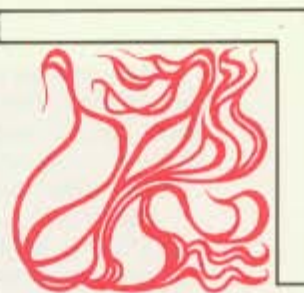


# fire protection planning report



BUILDING CONSTRUCTION INFORMATION FROM THE CONCRETE AND MASONRY INDUSTRIES

NO. 11 OF A SERIES

## Fire Protection for Industrial and Warehouse Buildings

*In one of the most costly structure fires ever, one of the world's largest and most modern retail distribution centers burned to the ground along with all of its contents. Losses to K-Mart's 1.1 million-sq ft warehouse located near Philadelphia are expected to exceed \$110 million.*

*In a little over one hour the huge warehouse and its contents were totally destroyed in spite of the presence of an operating, full-coverage, automatic sprinkler system and quick response by dozens of firetrucks. Only the general offices and computer center survived, separated from the rest of the structure by masonry walls.*

*How could such a fire happen? There were many factors contributing to the destruction, all of which appear common to storage-type occupancies. This report presents a rationale for good fire protection design in industrial and warehouse buildings.*

Since World War II, national economic growth and increasing consumer demand have resulted in the construction of more and larger commercial and industrial buildings. These facilities often have fire areas in excess of 500,000 sq ft and house total operations—from raw materials to production to storage of finished goods—under one roof.

The rationale for creating these so-called super-plants are greater operational efficiency, cost control, and economy of scale. However, there is a high concentration of goods and property at risk with potential losses upwards of \$100 million from a single fire.

Not only has the physical structure and layout of these buildings changed, but a dramatic change has also occurred in plant occupancies. The development of high-rack storage is one such occupancy, with storage of materials from 20 to 80 ft high. Also, the wide use of plastics in products and packaging has created fire hazards too severe for ordinary measures of protection. Unless something is done to reduce the risk of catastrophic loss, multimillion dollar fires will continue to occur.



Photos courtesy of Bob Sherman, Jr., International Fire Photographers Association.

Is it impossible to prevent these large-loss fires? Certainly not. The old lessons from the past simply need careful study and application. Two time-tested approaches need to be used more fully:

1. Compartmentation—to reduce the value at risk.
2. Zealous fire prevention.<sup>(1)</sup>

These measures are needed in addition to automatic sprinkler systems because sprinklers alone cannot ensure adequate protection. A brief look at some recent large industrial and warehouse fires should make this more apparent.

### Large-Loss Fires

- In October 1977, a fire at the Ford Parts Department in Merkenich, Germany, caused destruction of 800,000 sq ft of warehousing valued at over \$100 million and loss of business estimated at over \$50 million. Despite the presence of automatic sprinkler systems that were in operation at the time, negative factors such as high-piled storage, temporary storage of highly combustible materials, delayed alarm, and lack of controls on employee smoking permitted the loss to occur. Only a masonry fire wall separating an additional 500,000 sq ft of warehousing and manufacturing halted the fire.
- In September 1978, a fire in a Montgomery Ward distribution center in Bensenville, Illinois, caused a \$25 million loss in this fully sprinklered warehouse. The fire, of suspicious origin, was fueled by idle storage of merchandise and pallets in the aisles. The operating sprinkler system was overpowered. Interior concrete block walls helped save 100,000 sq ft of this 300,000-sq ft warehouse. Only 16 minutes after discovery of the fire, the metal-deck-on-bar-joist roof system collapsed, destroying the sprinkler system.
- In January 1979, fire was discovered in a 20-ft-high-rack storage warehouse in Edison, New Jersey. Although the building was fully sprinklered, the fire progressed so rapidly that manual firefighting efforts were not possible. The building began to collapse only 12 minutes after discovery of the fire. The 267,000-sq ft warehouse was totally destroyed with a resulting loss valued at \$30 million.

In these catastrophes, even the full-coverage, automatic sprinkler systems proved to be insufficient fire protection.<sup>(2)</sup> The large losses and many others like them are a costly reminder that even the best of fire extinguishing control hardware by itself is not enough.

Many of today's large warehouses and manufacturing plants are built under unlimited-area provisions of the model building codes. These provisions permit buildings of assembly, business, factory, mercantile, and storage occupancies to

be built one story high (two stories are permitted by the Uniform Building Code) and of unlimited area. Under this provision no built-in fire resistance is necessary. Only the installation of a fully automatic sprinkler system and compliance with minimum separation distances are required. However, as witnessed by recent large-loss fires, when the sprinkler system fails to operate or is inadequate, little can be done to prevent total loss. The need for large undivided buildings is recognizable, especially in occupancies such as automobile and aircraft assembly plants. Nevertheless, the need for unlimited open areas in other occupancies, such as warehouses, is not so apparent and the effective use of compartmentation would greatly limit the total value at risk without hampering operations. A reevaluation of the unlimited-area provisions is therefore recommended.



Fire at Ford warehouse, Merkenich, Germany.



Fire at Montgomery Ward warehouse, Bensenville, Illinois. Photo courtesy of National Fire Protection Association.

<sup>\*</sup>Superscript numbers in parentheses denote references at the end of this report.



## Arson—Leading Cause of Industrial Fires

Arson is the leading cause of fire in industrial occupancies, representing 24% of the industrial total (1981 National Fire Incident Reporting System, U.S. Fire Administration). In storage occupancies, incendiary or suspicious fires are by far the number one cause of fire and total dollar loss (see Table).<sup>(6)</sup>

With the arson rate as high as it is, additional fire protection measures are necessary. Arson fires are characterized by the use of accelerants, multiple ignitions, and tampering with fire detection and suppression systems. Because of this, redundant defenses should be used.<sup>(6)</sup> These should include fire-resistive construction and complete sprinkler protection, particularly in storage areas. A security system of guards and electronic devices should be considered to detect intruders. Provide and monitor fire walls and other cutoffs (vertical and horizontal) including fire doors and other opening protection. Provide inside hose connections and equipment, and portable fire extinguishers. Also, properly isolate and secure all flammable liquids and maintain a high degree of housekeeping that otherwise could be used to advantage by an arsonist. Exterior storage yards are also highly vulnerable and should be completely fenced in and adequately lit to deter arsonists. Where any of these factors of control are lacking, there is an excellent chance that an incendiary fire will produce a large loss.<sup>(7)</sup>

## Arson Fires in Industrial Occupancies 1977-1981\* with Unknowns Allocated

	% of fires caused by arson	% of dollar loss caused by arson
<b>Manufacturing</b>		
1977	8.4%	23.3%
1978	8.3	18.1
1979	8.9	28.3
1980	9.6	30.5
1981	9.2	24.3
Avg.	8.9	24.9
<b>Storage</b>		
1977	29.1%	22.3%
1978	29.0	52.8
1979	28.5	35.3
1980	29.1	40.8
1981	28.8	32.7
Avg.	28.7	36.8

\*Source: 1977-1981 NFIRS data and FEMA analysis of National Fire Protection Association survey data.

It is significant that in none of the above incidents was the sprinkler system impaired at the time of the fire. In other words, full protection was in service when ignition took place. Other negative factors permitted the fire to grow uncontrolled. These negative factors include—

- Absence of adequate fire separations
- Absence of adequate fire resistance in roof construction
- Storage of more hazardous materials than originally anticipated (such as aerosols, plastics, flammable liquids)
- Temporary storage in aisle spaces
- Deliberately set fires (multiple ignitions or use of accelerants)
- Poor housekeeping and lack of employee-smoking controls
- Storage materials stacked higher than assumed in design
- Delayed alarm

Most of these factors are the result of human error in the sense that someone deliberately or unknowingly permitted them to exist. Such error can have disastrous effects, undermining even the best automatic extinguishing systems. Efforts to prevent poor storage practices, housekeeping, and maintenance are not always effective. Fire separations and minimum specified fire resistance for roofs, which are not as easily affected by human error, are necessary to assure adequate levels of fire protection.

## Essentials of Firesafe Construction

Unfortunately fire protection is being treated in many sectors of the building industry as an exact science when in reality it has not progressed beyond the state of a refined art.<sup>(2)</sup> Past experience must still serve as a guide in designing today's buildings for firesafety.



This section identifies those fire protection measures that have proved through experience to provide adequate fire protection in industrial and storage buildings.<sup>(3)</sup> Following sections will provide more details of application and design for some of these measures. Important points to consider include the following:

1. For highly combustible contents and for multistory buildings, select building materials (such as reinforced concrete, concrete block, or brick) that resist fire.
2. For industrial occupancies, use construction that will not contribute to the spread of fire and that has a fire resistance of two hours.
3. If construction or contents are combustible, subdivide large areas by fire walls with adequately protected openings to limit the potential damage. Provide as much yard space as is practical between buildings.
4. Provide complete automatic sprinkler protection wherever there is combustible construction or combustible contents.
5. If the building is of more than one story, enclose stairs, elevator wells, conveyors, and chutes with two-hour fire-resistive walls, and install automatic fire doors at openings.
6. Processes involving flammable liquids or other explosion hazards should be isolated in detached buildings. If an isolated location is not possible, hazardous material should be stored at exterior walls of main buildings and isolated from the rest of the building by fire walls.
7. Provide for smoke removal from windowless buildings by fans, dampers, or vents.

### Sprinklers? Yes, but not alone

In spite of the failures previously cited, sprinklers have proved to be an effective measure for providing fire protection for industrial buildings. Sprinklers are most effective when combined with other fire protection measures to form a series of defenses. This is because sprinklers are susceptible to many adverse conditions that could render them inoperative or inadequate. These include poor maintenance, shutdown for repairs, inadvertently shut valves, malfunctioning pumps, and lack of electrical power. Also, if the combustible contents of the building have increased due to a change in occupancy since the system was first installed, the water supply may be inadequate to handle the greater fire hazard.

A study of fire-loss statistics indicates the hazards of inadequate sprinkler systems.<sup>(4)</sup> Table 1 shows that the average loss in an inadequately sprinklered area is nearly five times that in an unsprinklered area. Having an inadequate sprinkler system results in greater risk of fire damage than having none at all, because building codes allow certain fire protection features to be eliminated if

**Table 1. Fire Losses in Sprinklered and Unsprinklered Areas\***

Average loss in sprinklered area	\$ 42,575
Average loss in unsprinklered area	160,839
Average loss where sprinklers failed	750,251

\*Source: Industrial Risk Insurers—analysis of 810 sprinklered fire losses and 313 unsprinklered fire losses.<sup>(4)</sup>



Automatic sprinklers have proved to be effective for providing fire protection for industrial buildings. However, if the sprinkler system is inoperative or inadequate, the fire-resistive integrity of the structure must be relied on to confine and limit the fire. Sprinklers are most effective when combined with other fire protection measures, such as fire-resistive construction and fire walls and partitions. Together these measures form a series of defenses with a better chance of controlling the fire than any one defense mechanism acting alone.



**Table 2. U.S. Large-Dollar-Loss\* Building Fires 1979-1981**

Year	No. of large-loss fires, all buildings	% of fires, sprinklered buildings	% of dollar loss, sprinklered buildings	Average loss, all buildings	Average loss, unsprinklered buildings	Average loss, sprinklered buildings
1979	368	10.6	15.5	\$1,440,005	\$1,360,642	\$2,109,508
1980	483	11.0	19.7	1,850,264	1,668,413	3,325,655
1981	368	12.0	21.3	1,666,817	1,490,628	2,964,209
Total/Average	1219	11.2	19.1	1,671,032	1,521,729	2,859,968

\*Building fires resulting in \$500,000 or more direct property damage.

Source: National Fire Protection Association—Fire Incident Data Organization System

a sprinkler system is included in the design. When the sprinkler system is inadequate to control a fire, backup systems such as fire separations are needed to confine the fire and limit the loss. Such protection should never be traded off because of the presence of an automatic sprinkler system.

In addition, people have little difficulty in identifying sprinklered and unsprinklered property and are more careful about the kind and quantity of combustibles stored in unsprinklered buildings. See Table 2. On the other hand, people are generally unaware of the design limitations of sprinkler systems. Not realizing that an inadequate system may be just as ineffective as a nonexistent system, they neglect to limit the amount of combustibles stored there. This raises the fire load of the poorly protected area and almost guarantees that the system will be overloaded in an emergency.

The large-loss fires examined earlier also indicate a problem that has become noticeable in other less costly and thus less dramatic losses; that is, the increasing trend toward highly refined protection specifications incorporating little if any safety factors beyond those inherent in hydraulic design. Minimal sprinkler densities and applied areas of demand are specified based on anticipated type and kind of storage. However, the type of material stored can change markedly over the life of the structure, particularly in storage occupancies. If more hazardous materials are later allowed to be stored, the design densities may not be adequate and a system upgrade may be necessary. An annual reevaluation of the sprinkler system's capability with respect to the materials currently being stored should be considered. It is unlikely, however, that such an evaluation is very common.

The sprinkler design is further refined by use of computer design for selecting minimum pipe sizes to meet the hydraulic criteria, which is usually based on waterflow tests taken near the building. Since the available waterflow may also change, periodic testing is recommended. All of this leaves little room for error. Even if the existing water supply is capable of handling much more than minimal demands, the selected piping effectively throttles or prevents it from being utilized by the sprinkler

system.<sup>(2)</sup> Therefore, in addition to sprinklers other fire protection measures are necessary.

## Fire Walls

Large properties or properties with high-value contents should be subdivided into separate fire areas to limit the spread of fire. Horizontal fire spread can be limited by providing adequate space between buildings or by fire walls or fire partitions. In multi-story buildings vertical spread from one story to another is limited by the floor construction and by fire-rated wall enclosures with fire doors around stairways, elevator shafts, and other openings.

The primary purpose of fire walls is to limit the amount of property exposed to a single fire. Fire walls are designed to prevent the passage of fire from one area to another even if the installed sprinkler system is out of service or is overwhelmed by the fire.

Separation of occupancies by fire walls, such as manufacturing operations from storage areas, is particularly important. Should the contents of a warehouse catch fire, the manufacturing facility will be able to continue in operation, preventing large losses and service disruption. Similarly, inventory in a warehouse can support normal shipments for some time in the event of a fire in the manufacturing facility.

Areas of high value or large areas of combustible construction or contents should also be subdivided. In warehouses particularly, hazardous materials such as flammable liquids, aerosols, and plastics should be stored in areas separated from the rest of the facility by fire walls.

The construction of fire walls must be sufficient to restrict the transmission of heat by conduction, convection, and radiation. Fire walls usually have three- or four-hour fire resistance ratings but higher ratings may be necessary depending on the fuel loading.

To be completely effective, fire walls must extend through and above any combustible roofs they are intended to protect. Parapets for combustible roofs should be at least 30 inches high. A concrete roof does not need a parapet. Endwalls to

prevent passage of fire around the ends of the fire walls should span from three to six feet on either side of the fire wall and have a two-hour fire resistance rating.<sup>(3)</sup>

The most important property of a fire wall is the ability to retain its structural integrity when exposed to fire. Such a wall must be stable enough to remain standing even when structural members on each side of it collapse. Strength is desirable so that the wall can resist minor explosions, glancing blows from falling materials, or pressure from collapsed portions of floors and roof leaning against it.

Fire walls should be planned in the early stages of the building design. The location of the walls should be selected to provide maximum fire protection without interfering with the intended function of the building. Substantial reductions in fire insurance premiums can be achieved with the judicious use and placement of fire walls. See Table 3. It is recommended that the designer work closely with the fire insurance carrier.

### Fire Partitions

Fire partitions or fire barriers are used to further subdivide major areas. They are intended to isolate hazardous processes, equipment, or materials and protect vital equipment or records. They can be used in industrial occupancies to separate parallel lines of operating equipment so that fire in one line will not damage companion units.



A properly constructed firewall with adequately protected openings can stop a fire from spreading even when automatic and manual firefighting efforts have failed.

In the design of fire partitions it is assumed that sprinklers are in service so that the primary function of the fire partition is to limit the lateral spread of heat and smoke to the immediate fire area. With sprinklers in service, fire partitions require only two-hour fire resistance and do not need to be freestanding.

Fire partitions form an important first-line defense against the spread of fire. By restricting the initial flow of heat and smoke to the area of origin, they limit the unnecessary operation of sprinklers outside the fire zone. They also provide sufficient time to coordinate and begin manual firefighting efforts from adjacent areas.

Thus, fire walls and partitions, installed in conjunction with automatic sprinklers and smoke and heat vents, form an effective fire defense system. A series of defenses are set up that together have a better chance of controlling and limiting the spread of a fire than any one defense mechanism acting alone.

### Roof System Is Important

In August of 1953 the General Motors Corporation's transmission plant in Livonia, Michigan, burned in what was the largest industrial fire loss to that date, \$32 million. It was later learned that the metal-deck roof containing a common bituminous adhesive and vapor barrier was the main factor contributing to the destruction of the plant. Extensive testing was conducted and construction compositions were developed to reduce the hazard inherent in this type of system.<sup>(5)</sup>

In January 1967 another lesson was learned about the importance of the roof system. The McCormick Place exhibition hall in Chicago sustained a fire with losses of \$40 million to the structure and \$100 million to the contents. Its steel roof high above the floor was left unprotected, based on the erroneous assumption that temperatures at that elevation would not be hot enough during a fire to cause collapse. However, collapse occurred only 30 minutes after the start of the fire.

The noncombustibility of steel lends unwarranted confidence in its suitability for uses where fire is of concern. Steel loses approximately half its strength when heated to 1100° F. However, the standard time-temperature curve reaches 1300° F in only 10 minutes. In an actual fire, this temperature can be reached even sooner, and collapse of an unprotected steel-roof system, regardless of height, can occur quickly. Experiences such as the McCormick Place fire point out the need to eliminate building code provisions based on the unwarranted assumption that height alone can protect exposed-steel framing from fire. Check your building code to make sure that such provisions do not exist.

In the last several years we have witnessed very destructive fires in several large superplants. The K-Mart and Ford warehouse fires have provided



**Table 3. Fire Insurance Cost Comparison—Warehouse and General Storage Building**

Coverage: Fire and extended; building \$1,500,000; contents \$2,250,000

Type of Construction	Fire rating (hour) Ext. wall/Roof	Total annual premium	Fire rating (hour) Ext. wall/Roof	Total annual premium
Unprotected noncombustible (with 3-hour fire wall)	0/0	\$215,813 (127,576)		
Protected noncombustible ext. wall unprotected noncombustible roof (with 3-hour fire wall)	1/0	83,700 (59,738)	2/0	\$79,763 (57,263)
Protected noncombustible (with 3-hour fire wall)	1/1	32,318 (28,943)	2/1	29,550 (26,693)
Protected noncombustible (with 3-hour fire wall)	2/2	27,315 (26,100)		

Dimensions: 300x400 = 120,000 sq ft; 1 story 20 ft high, no basement; ext. wall with max. 20% glass, no exposures. Fire wall, 3-hour rated and freestanding, divides building in half. Rates are based on 80% coinsurance, class-6 public protection in Cook County, based on Insurance Service Office of Illinois rate schedule in effect 3/83, using ISO HULC (historical underlying loss cost) for each structure, and an average operating and expense factor for insurance companies.

Rates calculated by NATLSCO, National Loss Control Service Corp., a subsidiary of Kemper Corp., for the Concrete and Masonry Industry Firesafety Committee.

Some of the cost benefits of using fire walls, fire-rated roofs, and fire-resistive construction are demonstrated in this insurance-cost comparison. Fire walls are particularly beneficial when used in the less fire-resistive types of construction and especially when there is an unrated roof. Providing a 1-hour-rated roof, in addition to being important in the event of a fire, also contributes significantly to reducing insurance premiums. By judiciously choosing one's building materials, great cost savings can be realized in reduced insurance premiums for fire-rated construction. Building with concrete and masonry almost always provides fire resistance ratings of 1 or 2 hours.

valuable lessons about the importance of the roof system. In spite of the presence and operation of complete automatic sprinkler systems, these fires went uncontrolled. Ceiling temperatures increased to the point where the exposed-steel roofs collapsed, bringing the sprinkler system down and any hope of controlling the fire along with it. Perhaps the designer of the new McCormick Place foresaw the lessons to be learned from these fires. The facility was designed with an extensive automatic sprinkler system, elaborate alarm and smoke-venting provisions, and was provided with a one-hour-rated fire-resistive roof.

One-hour-rated roof systems offer several advantages. They resist high temperatures that can cause distortion and rupture of sprinkler piping. Most importantly, one-hour-rated roofs resist early collapse in fires uncontrolled by the sprinkler system. This keeps the sprinklers in place and applying water to the fire area. Also, the roof systems lessen the possibility of sudden collapse of the roof, which is a severe hazard to firefighters, and permit an internal fire attack that would otherwise be too risky to attempt.

The insurance industry has long recognized the advantages of a rated roof system. Consequently they provide significant reductions in premiums when a rated roof system is used. See Table 3.

## CONCLUSIONS

The responsibility for the fire protection of a new warehouse or industrial facility should be shared by both the owner of the facility and the community in which it is to be constructed.

Company management must be aware of the high concentration of value it has at risk from a single incident. They must show more concern for providing fire protection in the new plant and reducing risk concentration than just the purchase of fire insurance. Providing automatic sprinklers in the plant is a very positive first step. However, the consequences should a failure occur are too great for plant management or even an insurer to assume. A reasonable limitation of values subject to one fire is necessary and easily accomplished with fire walls and partitions. For added safety, a minimum one-hour-fire-rated roof assembly should be provided to assist in the continuity and operation of the sprinkler system even though it may be overpowered by the fire and permit an internal fire attack by the local fire department.

Community interest in a new plant's fire-protection features should be high. Provisions in the local building code for adequate built-in fire protection to assist the local firefighting forces in preventing a catastrophic loss should be required by the community. This should include automatic detection and extinguishing equipment, use of fire-resistive construction such as fire walls and partitions to limit maximum probable loss, and at least one-hour-rated roof construction to prevent collapse and permit effective use of automatic and manual firefighting capabilities.

It is apparent that both the private and public sectors have an interest in preventing catastrophic loss and should work together. Past large-loss fires have shown that reliance on any one system or method of protection is not adequate. What is needed is a well-balanced design that provides a series of defenses acting together to provide maximum protection.



### For Every Direct Loss an Indirect Loss

In addition to the costs incurred from direct fire loss, there is associated a series of indirect losses. In industry, indirect fire losses and business interruption are often more severe in eventual cost than direct losses. A few of these indirect losses include loss of important customers, loss of records and inventory, continuing expenses, and high cost of replacing plant and equipment.<sup>(9)</sup> It is not surprising that most plants after a severe fire are never able to reopen.

The decision to build a large warehouse or manufacturing plant in a particular area can have a great impact on that community. It can mean hundreds of new jobs and a greatly increased tax base. Therefore, the community has much at stake should a severe fire occur in the plant. Economically, a fire loss can have a negative impact on a community by depriving it of employee payroll circulation, tax revenue, and business derived from suppliers of materials and services to the fire-stricken plant, and by adding to the welfare burden.

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### Organizations represented on the CONCRETE AND MASONRY INDUSTRY FIRESAFETY COMMITTEE

BIA	Brick Institute of America
CRSI	Concrete Reinforcing Steel Institute
ESCSI	Expanded Shale Clay and Slate Institute
NCMA	National Concrete Masonry Association
NRMCA	National Ready Mixed Concrete Association
PCA	Portland Cement Association
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