CHURCH FIRE
St. Louis, MO
April 28, 1994

NFPA
INTERNATIONAL

FIRE INVESTIGATIONS

NATIONAL FIRE PROTECTION ASSOCIATION

1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101 USA
Telephone: 1-617-984-7263 E-mail: investigations@nfpa.org

NFPA®

National Fire Protection Association
International

Executive Offices
1 Batterymarch Park
P.O. Box 9101
Quincy, Massachusetts 02269-9101 USA
Telephone (617) 770-3000 Fax (617) 770-0700

SUMMARY
FIRE INVESTIGATION REPORT

CHURCH FIRE

ST. LOUIS, MISSOURI

APRIL 28, 1994

PREPARED BY

MICHAEL S. ISNER

FIRE PROTECTION ENGINEER

NATIONAL FIRE PROTECTION ASSOCIATION

At approximately 8:26 a.m. on Thursday, April 28, 1994, the St. Louis Fire Department received notification of a fire at St. Anthony of Padua Church, a large church in its community. Upon arrival, fire fighters found the combustible concealed space below the church's roof heavily involved in fire. Five alarms were sounded before the fire was extinguished, approximately two hours after the initial fire report. The fire caused heavy damage to the church's roof assembly. However, fire fighters were able to minimize fire damage in other areas of the structure.

Fire investigators have determined that the fire was most probably caused by a lightning strike, even though the church was equipped with a lightning protection system. An inspection of the church's lightning protection system revealed that several installation and maintenance details were not consistent with requirements of current NFPA documents. However, investigators were not able to determine whether these inconsistencies contributed to the ignition of the roof assembly.

Introduction

The National Fire Protection Association (NFPA), with the cooperation of the St. Louis Fire Department, investigated this fire as part of its ongoing program to investigate technically significant incidents. It was not NFPA's intention that the investigation and resulting report pass judgment on, or fix liability for, the loss of property resulting from this fire. Rather, the NFPA documented and analyzed this incident intending to determine the significant factors that resulted in the loss of property and to report the lessons learned so that the fire service and other concerned parties can reduce the potential for future property losses.

Background

St. Anthony of Padua Church was located on top of a hill and was the tallest structure within several miles. The church was built between 1908 and 1910 and was of Romanesque design. The large cathedral-like building (see Figure 1) was in the shape of a cross, with its longest part, the nave, in the north/south direction. The nave was approximately 220 feet long and 75 feet wide. The transepts, small wings creating the building's cross-shape, were approximately 26 feet deep and 36 feet wide and were constructed in the east/west direction. These wings were located approximately 64 feet from the south end of the building. Two steeples, approximately 175 feet high, had been constructed at the north end of the building; one steeple was on the east of the building's main entrance and the other steeple was on the west side of the main entrance.

The building was of ordinary construction with masonry-bearing walls and pilasters. The roof assembly had both steel and wood structural members. Steel I-beams supported 2-inch x 8-inch wood rafters which, in turn, supported 1-inch x 6-inch tongue and groove, wood sheathing. Slate shingles covered the wood sheathing, and copper was used for flashing in roof valleys and ridge caps. Gutters, fascia, and eaves were also constructed of copper.

A cupola had been constructed above the roof and was located at the intersection of the nave and transepts (i.e., north/south and east/west portions of the building). The cupola was a six-sided structure with a steel frame forming the sidewalls. The steel members of this frame were bolted to the roof's steel frame. Wood was attached to the steel frame providing a nailing surface for the sidewalls' wood sheathing. The wood sheathing was, in turn, covered with copper and had a large copper vent. Like the main structure, the cupola's roof had wood rafters and wood sheathing covered by slate shingles.

The church's sanctuary occupied most of the space in the building. This area had an arched ceiling approximately 65 feet above the floor. The ceiling was supported by 2-inch x 6-inch joists that had been laminated together and cut in order to attain the arch shape. Plaster over wood lath provided the ceiling finish. Several inches of non-combustible fiber insulation covered the plaster and lath filling the joist channels. An unfinished attic space was above the arched ceiling and below the roof assembly. Since the attic was typically unused, there was no finished floor for this area. However, a wood catwalk for maintenance personnel had been constructed along the apex of the ceiling's arch.

The church had a lightning protection system that appeared to have been installed when the church was constructed. However, the exact date of installation could not be verified. The lightning protection system included numerous air terminals and several down conductors to bring electrical charges to earth.

Most of the air terminals on the building were designed to blend into the church's exterior detail. Five air terminals were shaped like crosses. (See Figure 2) Two of these air terminals were installed on top of large steeples at the front (north end) of the church; the third cross-shaped air terminal was installed on the gable end at the front of the church, the fourth was on top of the cupola, and the fifth cross was installed on the roof at the south end of the building. In addition, three decorative metal fixtures also served as air terminals. One of these fixtures was installed toward the south end of the building's roof. Another decorative metal fixture was located on the ridge of one transept's gable end, and a third fixture was located on the ridge for the other transept's gable end. The last air terminals were typical metal rods and were installed on top of a chimney.

A network of conductors connected the air terminals. Air terminals on gable ends were interconnected by large braided copper wires called "cross-run conductors." The metal bolts secured the cross-run conductors to the ridge of the roof. Because the cupola was constructed at the intersection of the nave and the transepts, the cupola prevented the cross-run conductors from running continuously in both the north/south and east/west directions along the ridge. As a result, a braided copper wire, similar to that used for the cross-run conductors, was installed at the base of the cupola, and that conductor looped around the cupola. This looping wire served as a bonding point for the cross-run conductors along the roof ridges and for a braided wire conductor attached to the cross-shaped air terminal on top of the cupola. Damaged conductors, reportedly from the area of the cupola, were recovered, examined, and measured. The cable was found to be 28 strands and 57, 350 circular mills in size.[1, 2] All bonds to the looped wire were made by wrapping one cable around the other rather than by using splicing devices designed for that purpose. (See Photo 1)

Five "down conductors" connected the system to earth. One down conductor was installed on each steeple, and the installation on each steeple was similar. Each down conductor was bonded to the cross-shaped air terminal on top of the steeple and ran down the exterior of the steeple's roof. Like the cross conductors on the main roof, down conductors were secured to the steeple's roof by bolts. A braided copper wire was spliced to both the steeple's down conductor and to the cross conductor on the ridge of the roof in order to bond the conductors. (See Photo 2) Again the splices were made by wrapping one cable around the other rather than by using splicing devices. Fasteners and bolts securely held each down conductor to the exterior of the steeple's masonry walls, and each down conductor was bonded to the copper gutter by a bolt and metal clamp. A clamp and bolt bonded each down conductor to a grounding cable that was set into the concrete sidewalk.

One down conductor was installed on the east transept's exterior wall. This down conductor was bonded to the metal decorative fixture used as an air terminal and was spliced to the ridge conductor by wrapping the wire together. Fasteners and bolts securely held the down conductor to the transept's exterior masonry walls,

---

1 The cupola was in an area that was more than 75 feet above the ground. Table 3-5 of NFPA 780, *Lightning Protection Code*, 1992 Edition, requires main conductors to be at least 115,000 circular mills in order to provide reliable protection.

2 NFPA 780, *Lightning Protection Code*, 1992 Edition will be used in this report as the basis for comparison of existing conditions in the facility with selected requirements of current codes. It is recognized, however, that NFPA 780 had not been adopted and was not being enforced by the City of St. Louis.

and the down conductor was bonded to the copper gutter by a bolt connector. The down conductor was bonded to its grounding point, which was a cable set in the concrete sidewalk with a bolt and clamp.

The down conductor for the west transept was spliced to a braided wire conductor used to bond the three air terminals (a metal decorative fixture on the top of the transept's gable end and two metal rods on the chimney). Similar to other splices, the splices between these conductors were made by wrapping one cable around the other rather than by using splicing devices. Fasteners and bolts held the down conductor securely to the side of the chimney. Due to damage of the roof and gutter, it was not possible to determine whether the down connector was bonded to the gutter. The down conductor was continuous over the full height of the chimney and was set into the concrete sidewalk. As a result, no bolt and clamp connections were used on this straight run to the ground.

The last down conductor was installed at the rear of the building (south end). Extensive damage to the roof at this part of the building prevented verification of some installation details. However, it appeared that the down conductor was bonded to a decorative fixture on the roof's ridge. Fasteners and bolts securely held the down conductor to the exterior of the building's masonry walls, and it was bonded to the metal gutter by a single bolt connector. The down conductor was continuous to a grounding cable that entered the ground in the soil of the courtyard. A metal clamp and bolts bonded the down connector with the grounding cable. The grounding point was next to the building's main electrical service drop, placing the down conductor within inches of that equipment.

There was no visible bonding among any conductors in the lightning protection system and many of the metal components of the main roof assembly. These components included the structural steel frame, copper flashing, and copper down spouts. Since the cupola was destroyed, it was not possible to determine whether metal components such as the cupola's steel frame and copper surface materials were bonded to the lightning protection system.

Several system components, such as sections of down conductors, electrical connections, and cable fasteners were visibly different from the apparent original system components. These differences suggested that the lightning protection system had been changed over the years. However, the property owner had no information or records documenting when or why the observed changes to the system had been made.

The Fire

On the morning of Thursday, April 28, 1994, a severe thunderstorm passed through the St. Louis area. A priest who was sleeping in the rectory building next to St. Anthony of Padua Church was awakened by a bolt of lightning and the sound of thunder. The entire area next to his bedroom was reportedly lit up by the bright flash and the boom shook his room. He was sure that the church had been struck; the time was approximately 5:40 a.m. Later that same morning, an 8:00 a.m. church service was being held as usual, and approximately 15 to 20 persons were in attendance. Early in the service, lightning struck the church again. Even though the people in the church believed that the lightning had struck something close by, nobody in the church realized it was the church that had been struck.

At approximately 8:25 a.m., someone outside of the church saw fire showing near the base of the cupola, and reported the fire to St. Louis Fire Department at 8:26 a.m. Upon receiving the report of fire at St. Anthony of Padua Church, the fire department dispatched four engines, one truck, one rescue, and three chief officers.

One of the first alarm engine companies was located in a station house only two blocks away from the church. When this company left the station, fire fighters immediately saw heavy smoke showing above the church and as they arrived on the scene saw flames close to the base of the cupola. The company officer entered the church, found the church service still in progress and told everyone to leave the building. A member of the church's maintenance staff, who had been in an adjacent building, met the officer and told the fire officer how to get up to the attic.

Guided by the maintenance person, the officer walked upstairs in the northwest steeple and entered the attic above the sanctuary. Finding heavy smoke in this area, the officer knew he had located the fire area and ordered his crew to advance a 1 3/4-inch handline into this area. By this time, fire fighters from the engine parked near the east wing had established a water supply by connecting to a hydrant. Realizing that their pre-connected hose line was unlikely to reach the attic area, the engine crew attached additional lengths before advancing the hose line into the building. Fire fighters entered the church through the main entrance at the front of the church and went up the stairway in the northwest steeple.

Once in the attic, fire fighters moved through the smoke, advancing the hose line along the catwalk toward the rear of the church. Reportedly, the nozzle man saw flames 25 to 50 feet ahead of him and thought he might be able to initiate an attack against the fire. However, before the nozzle man discharged water from hose, the incident commander ordered all personnel out of the attic.

Knowing that his personnel were working above the vaulted ceiling, the incident commander was concerned about possible collapse. As a result, he made preparations to switch from an interior fire attack to an exterior fire attack while the fire fighters inside the building were still preparing for their interior attack crews. The incident commander ordered a truck equipped with a snorkel nozzle to park in front of the church and extend its nozzle up to a small attic window in the front of the building. After all personnel were out of the attic, the snorkel discharged water into the fire area; this was the first application of water against the fire.

Other fire fighters brought a 2 1/2-inch hose line into the sanctuary in order to control fire that might spread into the sanctuary from burning materials dropping from the ceiling or from other sources. Concerned about ceiling collapse, fire fighters working in the sanctuary remained close to the perimeter of that area.

The primary fire attack used a number of aerial pipes operating from 12 aerial apparatus and three master stream appliances placed on the lawn on the west side of the building. Ultimately, five alarms and two special calls were made, bringing 34 fire apparatus, 6 chief officers, 144 fire fighters, and several fire investigators to the scene. With this resource commitment, the fire was brought under control at 10:25 a.m. and was declared extinguished at noon.

The roof covering the church was heavily damaged by the fire. (See Photos 3 & 4) The vast majority of the combustible materials in the roof assembly were completely consumed by the fire, leaving in place only steel structural members and copper conductors for the lightning protection system.

A large section of the arched ceiling directly below the cupola collapsed, depositing burning materials in the sanctuary. Several rows of pews were buried under the debris and burned. Despite this, the majority of the sanctuary and the church's extremely ornate, 50-foot high altar were not damaged by flames or heat. Both sustained some smoke damage and the sanctuary sustained some water damage.

Analysis

Local investigators indicated that the fire was probably the result of the lightning strike shortly after 8:00 a.m. However, they could not rule out the possibility of the earlier lightning strike having ignited the fire. As a result, local fire investigators were not able to determine how long the fire burned before being observed and reported to the St. Louis Fire Department.

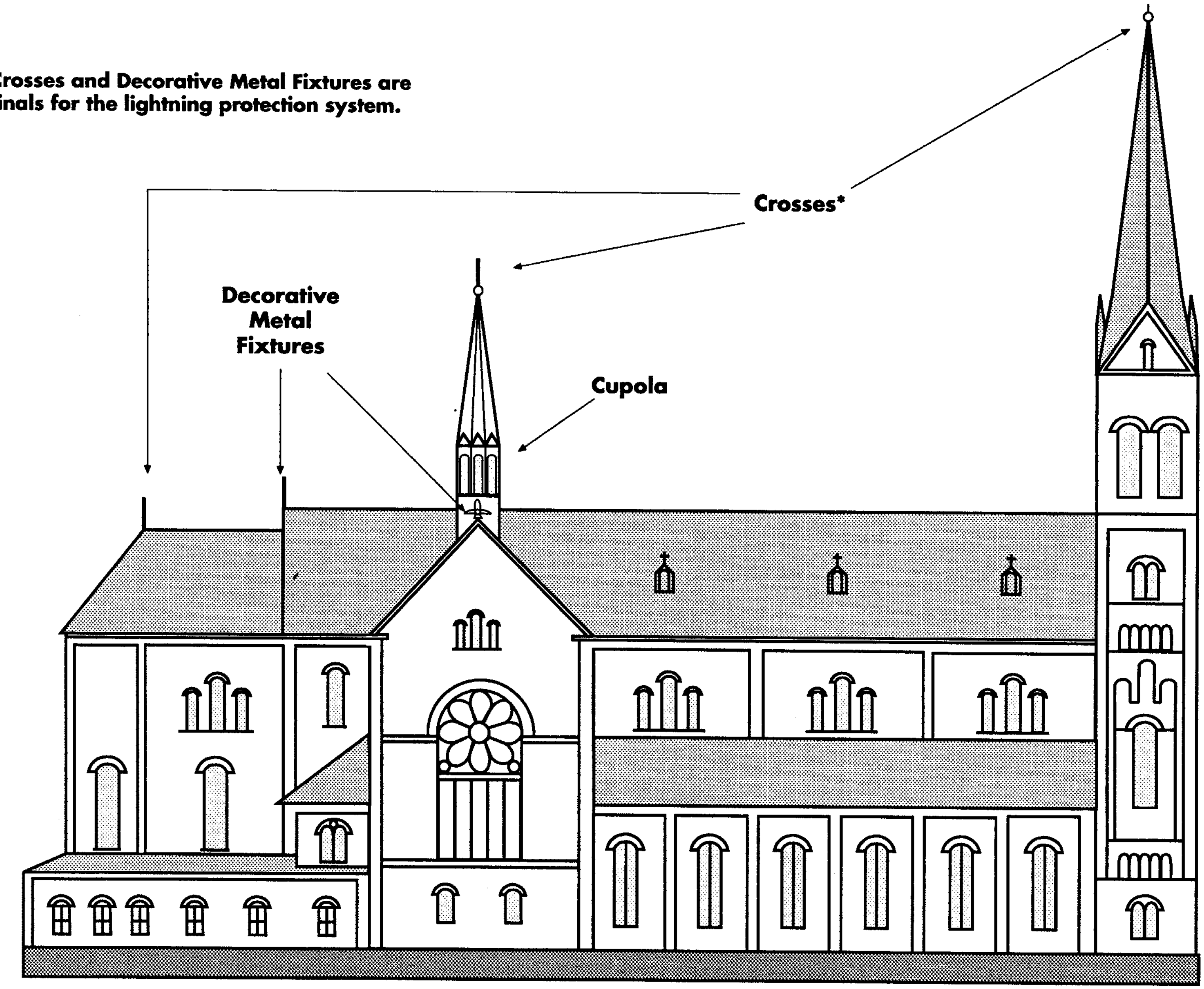
The observations of fire fighters who first arrived on scene, witness statements, and video footage taken early in the fire consistently placed the initial fire in the area of the cupola. Accordingly, the first materials ignited probably were wood structural members or other combustible materials in the cupola, in the roof assembly near the cupola, or in both areas. Once these materials were ignited, the fire spread through the attic area and combustible materials in the roof assembly became the primary fuels.

Even though local investigators were not able to determine the exact sequence of events that resulted in the ignition of wood structural members in the roof assembly, they did establish several theories regarding the ignition. One theory proposed that the lightning protection system might have been damaged by lightning strikes in previous storms or by reported lightning strikes during the storm on the morning of the fire, and that damage could have reduced the system's ability to direct the electrical charge safely to earth. Another plausible theory focused on physical conditions that were not consistent with requirements of NFPA 780, *Lightning Protection Code*, 1992 edition. These conditions included electrical connections made without proper hardware, undersized main conductors, and unbonded and ungrounded metal bodies (roof metal frame, cupola metal frame and exterior metal sheathing on the cupola). Investigators proposed that these conditions may have reduced the effectiveness of the lightning protection system. In addition to these conditions, the lightning protection system had apparently been modified and/or repaired over the years, and there were no records indicating that continuity testing had been performed nor that the lightning protection system was functioning properly after the modifications. Accordingly, investigators theorized that the modifications could have also reduced the effectiveness of the lightning protection system.

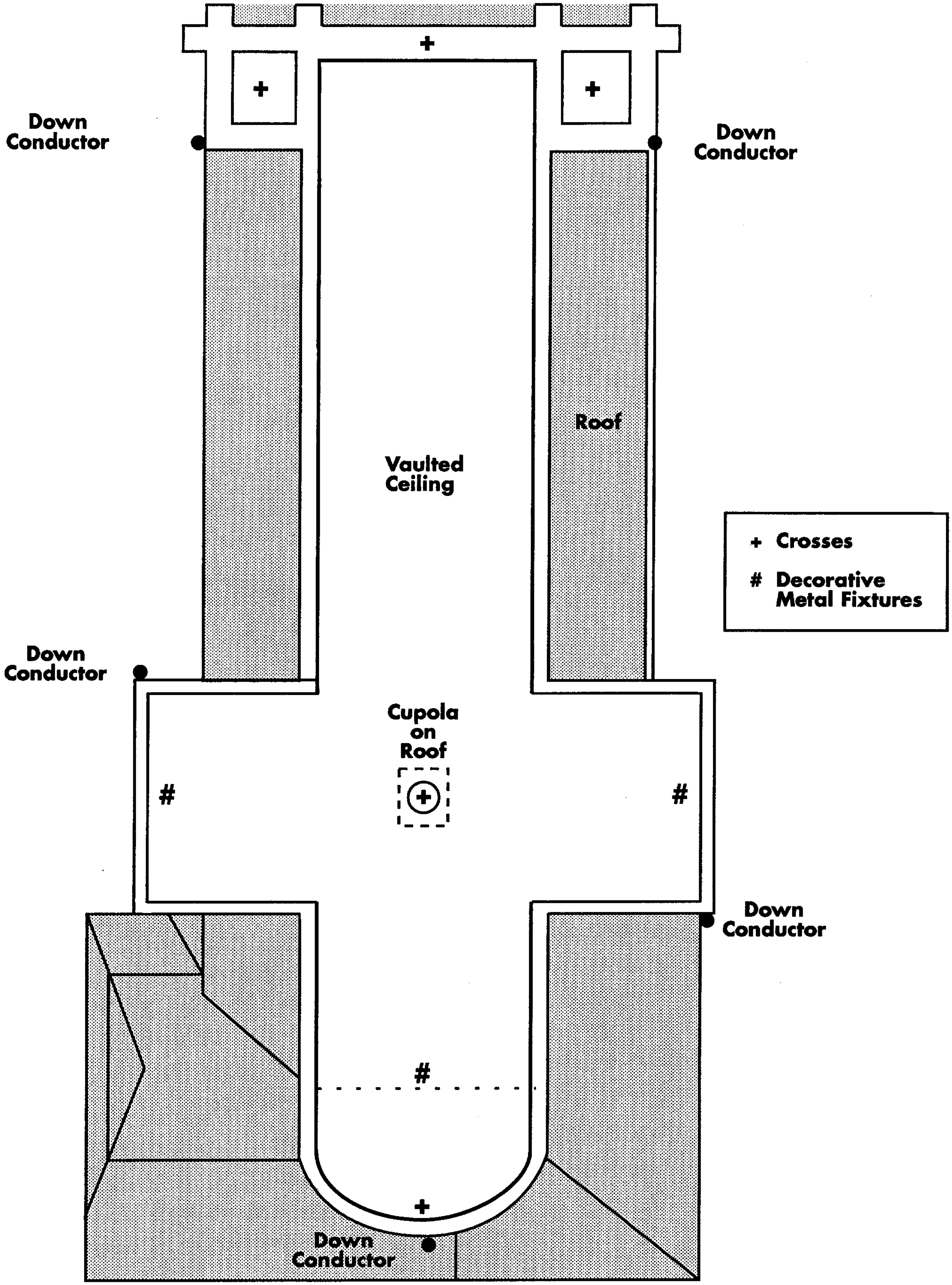
Though any one of the observed inconsistencies with current code requirements could have contributed to the lightning protection system's failure to dissipate the energy and to the ignition of wood structural members, investigators also recognized that the failure of the lightning protection system could have been the result of a combination of the identified problems or even a result of factors that have not yet been identified.

To ensure proper operation, lightning protection systems should be periodically inspected and maintained. Recognizing the importance of proper inspection and maintenance, NFPA 780 has provided, in Appendix B, an extensive discussion of existing lightning protection system inspection and maintenance. The appendix discusses factors to consider when establishing inspection and maintenance schedules. In addition, the appendix provides guidelines for provisions that should be incorporated into effective inspection and maintenance programs. Finally, the appendix states that records of all inspections, maintenance, and corrective actions should be kept. These records will provide a means to evaluate system components and the effectiveness of ongoing maintenance activities. Adherence to the recommended inspection and maintenance procedures should greatly increase the potential of an existing lightning protection system to perform effectively during a lightning strike, and proper record keeping will provide documentation confirming that these activities have been performed.

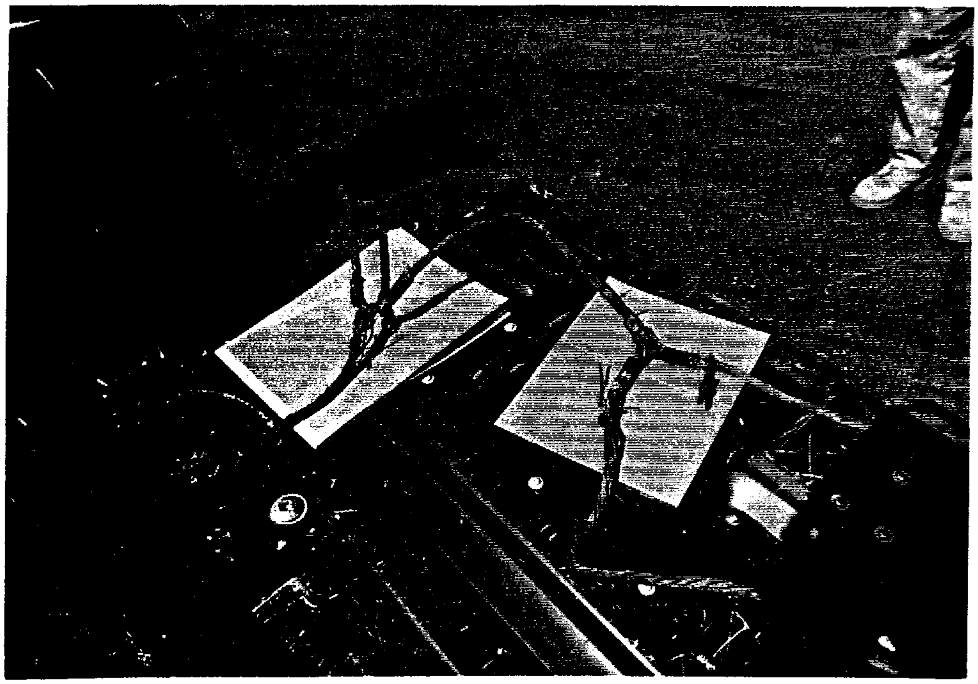
*Note: Crosses and Decorative Metal Fixtures are Air Terminals for the lightning protection system.



East Side Elevation
St. Anthony of Padua Church
Figure 1

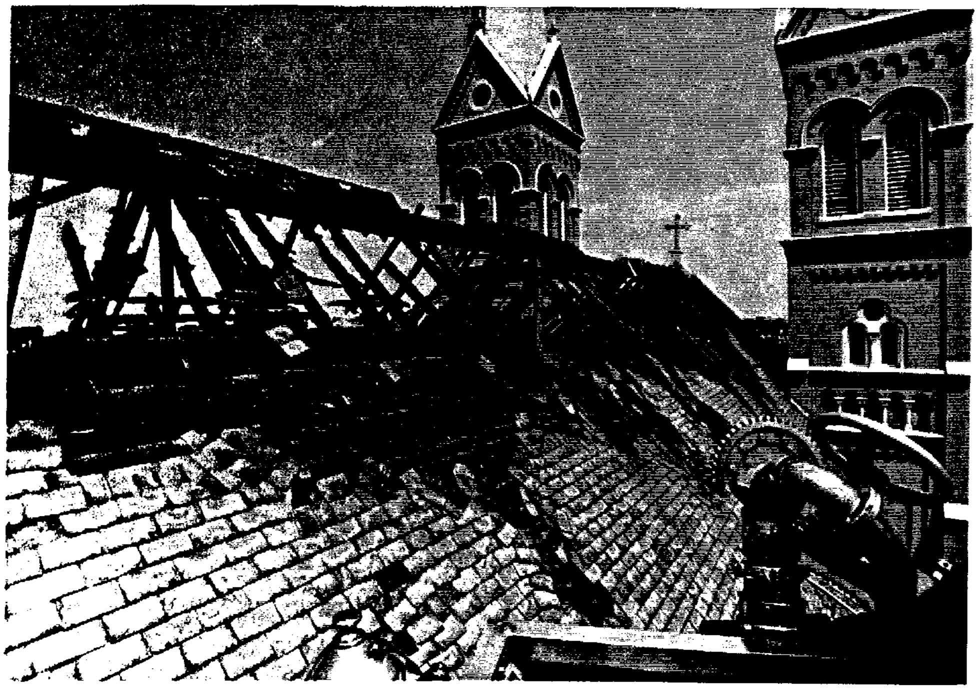


Plan View
St. Anthony of Padua Church
Figure 2

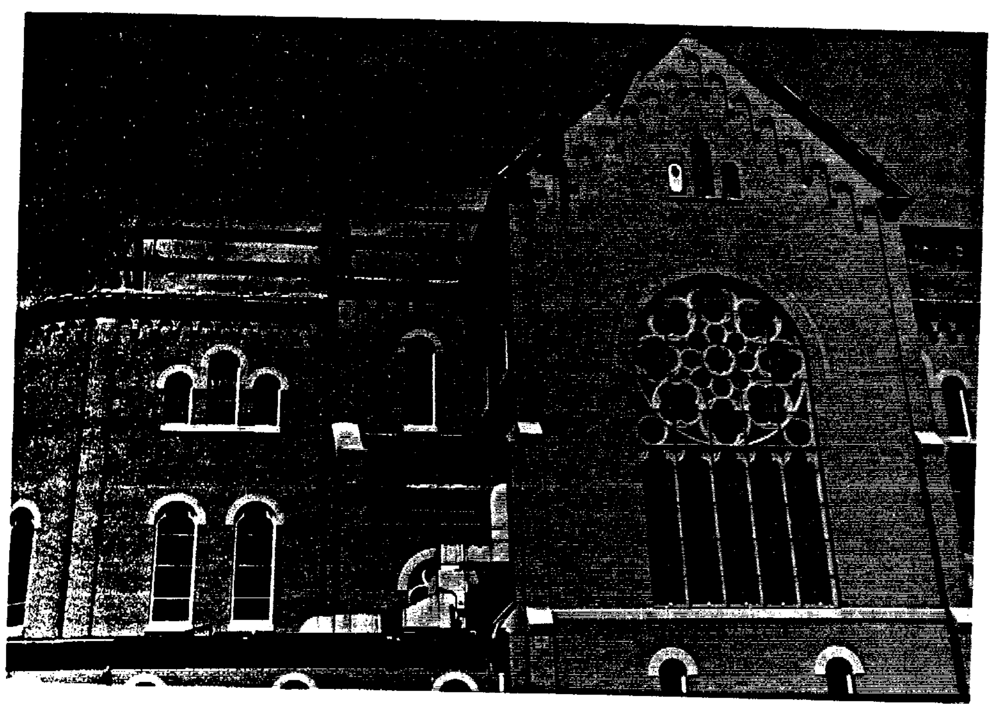


Wrapped wire splice on conductor from cupola area.
Photo 1

Down conductor installation near east steeple and main roof.
Photo 2



Roof damage looking toward the north end of the church.
Photo 3



Roof damage at the south end of the church.
Photo 4