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Edited by Edwin O. Sachs.

How to Build "Fire-proof."

A Paper

BY

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The main objects of the Committee are:—

To direct attention to the urgent need for increased protection of life and property from fire by the adoption of preventive measures.

To use its influence in every direction towards minimising the possibilities and dangers of fire.

To bring together those scientifically interested in the subject of Fire Prevention.

To arrange periodical meetings for the discussion of practical questions bearing on the same.

To establish a reading-room, library and collections for purposes of research, and for supplying recent and authentic information on the subject of Fire Prevention.

To publish from time to time papers specially prepared for the Committee, together with records, extracts, and translations.

To undertake such independent investigations and tests of materials, methods and appliances as may be considered advisable.

The Committee does not hold itself in any way responsible for the opinions expressed, or methods advocated, by members and others who kindly contribute to these publications.

Comments on the opinions expressed in these papers, or further information on the subjects under consideration, are cordially invited by the Executive, at whose discretion they will be circulated among the members of the Committee.

NOTE.

In the present paper a summary is given of various suggestions as to methods of erecting "fire-proof" buildings. This summary has been prepared in America, and the whole of the questions dealt with have particular reference to the constructional practice of the United States. This fact, however, in no way lessens the value of the paper for the Metropolis and the other great centres of the Empire; for, with slight modifications, it applies equally to the buildings of all countries. But what, perhaps, especially enhances the value of this paper is the intimate association of the author with the insurance world of America and the fact that he has also acted on the Board of Examiners of the New York Building Department. It is the member of a controlling authority, whether he be architect, engineer, surveyor, or public official unattached to any particular technical profession, who takes the broadest view of questions of Fire Protection, and certainly gains a wider experience than is possible in any private practice. And since to this exercise of a controlling authority the writer adds the experience of general manager to an insurance company—for such, or very nearly, is the position of a "president" in the United States—his words cannot fail to carry considerable weight. In this case, however, the paper speaks for itself as a contribution to the subject of exceptional value and of the highest importance to those interested in buildings of the warehouse or factory class. There is no need to speak here of the high qualifications of the author.

As in the case of former papers, it is not my intention to put forward any comments of my own, but I would, nevertheless, draw attention to the interesting remarks on the effect of rust on ironwork and the advisability of making part of the coverings movable to allow of periodical examination. With a growing tendency to run supply and waste pipes inside the terra-cotta or earthenware covering of iron columns and the like, the rust question becomes even more important than it was when only the deterioration of ironwork from atmospheric conditions was taken into consideration. It is to be hoped that this important matter will secure increased attention, inasmuch as the general introduction into the Metropolis of what are termed "frame buildings" as used in America for warehouses and offices, cannot be far distant. It would, indeed, be bad policy if, while reducing the risk from fire, we were not equally to safeguard a building from the hazard of collapse.

In conclusion, I would take the opportunity of thanking the editor of the Boston "Brickbuilder" for his courtesy in placing at the disposal of the Committee this valuable paper, which was originally prepared for his journal.

EDWIN O. SACHS.

LONDON,
July 1st, 1898.

HOW TO BUILD "FIRE-PROOF."

BY way of preface to the following paper, I wish to say that it has been prepared after careful consultation with well-known experts, and after careful observation and study of numerous fires in this class of structures, and especially in those which caused losses to my own company. **Introduction.**

I think it advisable, in an article of this kind, to state, as premises, certain propositions which might be treated as deductions. Some of them are axiomatic or self-evident, needing no demonstration, and ought to appeal to any practical mind as being truths, rather illustrated than demonstrated by the experience of the past few years. In accordance with this line of treatment, I desire to state by way of premise :—

"Slow Burning."

First. It may be claimed that no construction is "fire-proof," and that even iron and masonry could with propriety be designated as "slow burning." The iron or steel used in a modern building has, in its time, been smelted in a furnace which presented no greater capacity for running metal into pigs than some of our modern buildings, whose interior openings from cellar to roof correspond to the chimney of a furnace, and the front door to its tuyere. If a pyrometer could be adjusted during the progress of a fire it would be found to rise quite as high as in any forge.

Openings in Façades.

Second. Glass windows will not prevent the entrance of flame or heat from a fire in an exposing building. It may seem strange that so obvious a proposition should be thought worth stating, and yet to-day more than 75 per cent. of the "fire-proof" structures of the country have window openings to the extent of from 30 per cent. to 70 per cent. of the superficial area of each enclosing wall without "fire-proof" shutters. Heat from a building across a wide street finds ready entrance through windows, and the several "fire-proof" floors serve only to hold ignitable merchandise in the most favourable form of distribution for ignition and combustion, like a great gridiron, to the full force of a neighbouring fire. This was the case in the burning of the Manhattan Bank Building, on Broadway, in New York, and of the Horne Building, in Pittsburgh. The latter building was full of plate glass windows, 16 by 16 ft. Such buildings are not more capable of protecting their contents than a glass show-case would be. A recent article on the Pittsburgh fire in the *Engineering News* aptly expresses this in the following words: "There seems to be some irony in calling buildings 'fire-proof' which opposed hardly anything to a fire from across the street more sturdy than plate glass!"

Openings in Floors.

Third. Openings through floors for stairways or elevators, gas, water, steam pipes, and electric wires, from floor to floor of "fire-proof" buildings tend to the spread of flame like so many flues and should be fire-stopped at each story. This fault is more generally overlooked than any other. Ducts for piping, wiring, etc., should never be of wood. In the Mills Building, in New York, a fire, not long since, jumped through two or three floors from the one on which it originated, by means of the passageways for piping, electric wiring, etc., comparatively small ducts, but sufficient for the spread of flame. In one instance the fire skipped one floor, where it was cut off, and ignited the second floor above.

"Fire-proofing" Iron Members.

Fourth. In view of the fact that it is necessary to cover iron with non-combustible, non-conducting material to prevent its exposure to fire and consequent expansion, and in view of the fact that all ironwork, except cast iron, will rust to the point of danger, it is best to use cast iron for all vertical supports, columns, pillars, etc. It is not advisable, of course, to have floor beams of cast iron (except in the form of Hodgkinson beams thoroughly tested). If a floor beam should give way, however, it might not necessarily wreck the building, whereas if a vital column should give way a collapse of the entire structure might result.

At a convention held some years ago in New York, at which were present a greater number of experts in iron than probably ever met before or since in one room, there was not one who contended that cast iron would rust beyond the harmless incrustation of the thickness of a knife blade, whereas there was not one who did not believe wrought iron would rust to the point of danger; and there was not one who claimed to know whether steel would or not, each admitting that steel had not been sufficiently tested as to rust to warrant a reliable opinion. If it could be relied upon as rust-proof, it would be superior to all other material for "fire-proof" buildings because of its great strength in proportion to weight. The use of steel in construction is growing, because it is cheaper than wrought iron, as lighter weights are used for the same strength, but while supposed to be superior to wrought iron, some of the prevailing impressions with regard to it are erroneous. Defects not possible of detection by tests are liable to exist in its structure. Among the first steel beams brought to the city of New York there were instances in which they were actually broken in two by falling from the level of trucks to the pavement, probably due to their having been rolled when too cold, as steel when rolled below a certain temperature becomes brittle. Better beams are now made. Rust.

In my opinion, cast-iron columns are superior to steel and more reliable. It is not generally known that American cast iron is vastly superior to English cast iron, and will stand a greater strain without breaking. Cast iron, moreover, will not expand under heat to the same extent as wrought iron and steel, which is another fact in its favour.

Columns should be stripped.

No bearing column should be placed in such a position that it cannot be uncovered and exposed for examination without danger to the structure. One of the ablest architects in New York makes it a rule to so "fire-proof" his columns that they can be examined at any time by removing the "fire-proofing" to determine whether rust has invaded their capacity to carry their loads. In my judgment, periodical examinations should be made, from time to time, in this way, of all wrought-iron or steel columns, as it may happen that a leaky steam or water pipe has worked serious harm. Such a discovery was accidentally made recently in an important New York building.

Cement as a Preventive to Rust.

Numerous newspaper paragraphs appear, from time to time, which claim that metal stripped of its covering of cement has been found exempt from rust, with the paint intact, etc., and the fact is cited as evidence that cement is a preservative of iron and that the danger of rust is over-estimated. It is probable that cement will protect paint for a long time, and, of course, paint, if properly put on, will protect iron while the oil in it lasts. Painting, by the way, should be done with the best quality of linseed oil and without the use of turpentine, benzine, or dryers. It should be thoroughly applied in three coats, with about a gallon to 400 sq. ft., and the iron should be first thoroughly cleaned of rust and dirt, by picking or other process. Paint is rarely properly applied, however, and even when of the best quality, is a preservative of the metal, as already stated, only so long as the oil in it lasts.

Those who claim to have evidence of the exemption of iron from rust rely, I think it will be found, upon iron which has been under exceptionally favourable conditions, free from dampness, the action of gases, etc., overlooking the fact that a leaking water pipe or steam pipe, or the escape of gases from boiler furnaces, will attack iron and gradually but surely consume it. A notable instance of this is the case of the plate girder of the Washington Bridge over the Boston and Albany Railroad in Boston, where a quarter-inch plate girder was recently found to be entirely consumed in places from the operation of gases from the locomotives passing below.

It is quite common to have advocates of wrought iron cite railroad bridges and the elevated railroad structures of New York as proof of their claims, but if they will take the trouble to examine these structures, they will discover that in spite of the fact that they are exposed to view, that they can be painted frequently, the evidences of rust are unmistakeable, especially about the rivets; and one can well imagine what would be the result in the case of riveted iron members in the skeleton structure of a building where such ironwork is entirely concealed from view, periodical inspections being impossible.

Rust is especially liable to be found in the cellars and basements of buildings. The wrought-iron friction brakes of freight elevators in the cellars of stores, for example, are frequently found so consumed with rust as to be easily rubbed to pieces in the hand.

Steel rivets are dangerous and they should never be used, unless of a very superior quality, so soft that hammering will not crystallize the material, and yet with sufficient tensile strength to insure perfect holding qualities. This is difficult to secure. Their use in columns for buildings is objectionable, as they rust badly under certain conditions; columns, therefore, should be without rivets, and the beam-bearing bracket shelf on cast iron columns should be cast in one piece with the column.

Expansion of Iron.

It is generally supposed, and frequently stated, that there is a great difference between the expansion of iron and masonry by heat. This is not the case. For example, the length of a bar which at 32 degs. is represented by 1, at 212 degs. would be represented as follows:—

Cast Iron	1·0011
Wrought Iron	1·0012
Cement	1·0014
Granite	1·0007
Marble	1·0011
Sandstone..	1·0017
Brick	1·0005½
Fire-brick..	1·0005

In the "fire-proof" building of the Western Union Telegraph Company, in New York, some years ago, a heavy brick pier, 7 or 8 ft. in diameter, adjoined the wall of the boiler furnaces. The difference in expansion in the brickwork next to this furnace wall as compared with that of the remaining brickwork of the pier was so great as to produce a crushing of the material from top to bottom of the pier for a depth of several inches, and it was found necessary to change the furnace wall and leave an air space between it and the pier.

Relative expansion of iron and masonry.

While the difference in expansion between masonry and iron incorporated with it is less per running foot than is generally supposed, and while the difference in expansion between a cubic foot of iron and that of a cubic foot of masonry would hardly be noticeable, especially if the iron were covered on all four sides, yet in stretches of 50 ft. or more, as in the case of iron I-beams and girders, the cumulative effect of expansion in uncovered iron might be a serious matter—quite sufficient with the rises of temperature due to a burning building to push out the bearing walls and wreck the building. Especially is this true of temperatures higher than 500 degs. It is unnecessary to suggest that metal differs from masonry in the important respect that heat does not travel throughout the entire length of the latter, while it does in the case of metal.

In other words, while the difference between the expansion of a lineal foot of iron as compared with a lineal foot of masonry, marble, brick, etc., is very slight, the difference in conductivity is very great. The conducting power of silver, for example, being represented by 1, copper would be ·845, cast iron ·359, gold ·981, marble ·024, and brick ·01—an important fact to be considered in the construction of buildings. Brickwork raised to a white heat would not raise the temperature of other masonry in the same wall a few feet away, but one end of an iron I-beam could not be raised to a white heat without raising the temperature of the beam for its entire length.

It is a well-known fact that iron responds so readily to temperature that, in surveying land, a surveyor's 100 ft. iron chain, will, in measuring the distance of a mile, result in a variation of 5 ft. between winter temperature and summer temperature, resulting in an error of one acre in every 533.

Preventions against expansion.

Where iron beams and girders are inserted in walls without sufficient space left for their expansion under heat they are almost certain to overthrow the bearing walls by their expansion thrust. A large warehouse in Vienna in which such provision had been contemplated by the architect was totally destroyed, with its contents, by reason of the fact that an officious subordinate, discovering the space in the wall purposely left at the end of each beam, deliberately poured liquid cement therein, which, having set, effectually thwarted the well-meant intention of the architect, and resulted in the destruction of the building.

Expansion thrust.

The expansion thrust of iron beams may be computed upon the following factor of expansion: Rolled iron of a length of 1,562 ft. will expand one-eighth of an inch for every degree of temperature. The heat of a burning building as already stated is enormous—sufficient to fuse most known materials; it may safely be estimated to be at least 1,000 degs.; therefore a length of rolled iron of 1,562 ft. at 1,000 degs. of temperature would expand about 125 ins., and a 50 ft. length of iron girder would expand between 4 and 5 ins., showing that there should be a play at each end of at least 2 ins. if the iron is not fire-proofed. Inasmuch as in iron construction the iron beams and girders are usually anchored to the walls to steady them, space should be left and the tie to the anchor should be by a movable hinge joint, which would be of the same strength with an inflexible anchor for all tying purposes, but would yield under the thrust pressure like an elbow and allow play of the beam, or stiff anchors should have elongated holes to allow expansion when beams are of great length. Girders are seldom over 25 ft. long, but if bolted together, as is frequently the case, they may be 120 ft. or more long, and a line of columns from cellar to roof ot a building may easily have one continuous iron structure of two hundred or more feet. It should be remembered, however, that this danger from the expansion of iron may be almost wholly counteracted by protecting it from exposure to fire through the use of non-conducting material. It is more important to protect girders than beams.

Unprotected ironwork.

The mistaken pride with which the owners of some buildings point to exposed iron beams in ceilings as evidence that the floors are "fire-proof," actually justifying the supposition that they are left exposed for such display, would be ludicrous if it were not serious. In buildings occupied for offices or dwellings, where there is not sufficient combustible material to endanger the beams, it is not so objectionable ; but in warehouses and stores, filled with merchandise, such construction is dangerous ; and if one of the upper floors should give way it would come hammering down to carry all below and thoroughly wreck the structure.

In this connection it is well to say that combustible merchandise should never be stored 100 ft. above the street grade even in a "fire-proof" building, since the average fire department cannot reach it at that height.

Roof.

Fifth. The roof, that portion of a building which ought to be most carefully watched during construction, is often the most neglected, woodwork entering into the composition, as in the case of the Horne Building, at

Pittsburgh, where the cornice was supported on wooden outriggers.

Sixth. Partitions. These should not be erected upon wooden sills, as is sometimes the case—only, however, with ignorant and inexperienced architects, who suppose that it is necessary to use wood in order to nail base-boards and other trim at the bottom of the partition. Porous terra-cotta will hold nails and should be used in preference to wood, which, as soon as it burns out, will let down the entire partition. Partitions.

Seventh. All buildings over 125 ft. high should be provided with 4 in., or, better still, 6 in. vertical pipes, with Siamese connections at the street, for the use of the fire department, extending to the roof, with hydrants at each story and on the roof. This would save the time of carrying hose to upper floors—a difficult task in the case of high buildings. Ample tanks of water should be provided on the roof, supported by protected iron beams resting on iron templates on the brick walls, to supply the building's inside pipe system for fire extinction, and secure pressure by gravity or by some other method constantly operative, especially on holidays and at night. Stone templates should not be used, and care should be taken to secure strong supports, so that, in the event of fire below, the tanks will not come crashing through the building to destroy it and endanger the lives of firemen. Two such disasters in "fire-proof" buildings within a year show how true is this proposition. Tanks in the basement, under air pressure, are also a great advantage, and recent invention has perfected them to the point of reliability. Water Standpipes.

Fire Marshal Swenie, of Chicago, urges that standpipes should not be less than 6 ins. internal diameter, and that a check valve should be provided, so that when steamers are attached, their force will be added to that of the local pumps. Each floor should have hose connections with the standpipes, and sufficient hose to reach to the most remote point of the floor above, and this hose should be frequently inspected to see that it is in order. He recommends that a code of signals, by which communication can be established between the firemen and the engineer of the building is essential.

Night Watchman.

Eighth. All high buildings should have constantly present, night and day, some competent person understanding the elevator machinery, fire appliances, etc., so as to aid the firemen in reaching the upper levels; and there should be sufficient steam in the boilers, at all times, to run one elevator.

I quote from the valuable treatise on handling fires in these buildings presented by Fire Marshal Swenie to the International Association of Fire Engineers held in August, 1897. He says:—

In case the elevators fail, it is necessary to use the stairway, and after the truck men should follow the pipe men bearing the necessary hose, and this must be carried on the shoulders of the men. A 50 ft. section of ordinary $2\frac{1}{2}$ in. cotton hose, with couplings, weighs from 56 to 60 lbs., and 250 ft. of $1\frac{1}{4}$ in. rope, about 65 lbs, either of which is a good load for a man who must climb a steep stairway to the height of 250 ft. With an average rise of 7 ins. per step, that means taking some 430 vertical steps before reaching the scene of action, and consuming from seven to ten minutes of time. If it is found necessary to use hose instead of the standpipes for taking the water from the street to the floor, the hose should be taken up in the elevator, if it is running, and then lowered until connection is made with the hose below.

Stone Staircase Treads.

Ninth. Marble, slate, and other stones are certain to disintegrate or crumble when subjected to the joint action of heat and water. For this reason 90 per cent. of the staircases in modern "fire-proof" buildings would be found utterly unreliable in the event of fire, either for the escape of the inmates or for the use of firemen—a serious consideration. Stone treads are usually let into iron rabbet frames, and as these stone treads would give way in case of fire, it would be impossible for a person to find a footing on the stairways; 2 in. oak treads might actually last longer; but a safer staircase would be one the framework of which is of iron, the tread having an iron web or gridiron pattern, the interstices or openings of which should be small enough to prevent the passage of a foot, underlying the stone or slate, so that if the stone tread should disintegrate, the staircase would still remain passable.

It is possible to have the supporting tread of open-work cast iron in an ornamental pattern, which, in relief against the white marble tread resting on it, would present a tasteful appearance from the underside or soffit of the staircase, with this great advantage, that, in the event the action of fire and water should pulverise the marble or slate tread, it would still afford a safe support for the foot. In the case of the burning of the two "fire-proof" buildings, Temple Court and the Manhattan Savings Bank, in New York, the slate treads yielded early in the fire, leaving staircases with openings the full size of the tread, which, within a few minutes after the fire started, were impassable for either firemen or inmates. It is astounding that this vital fault should be so generally overlooked in "fire-proof" buildings.

I may here state that the Manhattan Savings Bank building did not deserve to be called "fire-proof," for the reason that it had hollow spaces under the wooden floor boards, and that the iron beams and girders were not protected. Some of them were large riveted box-girders, which yielded quickly to the heat of burning goods and pushed out the side walls.

It is generally supposed that it is not necessary to be careful as to stone treads in buildings occupied solely for offices separated in "fire-proof" hallways in which, it is claimed, there is nothing to burn; but in the case of one large "fire-proof" building of this kind in New York, I found the space under the staircase in the basement story was used to store the waste paper and rubbish of the building—material particularly likely to cause a fire by concealed matches, oily waste, cigar or cigarette stumps, etc., and to make a lively and quick fire, quite sufficient to destroy stone staircase treads. Even where there is no combustible material in the hallway, if the staircase is near windows, stone treads may be destroyed by exposure to burning buildings and by the combustion of window frames, dadoes, and other wooden trim.

Tenth. No building should exceed in height the width of the street on which it is located, from the view Height of buildings.

point of light and health; nor, in any case, in excess of 95 ft. for mercantile occupancy, nor a height in excess of 200 ft. for office occupancy.

Destructibility of Contents.

Eleventh. It should be remembered that merchandise, furniture, etc., are combustible, no matter whether located in "fire-proof" buildings or in ordinary buildings. This obvious fact seems generally to be ignored. In fact, combustible material will sometimes be more effectually and thoroughly destroyed in a "fire-proof" building than in an ordinary building, since the early collapse of the latter may smother the fire and effect salvage, whereas "fire-proof" floors support the contents of the former, and distribute them so that they are more certain to be destroyed. There was not a dollar of salvage in the great stock of merchandise in the Horne Building, at Pittsburgh. The entire household furniture of a tenant in one of the best "fire-proof" apartment houses in New York, was totally cremated, and a fire in the Great Northern "fire-proof" Hotel, at Chicago, seriously burned the automatic organ to the extent of over $4,000. There is no more reason why the combustible contents of a "fire-proof" building should not be consumed than why the fuel in a stove should not be burned.

Enclosing Walls.

Twelfth. Enclosing walls. These should be of brick, the brickwork of the lower stories especially, if not of all, being laid in cement mortar. In fact, the specifications for a building in the compact part of the mercantile section of a city, ought to be drawn in contemplation of the possible cremation of its contents, and the generation of heat considerably greater than 2,000 degs. Fahr. The heat of a wood fire is from 800 to 1,140 degs.; charcoal, about 2,200 degs.; coal, about 2,400 degs. Cast iron will melt at between 1,900 and 2,800 degs.; wrought iron, 3,000 to 3,500 degs.; steel, 2,400 to 2,600 degs.; and if an architect should be required to draw specifications for a building adjoining others, with the knowledge beforehand that its entire contents, from cellar to roof, were to be totally consumed, and he were under a bond to pay damages to surrounding property, he would not be more severe in his exactions than should a building law protecting neighbourhood rights in the enjoyment of property; for a mercantile or manufacturing building sometimes generates a greater heat in combustión than a smelting furnace.

Foundation.

It is hardly necessary to deal with the foundations of buildings. The question is an engineering problem which hardly requires suggestions from a fire standpoint, and I shall not deal with it here, other than to touch again upon the important point of not having wrought-iron or steel columns in the cellar or basement, where moisture and gas conditions would increase the danger of rust.

Enclosing Walls.

These, as already stated, should be of brick, the lower stories laid in cement mortar, not less than 16 ins. thick at the top of the building and increasing 4 ins. in thickness for every 25 ft. in height to the bottom. This would require a 44 in. wall at the grade for a 200 ft. building. The thicknesses here recommended are for buildings not exceeding 100 ft. in depth. If they exceed this depth without curtain or cross walls, or proper piers or buttresses, the walls should be increased in thickness 4 ins. for every additional 100 ft. in length.

Brick is the best known resistant of fire. Stone yields readily to the combined effect of heat and water, and even terra-cotta or burned clay tile cannot be regarded as a perfect substitute for hard-burned brick.

Under no circumstances should the iron framework of a skeleton building be incorporated in thin enclosing walls. No wall that has not a cross section sufficient to support itself without the ironwork should be allowed, aside from the importance of having it thick enough to prevent the passage of hot air from an adjoining building.

Curtain walls for enclosing walls supported by the longitudinal members of skeleton construction are objectionable; they are liable to be buckled out by the expansion of the framework. The great trouble with modern "fire-proof" structures, even under the New York building law, is that while the separating "fire-proof" floors tend to prevent the passage of flame from one story to another, the enclosing walls are often insufficient to prevent heat from igniting the contents of an adjoining building, so that what is gained by preventing the spread of fire vertically is lost laterally.

Thickness of Walls.

It should be borne in mind that the thickness of walls herein recommended is not for carrying capacity as bearing walls. Thinner walls would answer for that purpose. It is intended to confine the heat generated by a fire, and should be required in the compact portions of cities, where every man should be compelled to build with reference to the safety of his neighbour.

Architects and builders generally seem to have in mind only the carrying capacity of walls, and to lose sight of this important fact.

As the contents of a mercantile building and its floors burn, they sink to the bottom, where enormously high temperatures are reached, and it is for this reason recommended that walls should increase in thickness as they approach the bottom, on the same principle that the walls of smelting furnaces are thicker at the bottom than at the top.

It is the generally accepted opinion that a 12 in. brick wall will prevent the passage of fire, but a much thicker wall will fail to confine the heat of a burning building, on the first floor particularly, sufficiently to prevent the ignition of combustible merchandise or other material in an adjoining building. In a fire which occurred in Boston, several years ago, combustible material was ignited through a 3 ft. wall, which became so hot as to thus conduct the heat into the adjoining building. In an isolated location an owner might be permitted to construct his walls with reference only to their carrying capacity, but where he builds in the compact part of a city, storing combustible materials from cellar to roof, he should be required to build so that a fire in his premises will not necessarily destroy his neighbour's property.

He may well observe a regulation which, in view of the fact that the buildings of his neighbours out-number his own a thousand to one, will ensure that he shall be in that proportion the gainer by rules which secure the safety of all though imposed on himself.

Skeleton Construction.

I do not believe "skeleton construction" so called should be permitted for stores, warehouses, or manufactories in cities, as the walls are not thick enough to confine the heat of burning merchandise.

In some of our Western cities, Detroit, Chicago, etc., the practice is growing of using hollow tiling, bonded like ordinary brickwork, 12 ins. thick, for enclosing walls, instead of brick, the exposed steel frame being protected by terra-cotta slabs about an inch thick. Such a building would burn more quickly than an ordinary wooden-joisted building properly constructed. The Leonard Building, in Detroit, destroyed by fire Oct. 7, 1897, was an example of the great danger of this style of construction. It was ten stories high, and as fast as the columns or wall girders were warped by the heat the tiling dropped out like loose bricks, leaving the entire structure after the fire a ragged cage-work of iron with very little of the tiling on the enclosing walls and none of the floors intact. The contents were, of course, totally destroyed.

Piers, Bond Stones, etc.

Bond stones should not be allowed in piers, especially in the cellar or basement, or in piers vital to the building or carrying great weights. Stone yields readily and quickly to the combined effects of water and heat and, disintegrating at its edges, gradually releases the bricks above it, so as, in time, to destroy the integrity of the pier. Bond stones are employed by the mason to steady his work. A green brick pier while being laid is frequently unsteady, and a bond stone enables him to progress with his work by steadying all below it so as to receive new courses of brick. In all cases the bond should be a cast-iron plate. If the plate should be cast with holes through it about $1\frac{1}{2}$ ins. in diameter, so that the mortar and cement can thoroughly incorporate the plate with the masonry above and below, it would be an improvement. Wrought iron is liable to rust and should not be used. Where bond stones are used in the outer walls of buildings they are less objectionable, but for inside piers they are so dangerous that they ought to be prohibited by law. Strangely enough, only stone for bonds used to be required by the New York building law, and such was the opposition of the stone men to the prohibition of bond stones altogether, when later it was proposed, that a compromise was reached allowing the use of cast-iron bonds as an alternative of stone bonds—an option seldom availed of by architects, builders, or owners, however, and construed generally by the public to mean that either is good enough.

Stone Pillars.

It not infrequently happens that a building of otherwise admirable construction has its weakest point in the cellar, where a stone pillar forms the basis of support of the entire line of columns through the building. In case of fire and the application of water these stone pillars, no matter how substantial, whether single monoliths or stone blocks, will rapidly disintegrate and bring down the entire structure; and inspectors should carefully examine, especially in the cellars, for such construction. After the great Boston fire, granite piers were shovelled up and carted away like so much sand. It is quite a common practice, but a most dangerous one, to employ single stone columns, often of polished granite, to support the centre of a long stone lintel carrying the wall over the ornamental entrance of a building. Such a column would surely yield to the effect of fire and water and perhaps let down the entire front. In almost any city (and New York is no exception), such faulty architecture may be observed. The writer passes every day a costly structure on Fifth Avenue whose corner is supported by a single granite monolith column of this kind. If stone columns are desired for architectural effect they should, wherever they carry heavy loads, contain a centre column of cast iron of sufficient carrying capacity to support the superimposed weight.

The vertical supports, columns, pillars, etc., as already stated, should be of cast iron, cylindrical in form, of liberal thickness, especially in the lower stories, thoroughly tested as to sand holes, thin places, etc. Cast iron columns should be round, and not square. In the former shape there is less likelihood of defects in casting, sand holes, etc., resulting in uniform sound thickness of the shell. The columns should be planed to smooth bearings, so that the entire system of columns, from the foundation to the roof, may be securely bolted together and form a continuous line with joints for expansion and without any inequalities of bearings. Under no circumstances should wedges or "shims"* be allowed. This most important matter is often neglected. The flanges and corbel brackets for supporting beams should be cast in one piece with the column and not depend upon rivets or bolts. Rivets, aside from the danger of shearing strains, are almost certain to rust to the point of danger. The beams should be riveted or bolted to lugs on the columns, however, as a tie between the side walls, holding the entire structure firmly and consistently together as one rigid whole and yet with play for expansion.

Cast-iron Vertical Supports.

Col. George B. Post, of New York, has devised a form of cast-iron cage construction consisting of pillars and floor beams the members of which lock into each other, without the use of bolts or rivets, forming a very rigid construction, and saving the cost of mechanics for bolt and rivet work. While I have not had an opportunity to examine it, I have great faith in his judgment; my impression, from his description of it, is that it would be a very rigid construction and admirably adapted to warehouses six and seven stories high. Above this height merchandise should not be stored in any kind of a building.

The factors of safety, in computing strains, should not be less than those prescribed by the standard modern authorities. Better be sure than sorry.

* "Shims" are pieces of slate or iron inserted to secure a true vertical, where the two surfaces have not been properly levelled or planed.

" Fire-proofing" Iron Members.

All ironwork, columns and pillars, beams and girders, should be "fire-proofed," *i.e.*, covered with at least 4 ins. of incombustible material, terra-cotta or brick. At the floor, and for a height of 4 ft. in mercantile buildings, a metal guard should be employed to prevent the column from being stripped by collisions with rolling trucks for moving merchandise. It ought to be unnecessary to suggest that wooden lagging should, under no circumstances, be used to cover iron, were it not for the fact that in one of the largest and most costly dry-goods stores in New York, the "fire-proof" covering of the iron columns, which had been seriously damaged by trucks, was being systematically removed in order to substitute wooden lagging, when the fault was, fortunately, detected by an inspector of the underwriters. 4 ins. of good brick-work is a good covering, but porous terra-cotta, or even wire lath and plaster, may prove effective. Where wire lath and plaster is used, the column should first be wrapped with quarter-inch asbestos, bound with wire. This would prove reliable and inexpensive.

It is a fact, showing how common is the neglect to cover iron with non-conducting material, that in the State Capitol, Albany, N.Y., in the library, is a large plate girder entirely exposed. This girder supports the ceiling beams, and there is enough combustible material in the oak bookcases, furniture, and flooring to wreck this portion of the building by expansion in case of their combustion. The New York Building Law was enacted in this building. The ceilings of the Assembly and Senate chambers are of heavy, hard wood, attached to the soffits of the iron beams, and they would, if ignited, probably warp and expand the beams to a dangerous point.

A notable instance, showing the necessity of protecting ironwork with incombustible material, and the danger of expansion in long lines of iron girders or beams, was that of the destruction of a "fire-proof" spinning mill at Burnley, England, recently. This mill was 210 feet long by 120 feet wide, six cast-iron girders of the Hodgkinson type, each 20 feet long, spanned the

120 feet width, being bolted to cast-iron columns, and carrying, in turn, cross girders of wrought iron. The expansion of these 120 feet girders (they were unprotected) resulted in the disruption of the floor and the destruction of the mill. The cast-iron columns, being unprotected, collapsed under fire and water. The floors were 10ft. 6in. bays. As already stated, beams should not be spaced over 5 ft. on centres. Wider spacing results in weak arches, liable to be buckled out by heat or punched through by the falling of safes or of other heavy articles from upper floors.

The probability is that if the 20 ft. girders in this building had been arranged with provision for expansion, and all the ironwork had been thoroughly protected with "fire-proof" material, little damage would have been done. The effect, if the floors had been loaded with combustible merchandise, would have been more rapid. There was little wood to burn in the contents of the spinning mill, and yet the destruction was thorough. Such buildings with uncovered ironwork are more dangerous than those of heavy wood construction, in which the timbers are 12 inches or more in diameter, and not more than five stories in height. A properly constructed building with protected iron, however, is of course superior to any other form of building. Experienced firemen are afraid to enter buildings supported by iron columns unless they are thoroughly "fire-proofed," as they are liable to snap without warning under the influence of fire and water, whereas wooden posts burn slowly and give notice of collapse. They will stand a severe fire without being charred for more than two inches of their surface.

Beams and Girders.

In mercantile buildings and factories, beams, as already stated, ought not to be spaced more than 5 ft. apart, no matter what kind of arch is employed; and while many experts claim that a heavy iron I-beam, thoroughly encased in "fire-proof" material on three sides, and having only its soffit or under side exposed, would not be expanded enough by the heat of a fire to cause its collapse, it is best to take no chances, but to protect the under side with "fire-proof" material, which can be cheaply applied with wire lath and plaster, or by having the skew-backs of the terra-cotta floor fillings extend below the soffit or bottom flange of the beam, and made with lips for protecting the iron.

Tie-rods.

It is a mistake, in my judgment, to dispense with tie-rods, even with the kinds of arches which employ wire cables or other metal ties. The claim is made that these act as tie-rods, but it should be remembered that they cannot be relied on during construction, when derricks for hoisting iron beams and other materials are resting on the girders. Dangerous lateral movements and twistings of the structure may be the result of want of rigidity, which can only be obtained by using tie-rods.

Material for Arches between Beams

It is my opinion—but there are many who entertain a different one—that the old-fashioned brick arch is the most reliable for resisting fire; that next to this in safety stands the porous terra-cotta segmental arch, with end construction, *i.e.*, the blocks or separate pieces placed end to end between the beams, instead of side by side, in what is known as "side construction." This is said to be stronger than side construction. It is claimed by many experts that porous terra-cotta is a better non-conductor than brick on account of its interior air spaces. The arch should not be less than 4 ins. thick, having a rise of at least 1¼ ins. to each foot of span between the beams, and there should be a covering of good Portland cement and gravel concrete over this to ensure a waterproof floor. Cinder filling will burn—crushed slag from blast furnaces is better, but the Portland cement concrete should not be omitted for waterproofing purposes.

There are many patent floor arches for filling between I-beams which have great merit when properly put in, but I doubt if any of them are equal to the two I have named, and it should always be borne in mind that when employed they should be inserted with the same care with which they are prepared for tests. This is almost equally true, however; as regards brick and burnt-clay arches, also. There is less likelihood of poor installation work, however, with brick arches or segmental arches of porous terra-cotta or burnt clay. Arches should be laid in Portland cement, not lime mortar. Under no circumstances should they be laid in freezing weather, and where concrete is used the broken stone or gravel should be carefully washed, and the cement should be of the best quality.

Waterproof Floors.

It is of great importance that the floors or all buildings should be waterproof, in order that the volume of water thrown by the fire department to extinguish a fire may be carried off without injury to merchandise on the floors below. Neglect of these precautions is criminal in view of their simplicity and inexpensiveness.

After the arches have been set between the I-beams they should be covered, for at least a thickness of 1 in., with the best Portland cement concrete, carefully laid, so that all water will run to the sides of the building and be carried off by water vents or scuppers, which may be arranged with pipes through the walls, having a check-valve which would prevent the influx of cold air and yet admit of the out-flow of water.

Ducts.

All ducts for carrying steam, gas, and other pipes and electric conduits should be protected with a metal sleeve going above the surface of the floor, and the space between and around the pipes should be filled in closely with mineral wool, asbestos, or some other expansive and "fire-proof" material to cut off draughts and flame.

Floor Surfaces.

Floor boards should be dispensed with, if possible, and asphalte or concrete employed instead. It is hardly practicable in office buildings, however, to dispense with wooden floors. Wherever used they should be so laid, especially in mercantile or manufacturing buildings, that there is no air space to supply a passage for flame and to form a harbourage for rats and mice, to which these vermin can carry matches, oily waste, or other combustible material, liable to be ignited by steam pipes or by spontaneous combustion.

"Fire-proofing" Wood.

Various processes, "electric," so called and otherwise, have been patented for "fire-proofing" wood. They undoubtedly increase the fire-resisting properties of wood for interior trim, window casings, etc. Whether or not they impair the durability of wood is a matter as to which I am not yet informed, and I doubt if sufficient time has elapsed for a proper test. The United States Navy has made trials of "fire-proof" woodwork—with what success I am not informed.

Ventilating and Light Shafts, Dumb-waiter Shafts, etc.

The enclosures of all ventilating shafts, for water-closets, etc., light shafts, and dumb-waiter shafts should be constructed in the same substantial manner as freight elevator shafts. It is a mistake to use thin plaster board or plaster with dovetailed, or other metal, lath, etc. No enclosure should be relied upon less than 4 ins. in thickness, well braced with angle iron, but brick walls are best, especially in buildings over 60 ft. high. The lights should be of wire glass, set in metal framework, and ventilators should have metal louvers arranged to secure ventilation but not to increase a draft. Slats should be riveted, not soldered, to metal framework, and the metal framework should flange well over the "fire-proof" material of shaft on both sides. It is possible to finish tin-covered "fire-proof" doors with wooden trim so as to be ornamental, with bead panel-work, etc.

Well-holes.

These should be avoided if the building is to be regarded as "fire-proof." The Horne Building had one 48 by 22 ft. It is almost impossible to control a fire starting in the lower floors where a well-hole opens through those above. Luxfer Prisms are now used to secure light from side windows, it is claimed, with great success.

A recent fire test of the Luxfer Prism, in Chicago (March, 1898), is stated to have been satisfactory to Fire Marshal Swenie, as showing that these prisms afford material protection from the heat of a neighbouring fire in an exposing building, and that, to some extent, they are substitutes for iron shutters.

Staircases, Elevators, etc.

These should be in hallways cut off from the rooms at each story by fire walls and doors, to prevent drafts. It is not so important, and is not so practicable, in the case of office and hotel buildings as in the case of mercantile and manufacturing buildings; but it is advisable, even in office buildings, to have the staircases, elevators, etc., in a separate hallway, the division walls of which should extend through and above the roof, and any skylights should be covered with glass not less than $\frac{1}{4}$ in. thick.

It is contended by some that skylights should be of thin glass, so that they will break easily and permit the escape of smoke and gas. Smoke is inflammable, and when it accumulates in a building, often spreads the fire from story to story, or blows out the walls by the explosion of its gases. But while thin skylights are contended for by many expert firemen, it should be borne in mind that nothing so facilitates the spread of fire as a draught, and it would be better to have the skylights adjusted with appliances for opening them, so that when the firemen arrive on the ground, and not before, they may be adjusted to permit the escape of smoke and allow the firemen to enter the building to see where to work to the best advantage. Under any circumstances a network of wire should be above the glass to guard it against flying embers, and another should be suspended beneath the skylights, so that when the glass cracks and breaks with the heat it will not injure the firemen below. Skylights.

These should be of brick or tile on all high buildings, the roof beams being of iron and, where tanks are supported, of sufficient strength to carry many times the actual probable weight of the water and the containing tank itself. Roofs.

Slate roofs, on very high buildings especially, on street fronts are objectionable, as, in case of fire, the slates would crack and, falling to the street, injure the firemen. A flat roof of brick tile is better than any other. Slate Roofs.

All water on roofs from rain or melting snow should be drained from the front or sides to leaders, so as to avoid drip points, from which icicles could be formed.

Too little attention is paid to the great danger of injury to pedestrians from falling snow or icicles on very high buildings. This may not be a suggestion strictly germane to this article, but it is a matter so often overlooked as to warrant its being referred to in an article intended to deal more or less thoroughly with the subject of "fire-proof" buildings.

Electric Light Installation, Dynamo Room, etc.

The electric light installation of a "fire-proof" building is an important and complicated matter. To insure safety, reference should be made to the rules of the National Board of Fire Underwriters, which can be obtained, without charge, from the nearest local board of underwriters.

The switchboard should be of incombustible material, and no steam, water, or sprinkler pipes should pass over or near it where, in case of a bursting pipe, water could reach the switchboard and cause disaster. This is an important matter almost universally overlooked.

An admirable floor for a dynamo room is one of deck glass, $\frac{3}{4}$ in. thick, on a wooden (not iron) frame. It will insure that the attendant upon the dynamos will be, at all times, effectually insulated. Such a floor will not become soaked with oil, as would a wooden floor, and can easily be kept clean. A strip of rubber floor carpet stretched over it will prevent slipping. The Continental Insurance Company has, probably, the only floor of this kind in the country in its large "fire-proof" office building on Cedar Street, New York.

Communications between adjoining Buildings.

It is sometimes necessary to have communications between adjoining buildings by doors in the fire walls, and it is not always convenient, for changing merchandise from one room to another, to have "fire-proof" doors closed during working hours. It is possible to have the "fire-proof" doors run upon trolleys on an inclined track, so as to close by the force of gravity, and held open by fusible metal latches or links which would release them when melted by the rising temperature of a fire. It has occurred to me that this difficulty may also be met by erecting between two adjoining buildings a separating "fire-proof" hallway of brick, which can be utilised for containing staircases and elevators, and for supporting the water tanks of automatic sprinklers. The doors which open into this hallway should not be opposite each other, but at opposite ends of it, so that fire in one of the buildings passing through the door would come against a blank wall opposite. Even if the "fire-proof" doors to these openings should happen to be open at the time of a fire in one of the two buildings, it is improbable that it would find access to the other.

Waterproof Floors.

The floors should be both fire and water proof, slightly lower than those of the two separated buildings, and with water vents or "scuppers" for carrying off surplus water thrown by a fire department. Indeed, it is well to have "scuppers" on all floors of every building.

The walls of this separating hallway or vestibule should rise 4 ft. higher than the roofs of the two buildings, and, if there are window or door openings near it, its walls should project beyond the line of enclosing walls at least 1 ft.

Water Tanks

The water tank, as already stated, should be supported on protected iron I-beams, resting on the brick walls, with cast-iron templates, so that the tank cannot fall, break down the staircases and wreck the building in case of fire.

It is important always to locate tanks so that they will not be over stairways or elevators, and endanger them in case the supports give way. With a "fire-proof" hallway of the kind recommended, containing no combustible material whatever, the tanks being supported by iron I-beams resting on the brick walls, this would not be an important matter, but in all other cases water tanks should be planned so as not to endanger staircases, and the supporting iron beams should be "fire-proofed," that is, covered with "fire-proof" material.

It ought to be unnecessary to state that there should be no combustible material whatever in this separating hallway, and that the staircase, elevators, etc., should be of metal and "fire-proof."

Separation of Wooden Buildings.

Indeed, such a hallway as this could be relied upon to separate wooden buildings. It should, however, for that purpose, be at least 10 ft. higher than the peak of their roofs, and should extend 4 ft. beyond their front and rear lines. It is probable that the extensive frame dairy buildings of ex-Vice-President Morton at Ellerslie, which burned several years ago, might have been saved by this simple precaution.

Outside Staircases.

Where it is not necessary to transfer merchandise from one building to another, and only requisite to have a passageway for employees, this may be arranged by an iron balcony, like a fire escape, cutting down the window on each side of the separating wall for a door, so that communication can be had by the balcony. The openings should have "fire-proof" doors. This would be practically safe. It might, with iron ladders, be utilised as a fire escape, and so prove of great advantage to firemen in fighting a fire, who could hold a hose nozzle at the different windows with perfect safety to the last moment. It is practicable, indeed, to have iron stairways with roofed balconies entirely outside of storage stores so that the floors do not communicate. There is a number of these in Philadelphia.

"Fire-proof" Doors and Shutters.

These should not be of iron, but of wood covered with tin. Solid iron shutters or doors are not reliable. Iron doors yield readily to flame, resulting sometimes in their warping open when exposed to fire in an adjoining building, exposing the one they are intended to protect to the full effect of the flames.

Where window openings are protected by iron shutters on rear courts they are almost certain to be opened by a fire in an exposing building, and cannot be relied upon. The tin-covered wood shutters are alone reliable. There is no recorded instance in which a solid iron door, exposed to the full effect of fire in an adjoining building, has protected the opening, whereas there is, on the other hand, no recorded instance in which the "Underwriters'" door has failed to serve its purpose—two important facts which are significant and ought to settle the question.

The "Underwriters'" door is constructed of ordinary white pine lumber, free from knots, of double or treble thickness, according to width of opening, the boards being nailed diagonally and covered with the best quality of tin, with lap-welded joints.

It ought to be unnecessary to state that on the exposed side of a building, not only the shutter, but the window-frame, sash, etc., should be of metal or covered with metal—riveted, not soldered. Where it is not possible to use a "fire-proof" shutter for want of room, wire glass in a metal frame will be found a desirable substitute. It will probably hold a fire until the fire department can cope with it.

It is not generally understood nor known that fire will travel from one story to others above by way of the windows in the outer or enclosing walls. Especially where a building has an enclosed court, it will sometimes reach upper stories in this way, even when the floors themselves are thoroughly cut off, the court acting as a chimney. This happened several years ago in the Temple Court Building, a "fire-proof" structure in New York. The woodwork on several floors was ignited by the lapping of fire through the windows from the lower stories, and serious damage resulted. A recent instance was the Livingston Fire-proof Building in New York, in January, 1898. All windows on exposed sides should be protected with fire-resisting shutters.

It may be well to suggest for the benefit of those who are not familiar with city fires that, as heat naturally ascends, the exposure of a low building is often much greater to a neighbour higher than itself than to a building of its own height, so that a tall, "fire-proof" structure, surrounded by smaller buildings, should be provided with fire shutters to all openings. These are not necessary where the exposing buildings are occupied for offices, and are themselves "fire-proof," as the amount of heat which escapes from the windows of a burning building, so long as its enclosing walls remain intact, is seldom sufficient to ignite a "fire-proof" building or its contents. The moment of greatest danger is when a burning building collapses, and the intense heat caused by its enormous bed of coals, exerts its full effect upon surrounding structures. In a recent fire in New York (Feb. 11th, 1898), three "fire-proof" office buildings were more or less damaged with their contents, although many feet away from the burning building.

It is to be hoped that some inventive genius will devise a plan for simultaneously opening or closing the shutters on any or all stories of high buildings by manipulation from the ground floor. They are usually left open at night, always in the day time, and might thus be closed in case of a dangerous fire in the vicinity. In some cases they are fastened open.

Comparative Tests of "Fire-proof" Material.

Tests of "fire-proof" material, iron beams, pillars, floor arches, etc., to be of any value must be conducted under circumstances which insure uniform conditions. Otherwise comparisons are unreliable. It is quite customary to refer to results of fires in different buildings, having differing forms of construction, as supporting theories of relative merit; but ordinary conflagrations cannot be relied upon, for the reason that in two buildings, side by side, the conditions may be widely different. Eddies and currents of air, changes of prevailing wind, etc., may secure exemption from damage. It happened in the large conflagrations of Chicago, Troy, Boston, etc., that the most phenomenal escapes were observed. In some instances frame buildings, surrounded by brick structures which were totally destroyed, escaped with no further damage than the blistering of paint.

Even where tests are carefully arranged, especially weight tests, obvious precautions are sometimes overlooked. It will be observed, for instance, where bricks are piled on a surface of floor arch and iron beams to secure a certain weight per square foot, the pile of bricks may be so disposed as to have a bearing on both of the iron beams and the full weight may not come upon the "fire-proof" arch between them. The lateral bond of a pile of bricks a few courses higher than the floor to be tested may have all the effect of a relieving arch and materially reduce the strains. In furnaces constructed to secure high temperatures, drafts and currents of air should be provided for with great care and under the direction of the most competent and intelligent experts.

Conclusion.

In conclusion it may be well to state, in view of the general misapprehension which prevails with regard to the interest of the fire underwriter in the improvement of construction, that it makes no difference to him whether a building be "fire-proof" or not; his rate of premium and the amount which he insures are both based upon the characteristics of each building insured. He would make just as much money on $100 of premium secured at a rate of 5 per cent. for $2,000 insurance on a wooden planing mill as on $100 of premium secured on $100,000 insurance on a "fire-proof" building the rate of which is $1 per $1,000.

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Fig. 1.