure. Also, since natural gas can ignite only in a range of 5 percent to 15 percent volume of natural gas in air, leaks are not likely to ignite because of a lack of sufficient oxygen.

Additionally, the fueling system for CNG is one of the safest in existence. The vigorous storage requirements and greater strength of CNG cylinders compared to those of gasoline contribute to the superior safety record of CNG automobiles.

F-3 Liquefied Petroleum Gas. There is a growing awareness of the economic advantages of using LPG as a vehicular fuel. These advantages include longer engine life, increased travel time between oil and oil filter changes, longer and better performance from spark plugs, nonpolluting exhaust emissions, and, in most cases, mileage comparable to that of gasoline. LPG normally is delivered as a liquid and can be stored at 100.4°F (38°C) on vehicles under a design pressure of 250 psi to 312.5 psi (1624 kPa to 2154 kPa). It is a natural gas and petroleum derivative. On one hand, it is costly to store because a pressure vessel is required. On the other hand, if engulfed in a fire, its heating could result in a rapid increase in pressure, even if the outside temperature is not excessive relative to its vapor pressure characteristics. Rapid pressure increase can be mitigated by venting the excessive buildup of pressure through appropriate relief valves.

F-4 Methanol (Alcohol-Fueled Vehicles). Currently, methanol is used primarily as a chemical feedstock for the production of chemical intermediates and solvents. Under the EPA's restrictions, it is being used as a substitute for lead-based octane enhancers in the form of methyl tertiary-butyl ether (MTBE) and...
The hazards of methanol production, distribution, and use are comparable to those of gasoline. Unlike gasoline, however, methanol vapors in a fuel tank are explosive at normal ambient temperature. Saturated vapors above nondiluted methanol in an enclosed tank are explosive at 50°F to 109.4°F (10°C to 42°C). A methanol flame is invisible, so a colorant or gasoline has to be added to enable detection.

F-5 Mitigation Measures. As the use of alternative fuels in road vehicles has gradually increased, each road tunnel operating agency has dealt with the issue of whether to allow vehicles through the tunnels for which it is responsible. Most road tunnel agencies throughout the world do allow the passage of alternative fueled vehicles.

The mitigation measures that can be taken by the road tunnel designer relate primarily to the ventilation system, which, in most circumstances, can provide sufficient air to dilute the fuel below any hazardous levels. It might be necessary to establish a minimum level of ventilation to provide this dilution under all circumstances. Other measures are to reduce or eliminate any irregular surfaces of the tunnel ceiling or structure where a pocket of gas could collect and remain undiluted, thus posing a potential explosive hazard.

Appendix G The Memorial Tunnel Fire Ventilation Test Program

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

G-1 General. The primary purpose for controlling smoke in a tunnel is to protect life (i.e., to allow safe evacuation of the tunnel). This involves creating a safe evacuation path for both motorists and any operating personnel located within the tunnel. The secondary purpose of smoke control ventilation is to assist firefighting personnel in accessing the fire site by again providing a clear path to the fire site, if possible.

The tunnel ventilation system is not designed to protect property, although the effect of ventilation in diluting smoke and heated gases, which removes some of the heat, results in reduced effects of fire size, tunnel grade and cross section, direction of traffic flow (unidirectional or bidirectional), altitude, type of ventilation system, and any other parameters that could have a significant influence on determining the ventilation capacity and operational procedures needed for safety in a fire situation.

Establishing specific approaches to permit effective reconfiguration for both new and existing tunnel facilities was deemed of equal importance. The goals and test matrices developed and documented in the Phase 1 concept report evolved into the test plan described below.

The purpose of the Memorial Tunnel Fire Ventilation Test Program was to develop a database that provides tunnel design engineers and operators with an experimentally proven means to determine the ventilation rates and ventilation system configurations that provide effective smoke control and/or removal during a tunnel fire emergency.

It was even more important to establish specific operational strategies to permit effective reconfiguration of ventilation parameters for existing tunnel facilities. While the life safety issue is paramount, it should be recognized that significant cost differentials exist among the various types of ventilation systems. In the instance where more than one ventilation configuration offers an acceptable level of fire safety, the project's overall life cycle cost needs to be addressed to identify the option with the optimum cost benefit.

In addition, the impact of ventilation systems that cause horizontal roadway airflow on the effectiveness of fire suppression systems (such as foam deluge sprinklers) can be better determined on the basis of full-scale tests.

The Memorial Tunnel is a two-lane, 2800-ft (850-m) highway tunnel located near Charleston, WV, originally built in 1928 as part of the West Virginia Turnpike (I-77). The tunnel has a 5.2 percent uphill grade from the south to the north tunnel portal. The original ventilation system was a transverse fan, consisting of a supply fan chamber at the south portal and an exhaust fan chamber at the north portal.

The tunnel has been out of service since it was bypassed by an open-cut section of a new six-lane interstate highway in 1987. The existing ventilation equipment was removed to allow installation of a variable speed, reversible, axial flow central ventilation fan. The equipment rooms were modified to accept the ventilation components needed to allow supply or exhaust operation from both ends of the tunnel.

There are six fans, three each in the modified north and south portal rooms. Each of the fans has a capacity to supply or exhaust 200,000 cfm (94.4 m³/s), and they are fitted with vertical discharges to direct the smoke away from the test facility and the nearby Interstate highway.

The existing overhead air duct, formed by a concrete ceiling above the roadway, is split into longitudinal sections that can serve as either supply or exhaust ducts, and a mid-tunnel duct bulkhead has been installed to allow a two-zone ventilation operation. Openings in the duct dividing wall and duct bulkhead have been designed to create airflow patterns similar to those that would be observed if the dividing wall was not present. The width of the ducts varies linearly along the length of the tunnel to provide maximum area at the point of connection to the fan rooms above the tunnel portals.

High temperature insulation was applied extensively to various structural elements, including the concrete ceiling and ceiling hangers, as well as all the utilities, instrumentation support systems, wiring, gas sampling lines, CCTV camera cabinets, and all other related items that are exposed to high tunnel fire temperatures.

G-5 Fire Size. Fires with heat release rates ranging from 20 MW — equivalent to a hazmat spill of approximately 100 gal (400 L) — to 100 MW — equivalent to a flammable liquid spill of approximately 200 gal (800 L) — were produced. The fires were generated in floor-level steel pans.

The actual burning rate differed somewhat from that used for the engineering estimate, due to effects such as heat reradiation from the tunnel walls and varying ventilation flow rates.
Therefore, the measured tunnel conditions were interpreted to
determine a measured heat release rate. The ventilation systems
configured and tested under varying flow rates and varying heat
release rates, with one or two zones of ventilation, included the
following:

(a) Transverse ventilation
(b) Partial transverse ventilation
(c) Transverse ventilation with point extraction
(d) Transverse ventilation with oversized exhaust ports
(e) Natural ventilation
(f) Longitudinal ventilation with jet fans

When the first four series of tests in Section G-5 (a) through (f)
were completed, the tunnel ceiling was removed to conduct the
natural ventilation tests, followed by the installation of jet fans at
the crown of the tunnel for the longitudinal jet fan-based
ventilation tests.

A fire suppression system that was available to suppress the fire
in an emergency was installed; however, it was also used during
several tests to evaluate the impact of ventilation airflow on the
operation of a foam suppression system.

G-6 Data Collection. All of the measured values were entered
into a data acquisition system (DAS) that monitored and
recorded data from all field instruments for on-line and historical
use.

The measurement of tunnel air temperature was accomplished
through the use of thermocouples located at various cross
sections throughout the length of the tunnel.

In total, there were approximately 1450 instrumentation
sensing points. Each sensing point was monitored and recorded
once every second during a test, which lasted from 20 minutes to
45 minutes.

Approximately 4 million data points were recorded during a
single test. All test data was recorded on tapes in a control center
trailer, where control operators monitored and controlled each
test.

There were instrument trees located at 10 tunnel cross
sections, which were designed to measure airflow using a modified
ASHRAE traverse method. Additional temperature measurements
were taken at five other tunnel cross sections and at two locations
outside of the tunnel portals. The measurement of airflow velocity
in the tunnel under test conditions was accomplished through the
use of differential pressure instrumentation. Temperatures in the
vicinity of the bidirectional pilot tubes and the ambient pressure
were combined with the measured pressure to calculate the air
velocity.

A gas sampling system extracted sample gas from specific
tunnel locations to analysis cabinets located in the electrical
equipment rooms. Sample gases were analyzed within the
analytical cabinets for CO, CO₂, and total hydrocarbon content
(THC). The analyzers were housed in climate-controlled

To ensure personnel safety, methane gas could be detected at
the test fire location through the use of individual in-situ
electromechanical cell-type analyzers at the control trailer. In
addition, portable detectors capable of detecting carbon
monoxide, total hydrocarbon, oxygen, and methane were
provided for personnel safety when entering the tunnel after fire
tests.

Two meteorological towers located outside of the north and
south tunnel portals include instrumentation that monitored and
recorded ambient dry and wet bulb air temperatures, barometric
pressure, wind speed, and wind direction.

These weather-related parameters were monitored for over 1 1/2
years to track weather conditions to assist in planning,
scheduling, and conducting the tests.

The closed-circuit television (CCTV) system originally
included six cameras, two located within the tunnel, two located
outside of the tunnel (near the portals), and two located on the
north and south meteorological towers. Another roadway-level
camera was added during the tests north of the fire to secure
added video footage of smoke movement.

G-7 Conclusions. The Memorial Tunnel Fire Ventilation Test
Program represents a unique opportunity to evaluate and develop
design methods and operational strategies leading to safe
underground transportation facilities. This comprehensive test
program, which began with the initial fire tests in September 1993
and concluded with the final tests in March 1995, produced data
that was acquired in a full-size facility, under controlled
conditions and over a wide range of system parameters.

The findings and conclusions are summarized below
categorized by ventilation system type.

(a) Longitudinal Tunnel Ventilation Systems.

A longitudinal ventilation system employing jet fans is highly
effective in managing the direction of the spread of smoke for
fires sizes up to 100 MW in a 3.2 percent grade tunnel.

The throttling effect of the fire must be taken into account in the
design of a jet fan longitudinal ventilation system.

Jet fans located 170 feet (51.8 meters) downstream of the fire
were subjected to the following temperatures for the tested fire
sizes:

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Fire Size (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 °F (204 °C)</td>
<td>20 MW</td>
</tr>
<tr>
<td>630 °F (322 °C)</td>
<td>50 MW</td>
</tr>
<tr>
<td>1250 °F (677 °C)</td>
<td>100 MW</td>
</tr>
</tbody>
</table>

Air velocities of 500 to 580 fpm (2.54 to 2.95 m/s) were
sufficient to preclude the backlayering of smoke in the Memorial
Tunnel for fire tests ranging in size from 10 MW to 100 MW.

(b) Transverse Tunnel Ventilation Systems.

It has been standard practice in the tunnel ventilation industry
to design tunnel ventilation systems for fire emergencies based on
fire capacities expressed in cfm/ lane foot (m³/s/ lane meter).

However, the MTFVTP demonstrated the longitudinal airflow
is a major factor in the ability of a ventilation system to manage
and control the movement of smoke and heated gases generated in
a fire emergency.

It was demonstrated in the MTFVTP that dilution as a sole
means for temperature and smoke control was not very effective.

Some means of extraction should be incorporated. Extraction
and longitudinal airflow when combined can significantly
increase the effectiveness of a road tunnel ventilation system to
manage and control the movement of smoke.

(c) Single-Zone Transverse Ventilation Systems.

Single-zone balanced full transverse ventilation systems operated
at 100 cfm/lf (0.155 m³/s/Im) were ineffective in management of
smoke and heated gases for fire sizes 20 MW and larger.

Single-zone unbalanced full transverse ventilation systems
generate some longitudinal airflow in the roadway. The result of
this longitudinal airflow was to offset some of the effects of
buoyancy for a 20 MW fire. The effectiveness of unbalanced full
transverse ventilation systems is sensitive to the fire location,
since there is no control over the airflow direction.

(d) Multiple-Zone Transverse Ventilation Systems.

The two-zone transverse ventilation system tested in the
MTFVTP provided control over the direction and magnitude of
the longitudinal airflow. Airflow rates of 100 cfm/lf (0.155
m³/s/Im) contained high temperatures from a 20-MW fire within
100 ft (31 m) of the fire in the lower elevations of the roadway
and smoke within 90 ft (27 m).

(e) Smoke and Heated Gas Movement.

The spread of hot gases and smoke was significantly greater with
a longer fan response time. Hot smoke layers were observed to
spread very quickly — 1600 to 1900 feet (490 to 580 meters) in the
initial two minutes of a fire.
Natural ventilation resulted in extensive spread of smoke and heated gases upgrade of the fire, but relatively clear conditions downgrade of the fire. The spread of smoke and heated gases during a 50-MW fire was considerably greater than for a 20-MW fire. The depth of the smoke layer increased with fire size.

A significant difference was observed in smoke spread with the ceiling removed (arched tunnel roof) and the ceiling in place. The smoke and hot gas layer, migrating along the arched tunnel roof, did not descend into the roadways quickly as in the tests conducted with the ceiling in place. Therefore, the time for the smoke layer to descend to a point where it poses an immediate life safety threat is dependent on the fire size and tunnel geometry, specifically the tunnel height. In the Memorial Tunnel, smoke traveled between 950 ft and 1200 ft (290 m and 365 m) along the arched tunnel roof before cooling and descending into the roadway.

The restriction to visibility caused by the movement of smoke occurs more quickly than does a temperature high enough to be debilitating. Exposure to high levels of carbon monoxide was never more critical than smoke or temperature for any test.

The effectiveness of the foam suppression system (AFFF) tested was not diminished by operation in high-velocity longitudinal airflow [800 fpm (4 m/s)]. The time for the suppression system to extinguish the fire with the nozzles located at the ceiling, ranged from 5 seconds to 75 seconds.

The maximum temperatures experienced at the inlet to the central fans closest to the fire, at approximately 700 ft (213 m) from the fire, were as follows for the tested fire sizes:

- 225°F (107°C) 20 MW
- 255°F (124°C) 50 MW
- 285°F (163°C) 100 MW

In a road tunnel, smoke management requires either direct extraction at the fire location or the generation of a longitudinal airflow in the tunnel capable of transporting the smoke and heated gases in the desired direction to a point of extraction or discharge from the tunnel. Without a smoke management system, the direction and rate of movement of the smoke and heated gases will be determined by fire size, tunnel grade (if any), prefire conditions, and external meteorological conditions.

(1) Enhancements.

The ability to extract smoke quickly and as close as possible to the fire location can significantly reduce smoke and heated gas migration in undesired directions and facilitate two-way traffic operations. This localized extraction is possible with the application of single point extraction openings (SPE) and oversized exhaust ports (OEP) to transverse ventilation systems.

Single point extraction systems are applicable to two-way traffic flow with a dependency on the location, size, and spacing of the SPE openings. Smoke and heat drawn from the fire to the SPE could pass over or possibly around stalled traffic and vehicle occupants. An SPE located upgradient of the fire is very effective in temperature and smoke management. With the SPE located downgradient of the fire, only minimal improvement in temperature and smoke conditions over a single-zone partial transverse exhaust system was achieved.

A single point opening of 300 ft² (27.9 m²) was most effective in temperature and smoke management of the SPE sizes tested. Significantly greater smoke and heat spread was observed with a 100 ft² (9.3 m²) opening, compared to the 300-8 ft² (27.9 m²) opening.

In the one test in which two single point openings north of the fire were utilized, a stagnation zone was formed, resulting in smoke accumulation between the extraction openings.

For 20-MW fires, partial transverse ventilation exhaust ventilation operated with 100 cfm/ft² (0.170 m³/s/m²) and supplemented with a large [300 ft² (27.9 m²)] single-point opening limited smoke and heated gases migration to 200 ft (61 m) from the fire. A partial transverse exhaust system supplemented with oversized exhaust ports and operated with 85 cfm/ft² (0.132 m³/s/m²) limited high temperatures to 100 ft (31 m) from the fire and sustained the smoke layer above the occupied zone.

For 50-MW fires, partial transverse ventilation exhaust ventilation operated with 110 cfm/ft² (0.170 m³/s/m²) and supplemented with a large [500 ft² (27.9 m²)] single-point opening limited smoke and heated gases migration to 280 ft (85 m) from the fire.

The results of the test program were processed and made available to the professional community for use in the development of emergency tunnel ventilation design and emergency operational procedures in late 1995, in a report titled "Memorial Tunnel Fire Ventilation Test Program Test Report," for the Massachusetts Highway Department, by Bechtel/Parsons Brinckerhoff. In addition, there was a comprehensive test report prepared. This report is reproduced and available in a CD-ROM format.

Appendix H Tunnel Ventilation System Concepts

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

H-1 General. Ventilation is required in most road tunnels to limit the concentrations of contaminants to acceptable levels within the traveled roadway. These systems can also be used to control smoke and heated gases generated during a fire emergency in the tunnel. There are some short tunnels that are ventilated naturally (without fans); however, such tunnels can require ventilation to combat a fire emergency.

H-1.1 This appendix is included in this standard to provide the fire protection engineer with a clear understanding of the various ventilation system concepts usually employed in the ventilation of road tunnels.

H-1.2 The systems used for mechanical or fan-driven ventilation can be classified as longitudinal or transverse. The longitudinal ventilation system achieves its objectives through the longitudinal flow of air within the roadway, while the transverse system achieves objectives through the uniform distribution and/or collection of air continuously throughout the length of the tunnel. The transverse ventilation system also experiences some longitudinal airflow; the quantity depends on the type of system.

H-2 Longitudinal Ventilation Systems.

H-2.1 Longitudinal ventilation is a system in which the air is ingressed into or removed from the tunnel roadway at a limited number of points such as a portal or a shaft, thus creating a longitudinal flow of air within the roadway with discharge at the exiting portal. (See Figure H-1.)

H-2.2 Longitudinal ventilation systems can be further classified into those using central fans [see Figures H-1(a), (c), and (d)] and those employing local fans or jet fans [see Figure H-1(b)].

H-2.2.1 Central fan longitudinal ventilation systems employ centrally located fans to inject air into the roadway, usually through a high-velocity nozzle or Saccardo nozzle. This injection of air can take place at the entering portal or in midtunnel [see Figure H-1(a)]. Both concepts can provide the required longitudinal ventilation within the tunnel. An exhaust shaft can be combined with the injection nozzle as shown in Figure H-1(c).

H-2.2.2 Jet fan-based longitudinal ventilation employs a series of axial fans mounted at the ceiling level of the tunnel roadway [see Figure H-1(b)]. These fans, through the effects of the high-velocity discharge, induce a total longitudinal airflow through the length of the tunnel.

H-2.3 In all longitudinal ventilation systems, the exhaust gas stream (pollutants or smoke) will discharge from the exit portal.

H-3 Transverse Ventilation Systems.

H-3.1 Transverse ventilation systems are those that feature the uniform collection or distribution of air throughout the length of the tunnel. There are both full transverse and semitransverse systems. In addition, there are both supply and exhaust versions of semitransverse systems.

H-3.1.1 Full transverse systems have both supply and exhaust systems throughout the length of the tunnel [see Figure H-2(a)]. When a full transverse system is deployed, the majority of the
pollutants or smoke will be discharged through a stack, with a minor portion of the pollutants or smoke exiting through the portals. A full transverse ventilation system can be either balanced (exhaust = supply) or unbalanced (exhaust > supply).

H-3.1.2 Semitransverse systems are those that have only supply or exhaust elements. The effluent exhaust from the tunnel is discharged at either the portals (supply semitransverse, see Figure H-2(b)) or through stacks (exhaust semitransverse, see Figure H-2(c)).

Figure H-1 Longitudinal ventilation system.

Appendix I Fire Apparatus

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

I-1 General. Fire apparatus suitable for fighting fires within the facilities covered by this standard should be available within the general facility area, thus permitting a rapid response to a fire emergency. This apparatus should be equipped to deal effectively with flammable liquid and hazardous material fires.

I-2 Capacity. The responding fire apparatus should be appropriately equipped to fight fire within the tunnel for a minimum of 30 minutes. If water supply is not available, suitable arrangements should be made to transport water so that the required apparatus delivery rate at the fire can be maintained for an additional 45 minutes.

I-3 Extinguishers. These fire-fighting units should carry multipurpose, dry chemical extinguishers and an extinguishing agent for Class D metal fires.

I-4 Bridges and Elevated Highways. Fire apparatus arranged for use on bridges and elevated highways should be equipped ladders for use by fire fighters where bridges and elevated highway structures are accessible from beneath.

I-4.1 The design of apparatus intended for use only on bridges or elevated highway structures should be based on the conditions to be encountered.

I-5 Road Tunnels. Where the tunnel is a high-capacity facility in a congested urban area, it could be appropriate to house such apparatus at the tunnel portal(s). It could also be appropriate at these urban tunnels to combine the fire apparatus with the apparatus provided to effect retrieval and removal of disabled vehicles from the tunnel.

I-6 Emergency Response Planning. Arrangements for the response of nearby fire companies and emergency squads should be made a part of the emergency response planning process (see Chapter 9). Means of access that allows the entrance of outside aid companies to the facility should be provided, and procedures for utilizing such access should be included in the emergency response plan. Appropriate precautions should be taken at these points of entry to alert and control traffic to allow safe entrance by emergency equipment.

Figure H-2 Transverse ventilation system.
Appendix K Bibliography

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

K-1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, F.O. Box 9101, Quincy, MA 92269-9101.


K-2 Other Publications.


PART II

512-1 - (Entire Document): Accept

SUBMITTER: Technical Committee on Motor Vehicle and Highway Fire Protection

RECOMMENDATION:


SUBSTANTIATION:

At the time it was initially published in 1952, NFPA 512, Truck Fire Protection, represented the best available compilation of fire protection and fire prevention information for commercial vehicles. Since then the reliability and durability of trucks, themselves has improved dramatically and many problems formerly creating the potential for fires have been significantly mitigated.

Fire hazards affecting trucks have also been reduced with the incorporation of fire-safety provisions in the Federal Motor Vehicle Safety Standards of the U.S. Department of Transportation. Fire safety provisions of the Department's Federal Motor Carrier Safety Regulations have now been adopted by all of the states and are applicable to vehicles operating in both interstate and intrastate commerce.

All operators of commercial vehicles must comply with these governmental standards which are also addressed in NFPA 512. In this light, NFPA 512 is redundant and no longer performs a useful function.

Fire safety on the nation's highways will not be adversely affected by the withdrawal of this standard.

COMMITTEE ACTION: Accept.

512-2 - (3-2): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION:

Add appropriate references to other alternative fuels for which NFPA standards exist in a manner similar to the reference to NFPA 58 in 3-2.3.

SUBSTANTIATION:

Provisions of the Clean Air Act require the use of alternative fuels by centrally-fueled fleets for light and some medium-duty vehicles. While the use of alternative fuels is not yet widespread, use will probably increase in the future and should be addressed.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CP1) that recommends the withdrawal of NFPA 512.

512-3 - (3-3.4): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION:

Revise text as follows:

"In the event that a driver discovers an overheated tire, he/she shall stop immediately and cause it to be removed from the vehicle to a safe distance. If the tire cannot be removed, the driver shall remain with the vehicle until the tire is cool to guard against fire. No tire which has been overheated shall be reinstalled unless properly repaired and found to retain its recommended inflation pressure. No such tire shall be placed anywhere in or on the vehicle unless it is cool to the touch."

SUBSTANTIATION:

The proposed revision is intended to more accurately address the applicable provisions of the Federal Motor Carrier Safety Regulations (397.17) and address real-world operating conditions.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CP1) that recommends the withdrawal of NFPA 512.

512-4 - (3-4): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION:

Amend title: Liquid-Burning-War to Flame-Producing Warning Signals - Liquid-burning Flares (Pot Torches) / Fuses.

Proposed revisions:

3-4.1 Liquid-burning flares (pot torches) shall be carried in a manner which will minimize the risk of fuel spillage. Mounting on the exterior of the vehicle is preferable. If carried in the cab of the vehicle, they shall be in a substantially constructed, rigidly

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closed container which will not be affected by the fuel, and so constructed as to resist overturning.

3.4.2 Fusees shall be stored in open racks or in a metal container used for no other purpose, in a location readily accessible to the driver. Fusees stored outside the driver's compartment shall be protected from the weather.

3.4.3 No lighted flame-producing warning signal shall be attached to any part of a motor vehicle.

3.4.4 No lighted flame-producing warning signal shall be used in close proximity to leaking or spilled flammable or combustible liquids, or leaking flammable gases.

3.4.5 No flame-producing warning signal shall be carried on or used in the vicinity of a motor vehicle using a flammable gas for propulsion or the operation of auxiliary equipment; for transporting hazardous materials in any of the following divisions or classes: Divisions 1.1, 1.2, 1.3 (explosives); Cargo tanks used for transportation of Class 3 (flammable liquids), or Division 2.1 (flammable gases).

SUBSTANTIATION: Under a Congressional mandate, the U.S. Department of Transportation has reauthorized the use of these types of emergency warning devices in addition to reflective triangles. Therefore, revisions are needed to this section. See other proposals submitted by me.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-5 - (3.7.1): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: Revise text to read:

3.7.1 Refrigeration equipment (including combination refrigeration/heating units) shall be installed so as not to constitute a fire hazard to the vehicle or cargo.

SUBSTANTIATION: Needs updating to include use of the combination units in the trucking industry.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-6 - (3.7.2): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: In the last line, change the word "suction" to "transfer".

SUBSTANTIATION: This would make the section applicable regardless of the means of fuel transfer and would give broader application.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-7 - (4.3 (New)): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: Add a new section under Chapter 4. Except for a mention under Fueling, smoking is not addressed. There are a number of provisions used by motor carriers to minimize fires, and there are regulatory prohibitions affecting the transportation of hazardous materials. The following are proposed subsections:

4.3.1 Smoking shall be prohibited on or within the cargo space of any motor vehicle.

4.3.2 Smoking shall be prohibited on or within 25 ft of vehicles transporting hazardous materials in the following divisions and classes: Class 1 (explosives), Division 2.1 (flammable gases), Class 3 (flammable liquids), Division 4.1 (flammable solids), Division 4.2 (spontaneously combustible materials), Division 5.1 (oxidizers), Division 5.2 (organic peroxides); and, cargo tank vehicles which must be marked or placarded for the transportation of hazardous materials in Class 3 (flammable liquids), and Division 2.1 (flammable gases).

4.3.3 Discarding lighted smoking materials shall be prohibited from a moving vehicle.

4.3.4 Drivers who smoke shall be made aware of the hazard of lighted sparks being blown around in the driver's compartment and the potential for fire.

SUBSTANTIATION: The topic is addressed to a very limited extent.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-8 - (A-1-1): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: Amend reference to Federal Motor Carrier Safety Regulations to read:
49 CFR, Parts 300-399.

SUBSTANTIATION: To incorporate proper reference.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-9 - (A-2.2.2 (New)): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: Add new text:

"Personnel shall be trained in the special requirements for inspecting, loading, unloading and handling of packagings containing hazardous materials. Such packagings shall be handled with care and shall be loaded, blocked and braced to prevent movement under conditions normally incident to transportation. Hazardous materials of different divisions and classes shall not be loaded into or transported in a vehicle except as permitted by regulations governing segregation of hazardous materials (49 CFR 177.548)."

SUBSTANTIATION: The standard should incorporate better information on the special requirements governing hazardous materials transportation.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-10 - (A-3.4): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION: Revise text:

"For safety, convenience, reliability, and maintainability, reflective triangles meeting the provisions of Federal Motor Vehicle Safety Standard 108 (49 CFR 571.108) are preferable emergency warning devices for stopped vehicles. Although the use of flame-producing warning devices has been reauthorized by the U.S. Department of Transportation, such use should not be initiated without training as to proper procedures, regulatory restrictions, and associated hazards."

SUBSTANTIATION: The Surface Transportation Efficiency Act of 1992 required US DOT to give fuses and liquid-burning flares equal standing with reflective triangles in the Federal Motor Carrier Safety Regulations. US DOT implemented this Congressional mandate in 1993 despite opposition from the trucking industry and others.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.

512-11 - (Table A-4.2.2): Reject

SUBMITTER: Neill Darmstadter, American Trucking Assn.

RECOMMENDATION:
1. Delete material for A and AB extinguishers.
2. Delete references to Halon from information on BC and ABC extinguishers.

SUBSTANTIATION: 1. A and AB extinguishers are not authorized for use on trucks.
2. Halon is not an appropriate agent for truck fires and was never used to a significant degree in the trucking industry because of the high cost.

COMMITTEE ACTION: Reject.

COMMITTEE STATEMENT: See Committee Proposal 512-1 (Log #CPI) that recommends the withdrawal of NFPA 512.
PART III

513-1 - (1-1.7 (New)): Accept in Principle
SUBMITTER: Steven R. Shinners, Yellow Freight System, Inc.
RECOMMENDATION:
Add a new section as follows:
1-1.7 For outside fleet vehicle re-fueling refer to NFPA 30A, Flammable and Combustible Liquids Code for storage and handling limitations
SUBSTANTIATION: This is a hazardous area located outside at a Motor Freight Terminal. Reference to the applicable code should be added.
COMMITTEE ACTION: Accept in Principle.

513-2 - (4-2.4 (New)): Accept
SUBMITTER: Steven R. Shinners, Yellow Freight System, Inc.
RECOMMENDATION:
Add a new section as follows:
4-2.4 Storage areas for LP-Gas located in the Freight Transfer Area shall comply with NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases.
SUBSTANTIATION: Many Motor Freight Terminals now use LP-Gas for forklift fuel. Interior storage of LP-Gas in Freight Transfer Areas is being utilized at many Motor Freight Terminals. Storage limitations should comply with NFPA 58. Section 5-7 makes reference to storage of LP-Gas but Chapter 5 only incorporated Vehicle Maintenance and Service areas, not Freight Transfer Areas.
COMMITTEE ACTION: Accept.

513-3 - (A-2-1): Accept in Principle
SUBMITTER: Steven R. Shinners, Yellow Freight System, Inc.
RECOMMENDATION:
Add the following text to A-2-1:
Factors to be considered when determining maximum sizes of undivided fire areas are: (a) type of fire protection provided; (b) mechanical conveying equipment such as drag line operations; (c) surveillance of goods to prevent possible theft; and if the building has multiple 60 ft side yards adjacent the building.
SUBSTANTIATION: Large motor freight terminals require unlimited area to allow for visual operational supervision to ensure safe loading and unloading procedures are being followed. Many designs of large motor freight building are a canopy structure with no exterior walls allowing additional access for fire fighting equipment. The UBC Code allows for unlimited area where the entire building is surrounded by 60 ft yards.
COMMITTEE ACTION: Accept in Principle.

513-4 - (A-2-2): Accept
SUBMITTER: Steven R. Shinners, Yellow Freight System, Inc.
RECOMMENDATION:
Delete:
"Areas used for repairing and servicing vehicles should be located in separate buildings from the freight transfer building."
SUBSTANTIATION: This statement is in conflict with Section 2-2.1, Service areas that are not located in separate buildings shall be separated from other terminal operations by walls and doors in accordance with 2-1.1 through 2-1.3.
COMMITTEE ACTION: Accept.