CHIMNEYS

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1.0 SCOPE

This standard provides recommendations for eliminating or reducing damage to chimneys and related equipment caused by fire, explosion, lightning, wind, structural failure, and earthquake.

1.1 Changes

February 2010. This document was revised to include information on FM Approved chimney flue liner products.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 All Chimneys and Liners

2.1.1.1 Increase the height of an existing chimney only after expert consultation, since extra height can affect the stability of a chimney's shaft and foundation.

2.1.1.2 Consult a chimney specialist before adding new gas load, or raising or lowering the temperature of gas flowing to a chimney.

2.1.1.3 In order to prevent chimney cracking, avoid the addition of extra weight by erection of a structure near a chimney shaft foundation, unless specifically evaluated.

2.1.1.4 Whenever the type or concentration of an exhaust gas is to be changed, evaluate the resistance of the liner or chimney. If necessary, coat or reline the chimney with specially resistant materials.

2.1.2 Reinforced Concrete Chimneys

2.1.2.1 Design and construct the chimney shell in accordance with the latest edition of ACI 307. Design the chimney to meet wind requirements per Data Sheet 1-28, *Wind Design.*

2.1.3 Steel Chimneys

2.1.3.1 Design and erect the steel chimney per the applicable standards and specifications published by the American Institute of Steel Construction.

2.1.3.2 Design the chimney and its anchorage to resist wind pressures per the latest edition of ACI No. 307 Standard. Additionally, ensure the chimney meets the wind requirements in Data Sheet 1-28, *Wind Design.*

2.1.3.3 In cold climates, use steels with superior fracture resistance at low temperatures (such as ASTM A131).

2.1.3.4 For chimneys built of steel with high transition temperatures ensure rigid linings are not in direct contact with the steel. Install mastic behind the brick, as shown in Figure 1, to provide flexibility.

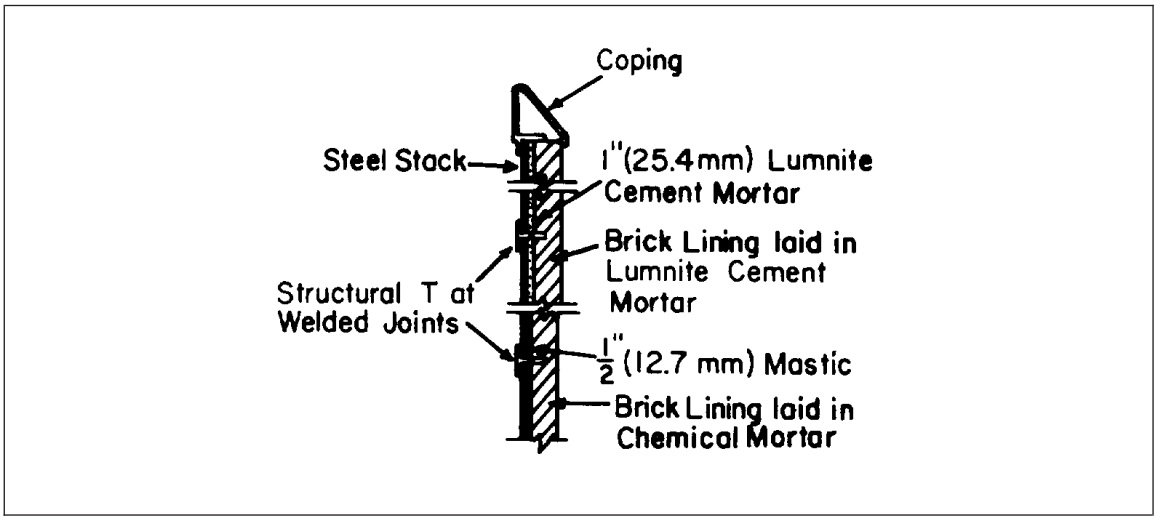
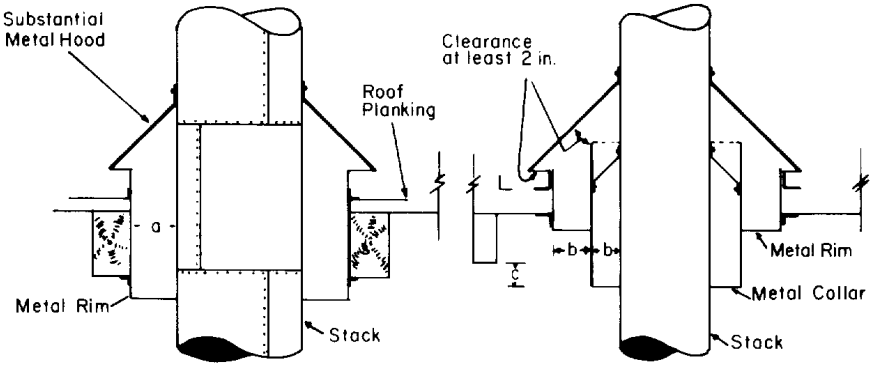


Fig. 1. Corrosion protection for steel chimney and lining

2.1.3.5 For steel chimneys with poor resistance to fracture at low temperatures that are taken off line in cold weather, provide heat by means of gas or oil-fired blowers to allow for a slow transition to the cold temperature.

2.1.3.6 Do not pass steel chimneys through combustible ceilings, walls, or floors. If passing a steel chimney through a combustible roof is unavoidable, provide metal collars, rain shields, and clearance in accordance with Fig. 2 or suitable insulation and/or clearances to keep the surface temperature of combustible roofs below 160°F (71°C).



Stack temperature	Stack Diameter	Clearance, in. (mm)		
		a	b	c
Under 600°F (316°C)	8 in. (203mm) or less	8 (203)	2½ (63.7)	6 (152)
	More than 8 in. (203mm)	12 (305)	4 (102)	9 (229)
600°F (316°C) and over	8 in. (203mm) or less	12 (305)	4 (102)	9 (229)
	More than 8 in. (203mm)	18 (457)	6 (152)	12 (305)

Fig. 2. Separation between metal stacks and combustible roofs or roofing components

2.1.3.7 When a chimney is to be used intermittently, provide a hood at the top. Extend the hood 8 to 10 in. (203 to 254 mm) beyond the sides all around. Bolt the hood in position with corrosion-resistant bolts that can be removed for interior inspection of the chimney.

2.1.4 FRP Chimneys

2.1.4.1 No special protection is needed for free-standing fiberglass reinforced plastic chimneys used in conjunction with small package boilers when installed from the boiler straight up through the roof of the boiler room.

2.1.4.2 When the chimney penetrates other fire areas by means of horizontal ductwork, provide protection as recommended in Data Sheet 7-78, *Industrial Exhaust Systems*.

2.1.5 Independent Brick, Corbeled Brick, and Concrete Liners

2.1.5.1 Design and construct the chimney lining in accordance with the latest edition of ACI 307. For independent brick linings, provide steel bands on the outside of the lining to resist tension stresses and control cracking. Ensure the bands are tight and in contact with the brick at all points around the circumference to provide effective control of cracks (Fig. 3).

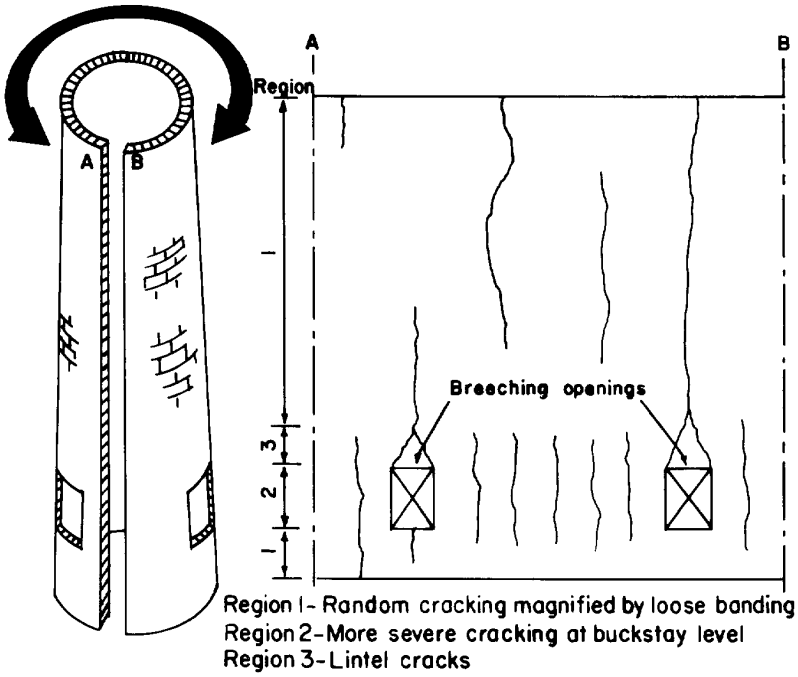


Fig. 3. Stretch-out development of a brick liner shows where cracks usually occur

2.1.5.2 Provide openings in independent brick linings with heavy jambs and substantial channel buckstays and tie rods, similar to those used in furnace construction. These openings guard against thermal shock and mechanical equipment vibration, and take the thrust from the arches (Fig. 4). Provide shear keys to improve the load-carrying capacity of the bands (Fig. 5). The shear keys enable relatively light structural sections to transfer uniform band reactions directly to the brickwork as compressive stresses. This gives a much greater degree of crack control.

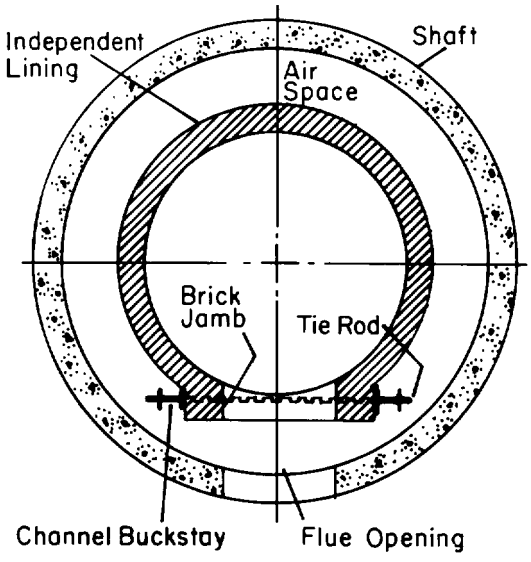


Fig. 4. Structural reinforcement of flue opening in brick lining

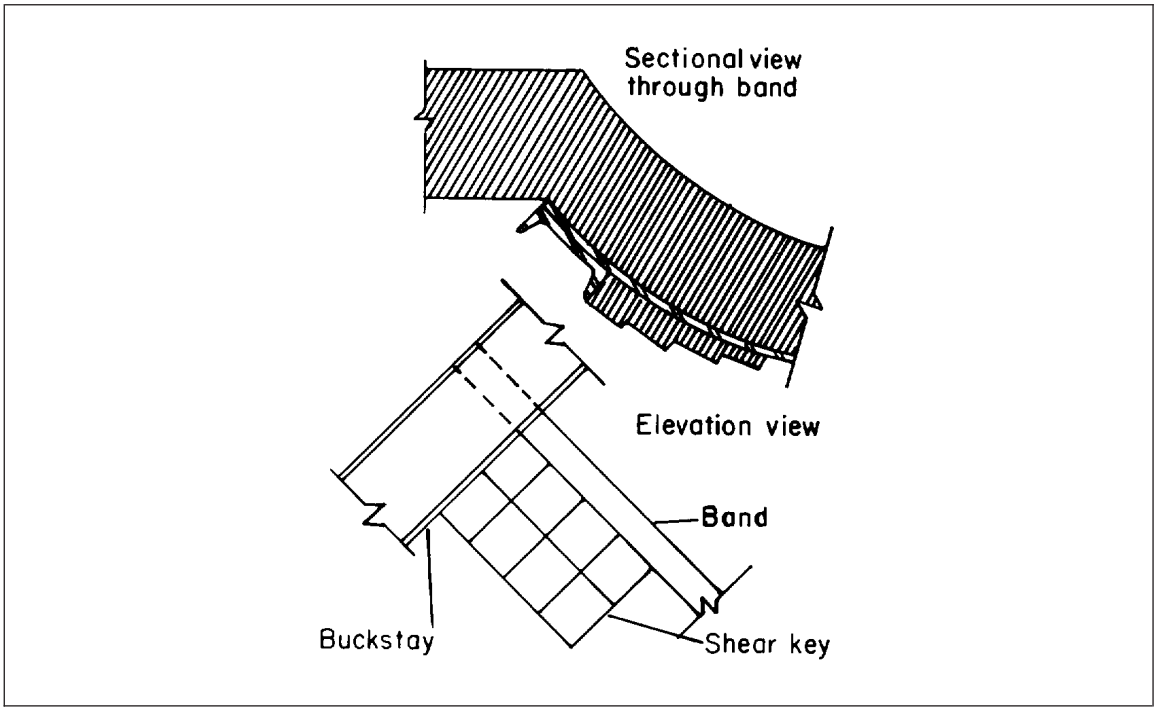


Fig. 5. Shear keys protruding from the brick liner face

2.1.5.3 On sectional linings supported on corbels where only a single thickness of brickwork and insulation is used, employ a coating to act as a vapor seal between the insulation and the brickwork.

2.1.5.4 Restrict the exit velocity from brick liners to not more than 90 ft/s (27.43 m/s) to avoid brickwork damage by induced vibrations.

2.1.6 Steel Liners

2.1.6.1 Design and erect a steel chimney liner in accordance with the American Society of Civil Engineers' *The Design and Construction of Steel Chimney Liners.*

2.1.6.2 Coat steel liners and steel breeching with a suitable material that can withstand the liner environment.

2.1.6.3 Limit the design gas velocity at the top exit of the liner to a maximum of 100 ft/s (30.48 m/s) to avoid unnecessary vibration. Higher velocity does not increase plume rise substantially because atmospheric drag tends to offset the added velocity.

2.1.7 FRP Liners

2.1.7.1 Design and construct fiberglass- reinforced plastic liners in accordance with the latest edition of ASTM D3299 and NBS Voluntary Product Standard PS15. The specifications in these standards cover the composition, performance requirements, construction practices and workmanship, design, and methods of testing filament-wound glass fiber-reinforced plastic tanks for use with corrosive chemicals; however, they are also applicable to chimney liners, ducts, and pipes exposed to similar corrosive environments.

2.1.7.2 Account for the effects of temperature upon the physical properties, in conjunction with the base and resin, in the design.

2.1.7.3 Keep the liner free from defects including indentations, delaminations, cracks, bubbles, pinholes, resin-rich areas, and resin-starved areas,

2.2 Protection

2.2.1 To limit the potential for fire spread in newly constructed chimneys, replace the fiberglass-reinforced plastic material with a metal alloy or other noncombustible material resistant to the corrosive environment to be handled in the liner, or install an FM Approved chimney flue liner.

2.2.2 If the ground-level space between the vertical liner and outer concrete shell is to have a combustible occupancy, provide the following protection arrangements:

- Construct a 2-hour-rated fire-resistant horizontal cutoff at the base of the chimney stack to separate the FRP breech opening from any adjoining occupancy such as oxidation air blowers or oil storage. Elevate this cutoff above any combustible occupancy and below the breech level of the liners.
- Provide automatic sprinklers beneath this cutoff. Design sprinkler spacing and density requirements for the specific type of occupancy. Ensure the base of the stack remains free of any combustibles.

2.2.3 When practical, to prevent spread of fire or the flow of flue gases at temperatures high enough to damage the liner in the area from the horizontal ductwork to the vertical chimney, install the following protection arrangement:

- Provide a one-hour-rated fire door where the horizontal duct enters the chimney (Fig. 6). Arrange the door to close automatically by activation of electronically operated heat detectors.

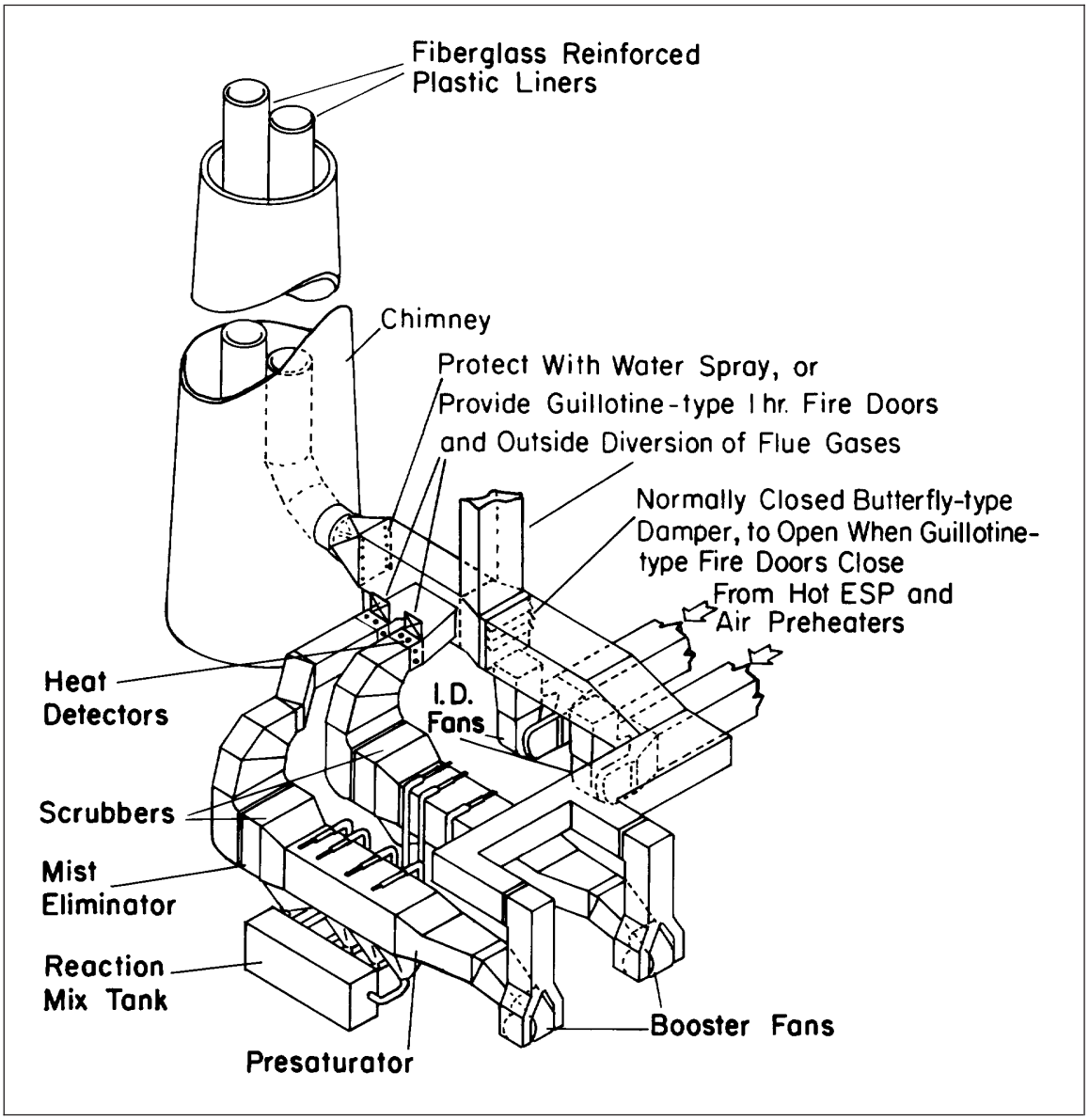


Fig. 6. Proposed fire-cutoff arrangement between the chimney liner, scrubbers, and ductwork

- Arrange the fixed-temperature heat detectors to activate the fire door at a temperature as low as practical, not to exceed that considered to damage the liner.
- Direct the discharge flow from the horizontal ducts and other associated equipment to the atmosphere, or have the fans interlocked to shut down upon activation of the fire door or the nozzles. To prevent any major damage to the boiler and other equipment as a result of the activation, incorporate special preventive measures in the design and operating sequences of the system.

2.2.4 When flow cannot be diverted or fans cannot be shut down, provide water spray protection as outlined in Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection* (Fig. 6).

2.2.5 Protect all horizontal ductwork system and associated equipment such as fans, plenums, and pollution control equipment leading into the stack in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

2.3 Equipment and Processes

2.3.1 Lightning Protection (See Fig. 7)

2.3.1.1 Apply the following criteria to conductors:

- Use copper conductors, of the grade required for commercial electrical work, generally having 98% conductivity when annealed.
- Ensure conductors weigh at least 6 ounces per linear foot or 375 lb per 1000 ft (0.6 kg/m).
- Ensure all wires in a cable are no less than No. 15 AWG (0.057 in., 1.45 mm); the thickness of all webs or ribbons is no less than No. 12 AWG (0.080 in., 2.03 mm); and the thickness of all tube walls are no less than No. 15 AWG (0.057 in., 1.45 mm).
- Minimize the number of joints in conductors and construct them with a joint efficiency of at least 50% (tensile strength).

2.3.1.2 Ensure fasteners are of copper or copper alloy that is as corrosion resistant as the conductor itself, and constructed to support its corresponding length of conductor. Space fasteners close enough to give ample support to the conductor, generally not over 4 ft (1.2 m) apart for vertical conductors, and not over 2 ft (0.6 m) apart for horizontal conductors.

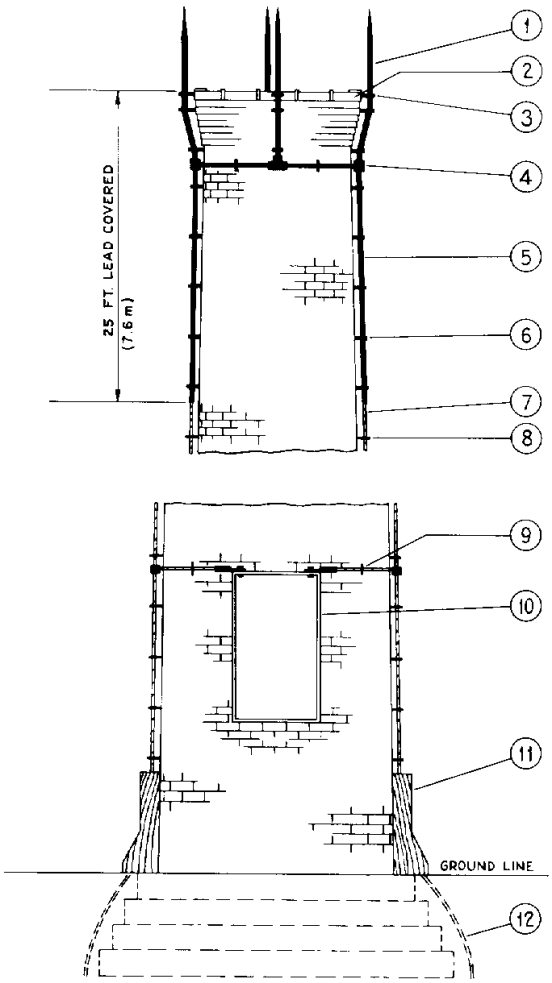
2.3.1.3 Apply the following to air terminals:

- Construct air terminals of the same grade material as the conductor, or of stainless steel, monel metal, or other equally corrosion-resistant metal.
- Extend air terminals 18 to 30 in. (0.455 to 0.8 m) above the top of the chimney, and space them uniformly around the rim of the chimney at intervals not exceeding 8 ft (2.4 m).
- Secure air terminals to the top of the chimney by expansion bolts or fan shank fasteners of substantial construction.
- Electrically connect the air terminals by an encircling conductor forming a closed loop near the top of the chimney. If there is a metal cap or crown, connect the air terminals to it.

2.3.1.4 Provide at least two down conductors on opposite sides of the chimney leading from the encircling conductor or crown at the top of the chimney to the ground. Interconnect both down conductors at the base unless they are individually connected to a water pipe. On tall chimneys, especially those greater than 160 ft (48.8 m) in height, interconnect the down conductors about midway between the top and bottom of the chimney.

2.3.1.5 To prevent corrosion, continuously cover the copper air terminals, conductors, and fasteners within 25 ft (7.6 m) of the top of the chimney with lead at least 1/16 in. (16 mm) thick. Protect joints between iron or steel and copper located within 25 ft (7.6 m) of the top of a reinforced concrete chimney against corrosion, either by a lead coating or by embedding them in the concrete.

2.3.1.6 Protect down conductors near the ground against physical damage by means of wood molding or other nonmagnetic material. If metal tubing is used for protection, electrically connect the down conductor to it at its upper and lower ends.



1. Air terminal
2. Chimney cap
3. Chimney cap connector (lead-covered)
4. Lead-covered conductor connectors
5. Lead-covered copper down conductor
6. Lead-covered down conductor fasteners
7. Bare copper down conductor
8. Plain down conductor fasteners
9. Conductor to metal flue
10. Metal flue
11. Wood molding for protection against physical damage
12. Ground connection to underground cast-iron water main, buried plate, or driven rod to obtain a resistance to ground of not over 5 ohms.

Fig. 7. Lightning protection for a brick chimney

2.3.1.7 Connect chimneys that have a metal ladder or lining to the lightning protection system at their upper and lower ends. Connect each down conductor to a metal flue by a separate conductor.

2.3.1.8 Electrically connect the steel reinforcing bars in reinforced-concrete chimneys to each other and to the down conductors at the top and bottom of the concrete.

2.3.1.9 Provide a ground connection for each down conductor, with resistance of the ground connection of 5 ohms or less. For effective functioning of a lightning-protection system, properly made ground connections and ample contact with the earth are necessary.

2.3.1.10 Provide a lightning protection system for all new concrete, hollow tile, and brick chimneys, and for all existing unprotected concrete, hollow tile, and brick chimneys when repairs or maintenance require the erection of ladders. Design the lightning protection system as described above, with resistance of the ground connection of 5 ohms or less. These recommendations apply if the chimney is part of a building and the top of the chimney is 35 ft (10.7 m) or more above the roof, or if the chimney is independent of a building and its top is 35 ft (10.7 m) or more above the ground.

2.3.1.11 Properly ground metal chimneys. If the resistance of the electrical connection with the earth for a new metal chimney is greater than 5 ohms, ground the base of the stack to an underground metal water main or to driven rods or pipes having a ground connection of 5 ohms or less.

2.3.1.12 Provide the inner surface of the chimney's plastic liner with a conductive filler to ensure electrical grounding to the lightning protection and chimney grounding system. The designer should indicate the maximum amount of electrical resistance (the overall ground resistance of the whole liner should not exceed 5 ohms), specify the method of measurement for the electrical resistance, and indicate the grounding point locations and interconnections.

2.3.1.13 Annually conduct a test of the resistance of the ground connections, as the ground resistance may not remain constant. If a high resistance to ground is found, improve it to 5 ohms or less. Use the Megger ground tester or other suitable means for testing ground resistance. See Data Sheet 5-11, *Lightning and Surge Protection for Electrical Systems*, for the various methods of testing ground resistance.

2.4 Operation and Maintenance

Failure of a chimney and liner can interrupt production just as definitely as failure of a boiler furnace or kiln; therefore a chimney should receive the same degree of attention to proper operation and maintenance. From both structural and functional standpoints, chimneys and liners are more complex and vulnerable than is commonly realized. The most common cause of accelerated interior or exterior deterioriation is neglect: failure to detect minor damage and repair it before it can progress. Once spalling has begun or cracks have opened, further damage can occur at a rapid rate.

2.4.1 Masonry and Concrete Chimneys and Liners

2.4.1.1 Establish frequent inspections to detect and repair the effects of deterioration before they become serious. Establish the frequency of inspections in accordance with facility experience.

2.4.1.2 Include the following items during regular inspections.

- Loose or missing brick, spalled brick, weathered joints, and cracked or weathered water tables (the slanted surfaces that cause water to drain from exterior chimney wall projections).
- Spalling, of special concern when it exposes the reinforcement of a concrete shaft

2.4.1.3 Vertical cracks, if opened appreciably, justify replacement of cracked bricks and careful repointing. In many cases, external steel bands 3 in. (76 mm) wide by ⅜ in. (9.5 mm) thick on about 5 ft (1.5 m) centers or equivalent round hoops with malleable iron lugs can be used. In extreme cases, rebuilding of a portion of the chimney may be necessary. Keep bands or hoops clean and painted to retard corrosion.

2.4.1.4 Maintain the interior lining in good condition to avoid rapid deterioration. Recommendations regarding the masonry chimney also apply to the masonry liner.

2.4.1.5 Check the following for looseness and corrosion:

- Lightning rod points or broken encircling cable that connects the points
- Lightning system's lead-in-cable, clamps, and connection to metal breeching

- All ladders and platforms
- Outside metal bands and fastenings
- Packing at the breeching entry

2.4.1.6 Make special inspections of the chimney exterior following any severe wind or electrical storm, paying particular attention to the lightning-protection system.

2.4.1.7 Neglected soot accumulation is a common cause of fire in a chimney. Do not allow soot to pile up more than 6 to 8 in. (152 to 203 mm) at the bottom before it is removed. Carefully inspect the chimney interior after an internal fire, no matter how minor.

2.4.2 Metal Chimneys or Liners

2.4.2.1 Inspect unlined metal chimneys at 2 or 3 year intervals for the first 5 or 6 years of service, and at 1 or 2 year intervals thereafter. More frequent inspections are necessary if the stack is used during the heating season only, or if inspection indicates accelerated corrosion. Inspections are usually combined with exterior painting as a matter of convenience. Inspections should include the following:

- Examination of the interior of the chimney as far as it is visible from the top.
- Complete hammer tests on the outside for the entire height to detect thin sections weakened by corrosion.
- Adjustment of guy cables.
- Inspection of stack and guy cable anchorage.

2.4.2.2 Clean out the base, including the breeching and horizontal runs of flue, at least annually and especially at the start of extended shutdown periods.

2.4.2.3 Have facility engineers occasionally make chimney inspections from the ground or roof to detect the following:.

- External rusting or holes
  Excessive looseness of guys (6 in. sag in 100 ft [152 mm in 30.5 m]) is normal
- Broken wires, especially at eyebolts or turn-buckles, where thimbles are recommended
- Looseness of bolts in clips or clamps
  Displaced guy collars
- Inadequacy of anchorage

2.4.2.4 Self-supporting chimneys lined for their full height with gunite or refractories need internal inspections only at 10 year intervals. Examine anchorage details at such times to determine whether they are in good condition. Clean and paint the exterior often enough to prevent corrosion.

2.4.3 Fiberglass-Reinforced Plastic Lining

2.4.3.1 Establish the following inspection and maintenance procedures to determine and correct the adverse effects sustained by the liner due to the handling of a particular environment. Consult the manufacturer for specific repair guidance.

- When large bubbles are found, press them with a blunt instrument. Remove the fractured surface and fill the void with a resin putty.
- Overlay cracks existing only on the surface of the laminate with equivalent liner material.
- In areas where the resin has drained from the reinforcement, fill the void with equivalent resin material.

2.4.3.2 Correct an actual separation of laminate visible on opposite surfaces and extending through the thickness.

2.4.3.3 Build up to required thickness any imperfection on the laminate that has the appearance of a wave molded into one or more plies of fabric or other reinforcement material.

2.4.3.4 Conduct inspections at the vertical and lateral supports and at the expansion joints to determine any possible failure, such as a fracture or ripping of the liner material.

2.4.3.5 Provide maintenance platforms at each vertical support.

2.4.3.6 Establish the frequency of inspections in accordance with facility experience.

2.4.3.7 Establish maintenance and inspection procedures for all horizontal ductwork systems and associated equipment such as fans, plenums, and pollution control equipment, leading into the stack in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

2.4.4 Borosilicate Glass Block Liners

These liners are virtually maintenance free, with a long service life.

2.4.4.1 Establish a routine inspection schedule to ensure the blocks and joint adhesive remain in good condition.

2.5 Human Factor

The following recommendations will help lessen the frequency of fire in an unprotected FRP chimney liner, especially while the operation is on shutdown for maintenance or repairs.

2.5.1 Provide dry hose standpipes on the exterior walkways and stairs of the scrubber module. These will be of benefit during maintenance and repairs on the unit, enabling the connection of a temporary sprinkler system. One temporary sprinkler system installation utilized in the past involved a small deluge valve with spray nozzles installed inside of the liner on the worker platform used to connect the vertical liner sections, and fed from a large fire hose connected to a water supply.

2.5.2 Provide a slide gate damper or a noncombustible temporary duct blank at the exit of the scrubber module that can be put in place during maintenance. This will mitigate the potential for a fire to spread to the stack through the FRP material.

2.5.3 Provide a slide gate damper or a noncombustible temporary duct blank at the FRP breech entrance to the chimney.

2.5.4 Duct any temporary heat needed for adhesive curing into the stack via indirect heating.

2.5.5 Provide adequately inspected and maintained portable fire extinguishers to protect all work areas.

2.5.6 Follow the procedures in Data Sheet 7-32, *Flammable Liquid Operations*, for the handling, dispensing, and use of flammable liquids.

2.6 Ignition Source Control

2.6.1 Use FM Global *Hot Work Permit System* to supervise any necessary hot work. Include fire watches as required following completion of the hot work. Try to avoid hot work whenever possible, especially in close proximity to FRP chimney liners, and consider all alternative methods to hot work first.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

The gaseous products handled by chimneys are often highly corrosive. Natural gas is practically free of sulfur, but oil and coal are not. The gaseous combustion products of oil, coal, and many industrial processes contain sulfur oxides and other corrosives that can combine with moisture to produce acids. This condition is not a problem when the chimney interior temperature is above the acid dew point. However, there are times when temperatures pass through the dew point and condensation occurs. Mechanical dust collectors, electric precipitators, scrubbers, and other air pollution control equipment contribute to the temperature reduction of the chimney interior. This produces a wet environment, creating the need for acid-resistant materials for the chimney and related equipment.

In previous years, the principal concern was sulfurous acid (H_2SO_3). Operations close to or below the dew point of sulfuric acid (H_2SO_4) have now become a threat to most chimney materials; sulfuric acid is relatively fast acting and highly corrosive. Lower temperatures will add other acids to the problem. In short, truly acidproof materials are needed to withstand these conditions.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-28, *Wind Design*
Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection*
Data Sheet 5-11, *Lightning and Surge Protection for Electrical Systems*
Data Sheet 7-32, *Flammable Liquid Operations*
Data Sheet 7-78, *Industrial Exhaust Systems*

4.2 Other

ASTM International. *Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks.* ASTM D3299.

ASTM International. *Standard Specification for Structural Steel for Ships.* ASTM A131/A131M

American Concrete Institute (ACI). *Code Requirements for Reinforced Concrete Chimneys* ACI 307.

American Institute of Steel Construction (AISC). *Steel Construction Manual*.

American Society of Civil Engineers (ASCE). *Design and Construction of Steel Chimney Liners*.

U.S. Department of Commerce. *Custom Contact-Molded Reinforced-Polyester Chemical-Resistant Process Equipment*. Voluntary Product Standard PS-15-69.

APPENDIX A GLOSSARY OF TERMS

Caps: Arrangements of corrosion resistant material installed at the top of shafts and liners, designed to help stabilize adverse wind effects and to allow condensation to drain to the base of the liner, where it is piped from a capped tee to a pump.

Chimney: Structure used to carry the gaseous products of combustion to the atmosphere. The elements that make up the chimney are: the shaft (column or shell), liner, foundation, and corrosion protection caps for the shaft and liner.

Foundation: Support for the shaft and liner, which is usually a thick octagonal mat of reinforced concrete, either soil-bearing or resting on piles. Provision for an ash pit and removal of ashes usually is made.

Liner: Is the operational element of the chimney, designed to resist chemical and physical actions of combustion gases and to protect the shaft from them.

Shaft: Is the structural element of the chimney designed to resist wind, temperature differentials, and earthquake loads, and to shield the liner.

APPENDIX B DOCUMENT REVISION HISTORY

February 2010. This document was revised to include information on FM Approved chimney flue liner products.

January 2009. This document was revised to eliminate the requirement for deluge fire protection for FRP chimney liners.

April 2007. This document was revised to include detail on additional types of chimney liners and to clarify the protection requirements for FRP chimney liners.

May 2003. Minor editorial changes were made for this revision.

September 2000. This revision of the document had been reorganized to provide a consistent format.

This document had editorial changes in May, 1998.

The December, 1979 version of this Data Sheet updated all the material in Chapter 77 of the Factory Mutual Handbook of Industrial Loss Prevention and included new information on tall reinforced-plastic chimney linings.